

High School Students' Out-of-Class Collaborative Design Practice  
in a Problem Solving and Design Competition

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**Abstract**

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Using activity theory, this study investigates high school students' experiences as participants in the Imagine Tomorrow problem solving and design competition in the state of Washington. In this competition, high school students from across the state form teams within their schools, identify problems that focus on environmentally sustainable alternative energy sources, and complete projects in which they develop solutions to these problems. The purpose of this research is to better understand high school students' project-based collaborative design practice in out-of-classroom settings, by exploring factors that contribute to team success in completing a project. Findings include a model of the tensions and contradictions within a project activity system, and strategies that facilitate completion of projects in the context of the competition.

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*Interviewer: [How do you feel about] how much the advisor helped with different tasks, or the information that [the advisor] provided?*

*Student: At first I was kind of.. 'Ehh..' cause I felt like [the advisor] wasn't really doing much. But now that I think about it, [the advisor] did help us by not doing much.  
[laughs]*

*Interviewer: What do you mean by that?*

*Student: Oh, we--we had to think farther instead-- 'cause--  
hmm--it's...like we had to think of a...like teachers usually think of a course, like a lesson plan, and students follow.  
But this--with the project it was like the students thought of the lesson plan and followed it ourselves, and got the end result...and then so we learned that process, but also learned about the environment and all that. So...by [the advisor] not being there to try to guide us, we learned how to guide ourselves...yeah.*

*- From an interview with an Imagine Tomorrow participant / student team leader*

## **Chapter 1: Introduction and Background**

In response to external and internal economic pressures, concerns over the quality of education, and the rapid pace of scientific and technological progress, a number of reports over the previous decade have made calls for reform of science, technology, engineering, and mathematics (STEM) education in the U.S. (National Academy of Sciences, 2005; National Science Board, 2007). In one such report, the National Science Board (2010a) advocated opportunities "to experience inquiry-based learning, peer collaboration, open-ended, real-world problem solving, hands-on training, and interactions with practicing scientists, engineers and other experts" as possible approaches for helping students to acquire STEM skills (p.16). The report cited "robotics and invention competitions" among the strategies for facilitating such experiences, provided these competitions demonstrate a "proven record of accomplishment in stimulating potential STEM innovators" (p.18). These recommendations are relevant to the topic of this research: project-based collaborative practice in the context of a STEM-oriented competition for high school students.

In particular, this dissertation examines the experiences of participants in the Imagine Tomorrow problem solving and design competition in the state of Washington, organized by Washington State University. In this competition, high school students form teams, identify problems in the areas of environmental sustainability and alternative energy, and develop solutions to these problems. The projects must align with one of four general challenge categories: design, technological, behavioral, and multidisciplinary. There are no pre-defined topics, so the teams are free to explore their own original ideas. The resulting projects reflect a wide range of interests, skills, and ambitions. The competition has grown in popularity since its

inception in 2008, inspiring a total of over 350 teams from dozens of schools across the state to participate during its first four years. However, nearly a third of the teams that register for the competition fail to attend the culminating event, where teams present their completed projects.<sup>1</sup> For the students who do attend Imagine Tomorrow, presenting their projects is an overwhelmingly positive and valuable process, an important milestone, and a highlight of their overall competition experience.

Widespread uptake of the Imagine Tomorrow competition by schools across the state represents a broader trend. Every year numerous local, regional, and national student competitions take place across the U.S., cumulatively involving hundreds of thousands of students. A recent survey of K-12 engineering-related competitions in the U.S. identified fifty three such competitions (Wankat, 2007). The most widely known of these, such as The West Point Bridge Design Contest and the FIRST Robotics Competition, each involve tens of thousands of students annually. As one example at the international level, participation in the Imagine Cup technology competition (sponsored by Microsoft) increased from fewer than 1000 students in 2003 to over 350,000 students in 2011.<sup>2</sup> The exponential growth in the popularity of competitions like the Imagine Cup reflects their attractiveness for the participants, and possible value for their learning and future professional success. A deeper understanding of the factors that shape student competition experiences therefore presents more than a scholarly interest. It has the potential to inform practice – the rules and policies which govern how competitions are organized, and the strategies, structures, and norms which govern how they are enacted “on the ground” – with implications for the quality and value of experience of their many participants.

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<sup>1</sup> Personal email communication with university office in charge of organizing the competition, based on registration data from the first four years of the competition.

<sup>2</sup> <http://www.imaginecup.com/CompetitionsContent/History.aspx>

The key to leveraging competitions to facilitate academic and career success of their participants may not be a matter of doing more of them, or doing them more elaborately, but of better understanding how they work. Research suggests that competitions can provide valuable learning experiences for their student participants, enhancing their skills, interests, and motivation (Labossière & Bisby, 2010; Mitchell, Dori, & Kuldell, 2010), and supporting their overall academic progress (ABET, 2006). On the surface, the principles which undergird most competition experiences – teamwork, real-world challenges, and adult guidance – are well known in contemporary instructional practice. Studies of instructional methods like project-based and problem-based learning (PBL), where teachers guide students as they work in groups to address complex problems, suggest that these methods may be effective, under certain conditions, for developing communication, higher-order thinking, and problem-solving skills (for reviews of research see, for example, Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hmelo-Silver, 2004; Krajcik & Blumenfeld, 2006). However, because methods like PBL are typically implemented as part of school curricula, most of their studies have been conducted in relatively structured, classroom-based environments where the teachers are required to teach and the students are expected to learn. In contrast many participants in student competitions work on projects on extracurricular basis, in settings where classroom norms and expectations do not apply. A large number of teams participating in Imagine Tomorrow engage with their projects in such arrangements, where their performance is unrelated to grades, their activities are not constrained by classroom norms or scripted by the course syllabi, and the teacher's role is not as defined as in a typical classroom. Research on the mechanisms and conditions associated with effective project-based collaborative work in such settings is currently limited.

Understanding what exactly it takes to succeed in a STEM competition like Imagine Tomorrow prompts questions aimed at the process through which projects come together. What does it take for a team to successfully complete a project when working in out-of-classroom settings? What challenges might arise in the process? How do teams address these challenges? What activities are essential in moving a project forward? What internal (team-related) and external (school and community-related) factors impact project-related activities? Although much practical experience with running competitions has been accumulated, and although there is a growing literature on the topic (see Appendix A), none of the studies that I found have explored in detail the process of completing a competition project in K-12 out-of-classroom settings.<sup>3</sup> This research seeks to shed light on these questions through a focused qualitative study of two high school student teams involved in the Imagine Tomorrow competition.

This study investigates how students work together to successfully address open-ended, realistic problems related to environmental sustainability and alternative energy. One important issue for the study is defining success. In the context of a student competition success is by definition associated with out-competing other participants, as evidenced by receiving the highest scores from the judges and being recognized with monetary or other prizes. The media coverage and popular press typically follow in these footsteps, with journalists and authors training their cameras, microphones, or pens on extreme cases and winners (e.g., Dutton, 2011). This is understandable, and commendable to an extent, since winning (or almost winning) is more dramatic and makes a better story, which can help raise awareness about competitions and inspire future participants. Notwithstanding a tendency to highlight projects completed in informal, out-of-class settings (such as a home basement, garage, or shop) such accounts mostly

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<sup>3</sup> The vast majority of these studies is based in postsecondary engineering settings, and does not directly inform the theoretical framework of this study.

offer anecdotal evidence of effective approaches that are unique to the individual student or team that ended up in the spotlight. In turn, in academic writing, most laboratory or classroom-based studies of individual (e.g., Atman & Turns, 2001) or collaborative design (e.g. Kolodner, et. al., 2003; Mentzer, 2011; Jurow, 2005), problem-solving (e.g. Gresalfi, 2009), and scientific inquiry practices (e.g., Engle & Conant, 2002; White & Frederiksen, 1998) allow researchers to focus their investigations within the known or identifiable boundaries of laboratory or school contexts, problems, and practices. This makes it possible to define, manipulate, and capture as data most of the relevant student behaviors. These approaches enable the researcher to call on the applicable disciplinary norms and learning objectives to set the criteria for successful performance. On the other hand, in the out-of-class Imagine Tomorrow projects, the cross-grade teams (students in grades 9-12 can work together), the multi-disciplinary and idiosyncratic problems, and the dispersion of project activities across time and multiple locations warrant reappraisal of what activities might be deemed successful, productive, or even relevant to a project.

At the same time, I found it helpful to impose some conceptual boundaries to frame project work for purposes of the present study. I use the term “collaborative design practice” (described in more detail in Chapter 2), which represents a combination of two analytic lenses: one grounded in the paradigm of engineering design, and one derived from a sociocultural notion of participation in valued enterprise of a given community. I do so with the awareness that high school students’ self-directed problem solving and designing may not map onto any accepted disciplinary models of the design process, and keep the definition sufficiently broad to favor an inductive analysis of their activities. At the same time, identifying some possible dimensions or elements of collaborative activity may be helpful for making sense of how project work is

coordinated across distributed out-of-class settings, and how the approach to completing project may change over time, rather than whether, in what order, or how frequently certain pre-defined steps are performed. Later I talk about four dimensions of collaborative design practice (project management, decision making, communication, and collaboration), which help to clarify what is meant when these terms are used in the analysis.

Although the meaning of success in project work varies across teams, individuals, and contexts, a working definition was adopted to focus the analytic approach of this study. Success here refers to a team's ability to complete a project on which the team spent a minimum of six weeks, and for which it received above-average scores from the Imagine Tomorrow judges. This definition rests on several assumptions. First, it is consistent with the rules and expectations of the competition. The minimum timeframe limit is based on the rule that the participating teams must formally register their project entries at least six weeks prior to the event. The above-average score, based on the scoring rubric, represents a more consistent and reliable indicator of quality, than a project's relative standing compared to others.<sup>4</sup> Although monetary prizes are awarded to top-scoring teams and some teams may regard winning as top priority, the award sums are not exorbitant, and a variety of additional "swag" awards are handed out (e.g., for projects voted "most inspirational" or "most likely to succeed in the marketplace"). According to exit surveys, the students regularly cite interaction with the judges as some of their most valuable experiences. These factors suggest that making a good effort on the project and receiving generally positive feedback from the judges is enough to call a project a success in the context of the competition.

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<sup>4</sup> Determining success based on prize awards alone is also risky considering the potential inequality among teams with regard to team-independent factors like availability of school resources, funding, technology, etc.

Second, presenting a project to the judges implies finishing it, and bringing a project to some degree of completion is a key factor in determining success in this study. According to the Imagine Tomorrow guidelines, finishing a project does not require flawless technical performance of a machine, actual re-building of a school according to “green” standards, or full implementation of a new conservation program. Works-in-progress and pilot projects that achieve or approach the stated objective, no matter how ambitious or modest, warrant consideration. Well thought-out models and prototypes, or partially implemented public outreach programs may be presented in their respective categories. Failure in the competition does not imply a show-stopping technical failure – the kind that may disqualify a team from a robotics competition. Rather, failure may be signaled by a team’s last-minute withdrawal from the competition, clear lack of effort, inability to show any reasonable progress down a particular path, or poor grasp of the basic topics or details around the proposed solution. Similarly, in this study, failure refers to inability to complete *any* project – inability to select and properly constraint a problem, to make time to research and take concrete steps toward addressing it, and to coordinate activities such that they yield a collective accomplishment. Although much can be learned from failed attempts – and failure *along the way* is a frequent and natural element in the design process – inability to get much of anything done may prevent a team from attending the culminating event, effectively shutting them out of the full range of competition experiences. At one extreme, such poor performance by most teams would have sabotaged the competition altogether. On the other hand, achieving at least some of the project’s goals, so that the team can show meaningful progress and rally behind their work, is sufficient to consider a project completed in the competition and for purposes of this study.

Finally, the definition of success in this study rests on the assumption that completing and presenting a project is generally a positive and valuable experience for the students, helping them gain knowledge and skills that are important to their future academic and career pursuits. This is consistent with Shernoff's (2010) conclusion from research on after-school programs, "that the relative *quality* of experience in programs [based on students' perceptions of program meaningfulness, challenge, interest, and enjoyment, among other factors] may be stronger and more positive predictor of academic performance than the *quantity* of experience in programs" (p. 335). It is reasonable to assume that students would have more positive perceptions, and derive greater benefit from competition experiences where they were able to complete a project, compared to experiences where their project never really panned out. In summary, success in this study refers to a team's ability to *complete a project* by investing a reasonable amount of time and effort to achieve certain common objectives and receive generally positive evaluations (marked by above-average scores) from the judges.

The study is grounded in the sociocultural and situative theoretical perspectives and the cultural historical activity theory (Engeström, 1987), and leverages activity systems analysis methods, namely thematic analysis (Yamagata-Lynch, 2010). Using a two-case case study research methodology, it examines the practices and perspectives of the members of each team, as well as the contextual elements that shape their project-related activities. Rather than centering analysis on overt results – which tends to be the focus of the judging at the main event – the study produces an account of an extracurricular collaborative project as a dynamic process, including its structure and the factors that direct, sustain, or impede progress toward the project's completion. Developing a model of a project activity system as part of the Imagine Tomorrow competition might help to theoretically account for the process of collaboration around a

complex, open-ended problem by students in out-of-class settings, thus contributing to theory development in this area of research. In applied terms, the study offers recommendations for effective ways to better support successful student projects, and thus overall positive student experiences, in the context of STEM-oriented competitions.

## **Study Rationale**

The ability to meaningfully interpret and draw inferences about the outcomes of a problem solving and design competition, such as the Imagine Tomorrow competition for high school students in Washington, is predicated on the ability to systematically account for the nature of the experiences of the participants. In the case of the Imagine Tomorrow competition, the voluntary basis of participation, the uneven duration of project activities, the distribution and fragmentation of authority and expertise, and the open-ended or ambiguous nature of the problem and the learning objectives complicate the ability to understand these experiences. Furthermore, because project and problem based learning strategies are typically implemented in the context of formal educational curricula, most research on these topics is situated in relatively structured classroom environments with predetermined norms. Little is known about how students collaborate on projects in less structured, out-of-classroom arrangements, especially in the context of competitions.

This study explores how high school student teams succeed in completing complex collaborative design and problem solving projects in the context of a STEM-oriented regional competition. The activity-theoretical perspective in which this study is grounded (Engeström, 1987; 1990; 2008) enables shifting the focus of inquiry from results to process, and the sociocultural and situative theoretical perspectives (Wenger, 1998; Greeno, Collins & Resnick,

1996; Greeno, 2006; Hickey & Granade, 2004; Nolen & Ward, 2008) inform the understanding of meaning-making and motivational processes across contextual boundaries. Of particular interest are the challenges that students encounter as they organize and carry out their project-related activities, and the conditions and strategies that could help resolve these challenges. In this study, the focal activity of the project team is conceptualized as collaborative design practice. Naturalistic inquiry using case study design and qualitative analysis is proposed for exploring the practices involved in moving a project from ideas to tangible results. The study also addresses the link between a completed project and other outcomes, such as enjoyment, college exposure, winning, and making a difference.

In terms of theoretical contribution, the analytic approach and findings uncover the potential tensions and contradictions which characterize out-of-class student design projects undertaken in the context of the Imagine Tomorrow design and problem solving student competition (and other similar competitions), and to inform a program of future research in this area. The study also enhances the understanding of motivational processes in loosely structured, collaborative, project-based activity settings. In practical terms, the study yields recommendations for adults involved in Imagine Tomorrow on how to effectively support the student participants to enable them to have more productive and fulfilling competition experiences.

### **Organization of the Dissertation**

Chapter One provides the background on student competitions and discusses the relevant literature on project-based learning environments and collaborative practice. Chapter Two presents a theoretical framework and the analytic foci framing the study. Chapter Three describes the methodology and research design, including a brief introduction to the two project

cases selected for the analysis. Chapter Four profiles the project cases, focusing on the advisor, the team, and how the project came together. Chapters Five integrates the findings from the case studies to address the research questions. Chapter Six connects the findings to the relevant literature and suggests directions for future research. Finally, Chapter Seven is dedicated to practical recommendations for advisors and students involved in Imagine Tomorrow and other student competitions.

### **Background: Stem-Oriented Student Competitions in the U.S.**

**STEM Education and Economic Competitiveness.** To understand why STEM-oriented student competitions exist, what purpose they serve, and why they attract substantial investment and sponsorship from the private and public sectors, it is important to consider the role of STEM education in the United States. There has been a growing recognition over the past several decades of the increasingly dynamic and global nature of social, economic, and environmental processes and issues facing all of humankind. Engineers, scientists, and technology professionals are expected to play an important role in how effectively these issues will be addressed by the future generations (e.g. National Academy of Engineering, 2005; NAS, NAE & IOM, 2007). Effective education and professional training of individuals willing to take on the future challenges in these areas is therefore not only a matter of national priority for a select group of developed economies, but a global imperative.

The modern American social identity is connected with a sense of the importance of education, and especially education related to the fields of science, technology, engineering, and

mathematics (STEM)<sup>5</sup>. A frequently mentioned reference point for STEM education today is the launch of Sputnik by the Soviet Union in 1957, and the ensuing “space race.” In the U.S., that race was spurred by the unsettling prospect of the Soviet Union’s supremacy in space, and by President John F. Kennedy’s charge to the nation in his May 1961 speech to travel to the moon and back before the decade’s end. In recent decades, however, that particular ideological tension has been supplanted by an equally potent economic one.

As Shirley Ann Jackson, President of the Rensselaer Polytechnic Institute and ex-Chairman of the U.S. Nuclear Regulatory Commission had stated, “energy security is the space race of the twenty-first century” (Jackson, 2007, p. 27). Speaking of the need to revamp U.S. STEM education, Ms. Jackson noted that “failure to act soon will undermine our national capacity for innovation, thereby threatening our economic well-being, safety, and global leadership” (p. 24). The sense of urgency in these comments reflects a growing concern about the state of U.S. STEM education on one hand, and a need for approaches that could yield visible results in the near term, on the other.

Despite the various external and internal pressures to upgrade the country’s education system, indicators of the quality of K-12 education, both at the national and state levels, give cause for alarm. In 2005-2006, only 62 percent of U.S. high school graduates went on to college, and in the state of Washington, only 48.7 percent did – the sixth lowest rate in the nation (National Center for Education Statistics, 2009). In 2008, Washington ranked 46<sup>th</sup> of all states in the proportion of 9<sup>th</sup> graders that were enrolled in college anywhere in the U.S. four years later, at about 35 percent (National Center for Higher Education Management Systems, 2012). In

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<sup>5</sup> This does not imply an exclusive preoccupation with specific subjects, but rather the types of professional identities for which good education would well position the student. For example, the publication “The Engineer of 2020: Visions of Engineering in the New Century” (National Academy of Engineering, 2005) describes an engineer as being well grounded in the humanities, social sciences, and economics as well as science and mathematics.

2010, over half of Washington 10<sup>th</sup> graders failed key portions of the High School Proficiency Exam; about 58 percent failed the math portion of the test, roughly 55 percent failed science, and 21 percent failed the reading portion (*The Seattle Times*, 2010). These figures have consequences for college degree production in STEM fields. Estimates suggest that the state might only be able to fill 67 percent of the expected annual job openings in engineering, 56 percent of jobs in computer science, and 65 percent of jobs in the medical profession between 2009 and 2014 (Partnership for Learning, 2009).

Another powerful impetus for education reform is provided by changes associated with rapid scientific and technological progress. Over the past century knowledge in STEM disciplines has been accumulating at an accelerated pace. Also, the proliferation and evolution of information and communication technologies suggest that knowledge and expertise have increasingly become more dynamic, time-sensitive, and distributed in terms of geography as well as social structures and institutions.<sup>6</sup> Two implications of these trends are relevant for STEM education. First, it is that effective learning in STEM disciplines is characterized by an ability to transfer and adapt knowledge to novel problems and situations (Bransford, et. al., 2005). Second, it is that effective application of this knowledge toward addressing complex scientific, technological, and social problems is contingent on the ability of individuals to collaborate.

These economic, technological, and historical developments, and the parallel recognition of the lagging and uneven quality of K-12 education have provoked in recent years a wave of policy-oriented reports calling for reform of STEM education in the U.S. (e.g., NAS, NAE & IOM, 2007; National Science Board, 2007, 2010).<sup>7</sup> On the whole, research and policy

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<sup>6</sup> Some examples of this include the “open source” movement in software development, and the analogous “open courseware” and “crowdsourcing” movements in online learning and scientific research, respectively, both made possible by the Internet.

<sup>7</sup> It is more accurate to say that these reports illustrate the latest in a series of reform-inspiring report “waves.”

recommendations suggest that learning experiences which center on multifaceted and realistic problems and involve coordinated social interaction may facilitate the kind of learning that is consistent with the goals of STEM education and the nation's current and future economic needs. STEM-oriented student competitions represent outreach initiatives by educational institutions, the industry, and government agencies to provide such experiences for K-16 students in the U.S. and beyond, in order to interest them in STEM careers, and to better position them for academic and professional success. Although a comprehensive account of the history of STEM competitions in the U.S. is beyond the scope of this dissertation, highlighting some examples and trends across the preceding decades situates the Imagine Tomorrow competition in a broader context and underscores the relevance of this study.

**STEM Competitions in the U.S.** STEM-oriented student competitions exist in a variety of formats: design-and-build competitions (e.g., First Robotics), science fairs (e.g., the Intel International Science and Engineering Fair, better known as ISEF), math Olympiads (e.g., United States of America Mathematics Olympiad), and paper-and-pencil tests (e.g., the Tests of Engineering Aptitude, Mathematics and Science, known as TEAMS). This overview focuses primarily on design and problem solving competitions, which, like Imagine Tomorrow, involve open-ended, hands-on, project-based collaborative activities that students engage in over a period of time, usually several weeks or months. Such competitions generally provide opportunities for students to exercise their skills across physical settings and disciplinary boundaries, to tackle realistic problems, and to work in concert with peers and adults. By engaging students in these ways, creating frameworks for adult advising or mentorship, and rewarding top performers, competition organizers strive to promote student interest and participation in STEM disciplines, and to raise their awareness of related careers.

In the U.S., STEM-oriented student competitions have been around for at least half a century. Among the collegiate engineering competitions, where students typically design in teams over a period of time, some of the longest-running programs include the ASCE (American Society of Civil Engineers) National Concrete Canoe Competition (NCCC, since 1971 with origins in the 60s) and the Baja SAE (Society of Automotive Engineers) Competition (since 1976). Among the longest-running high school student competitions, the JETS (Junior Engineering Technical Society) Engineering Design and Problem Solving Competitions have been around at least since the 1970s.<sup>8</sup>

The heightened public awareness of certain issues, such as the need to transition to alternative energy sources in the face of accelerating climate change, or the persistent underrepresentation of women and racial/ethnic minorities in computer science and engineering despite increasing career opportunities in these fields, may suggest that student competitions in these domains are a relatively recent phenomenon. This is only partially the case. While at present there are many competitions focusing on computing, robotics, and alternative energy systems, the history of such programs covers several decades. For instance, the Association for Computing Machinery (ACM) International Collegiate Programming Contest has been around since the late 1970s,<sup>9</sup> and the JETS Computer Problem Solving Competition for high school students (using the BASIC computer language) extends to at least 1985.<sup>10</sup> One of the earliest robotics challenges, the Society of Manufacturing Engineers (SME) Robotic Technology and Engineering Challenge (presently the National Robotics Challenge) for students in middle school

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<sup>8</sup> In 2011 the JETS competition programs were acquired by the Technology Student Association ([http://www.tsaweb.org/TEAMolly\\_UNITE](http://www.tsaweb.org/TEAMolly_UNITE)).

<sup>9</sup> <http://icpc.baylor.edu/ICPCWiki/Wiki.jsp?page=The%20Early%20Years>

<sup>10</sup> Huntington, M. A. (1985). JETS Program Aids. Junior Engineering Technical Society, 1420 King St., Suite 405, Alexandria, VA 22314-2715 (\$5.50). Retrieved from <http://eric.ed.gov/ERICWebPortal/recordDetail?accno=ED281712>

through college began in 1986.<sup>11</sup> Finally, the collegiate Energy Resource Alternatives (ERA) Competition dates back to 1974 (ERA's precursor, the Great Electric Car Race, was started in 1968).<sup>12</sup> The ERA competition "arose from the increasing awareness of the world's energy problem," and was "an effort to demonstrate the feasibility of shifting homes and small industry from their almost exclusive dependence on petroleum and natural gas as the primary supply for their energy needs" – a purpose that would be equally applicable to a competition of this kind today (Radtke, 1976, pp. 4-6).<sup>13</sup> In retrospect, besides providing valuable learning opportunities for students at the time, innovative and successful competition programs such as these served as the trailblazers for the contemporary regional, national, and international STEM competitions.

Taking into account Washington State University's participation in the 1975 ERA competition, it may seem like history coming full circle with WSU now hosting its own alternative energy competition, Imagine Tomorrow. However, the university's outreach program reflects a broader trend. Over the past 20 years STEM-oriented competitions for students at all grade levels have proliferated, covering virtually every scientific and engineering specialization. In a recent study Wankat (2005) identified forty-four active national competitions for college students in engineering fields.<sup>14</sup> Of these, over 80% were team-based, and 68% involved building working prototypes (rather than just conceptual designs on paper). In a follow-up study Wankat (2007) identified fifty-three additional competitions for students at primary and

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<sup>11</sup> <http://www.smeef.org/programs/national-robotics-challenge.php>

<sup>12</sup> Radtke, M. L., & Et.al. (1976). The Final Report: 1975 Energy Resource Alternatives Competition. SCORE. Retrieved from <http://eric.ed.gov/ERICWebPortal/recordDetail?accno=ED164322>

<sup>13</sup> In 1975, a total of 42 teams from 34 universities in the U.S. and Canada took part in the ERA competition, including a team from Washington State University, which placed 27th.

<sup>14</sup> Regional qualifying events and competitions limited to only one or several institutions were excluded.

secondary levels (K-12).<sup>15</sup> Similar to the collegiate events, over 80% of these competitions required or allowed the participants to work in teams.

In recent years, some of the largest pre-college STEM competitions have been the West Point Bridge Design Contest, in which over 100,000 junior high and high school teams have taken part since 2001<sup>16</sup>; the FIRST (For Inspiration and Recognition of Science and Technology) Championship, “reaching close to 250,000 young people” through their series of competitions for grades K-12 since 1992<sup>17</sup>; and BEST Robotics, started in 1993, which involves around 11,000 middle school and high school students annually<sup>18</sup>. In addition, within the last decade a number of corporations have leveraged the Internet to launch student competitions on a global scale. Examples include Microsoft’s Imagine Cup computer technology competition for high school and college students, the Google Science Fair for students aged 13 to 18, and the Siemens Competition in Math, Science & Technology for high school students. Increased popularity of such programs is illustrated by the history of Microsoft’s Imagine Cup: “During the past nine years, the Imagine Cup has held its worldwide competitions all over the globe. And while its modest beginnings back in 2003 were in fact pretty humble (fewer than 1,000 student competitors), the Imagine Cup has grown to more than 325,000 registered students last year alone<sup>19</sup>” (Imagine Cup, 2011).

The growth in the number and scale of student competitions in recent decades may be altering the STEM education experience, at least in engineering. Some evidence for this is cited in a 2006 report by the Accreditation Board for Engineering and Technology (ABET),

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<sup>15</sup> Regional qualifying events that feed into the larger competitions were excluded, but a handful (about 10%) of local fairs were included as a “sampler of the many similar programs” (Wankat, 2007, p. 75).

<sup>16</sup> <http://bridgecontest.usma.edu/publicity.htm>

<sup>17</sup> [http://www.usfirst.org/aboutus/first-history#frc\\_history](http://www.usfirst.org/aboutus/first-history#frc_history)

<sup>18</sup> [http://www.bestinc.org/b\\_about\\_best.php](http://www.bestinc.org/b_about_best.php)

<sup>19</sup> <http://www.imaginecup.com/about/history>, accessed on April 30, 2011.

Engineering Change: A Study of the Impact of EC2000. The report highlights the findings of a comprehensive study on the impact of ABET's revised accreditation criteria, introduced in 2000, on college engineering programs and students. As part of the study, between 4,000 and 5,000 engineering graduates from the classes of 1994 and 2004 were surveyed about their college experiences. Among other findings, the report states:

Compared to their 1994 counterparts, and after taking differences in graduates' and institutional characteristics into account, 2004 graduates reported:

- More active engagement in their own learning;
- More interaction with instructors;
- More instructor feedback on their work;
- More time spent studying abroad;
- More international travel;
- **More involvement in engineering design competitions;** and
- More emphasis in their programs on openness to diverse ideas and people. (ABET, 2006, p.6, emphasis added)

Thus, among engineering students, the extending reach of STEM-oriented competitions might be contributing to a qualitatively different college experience.

How do students participate in STEM-oriented competitions? What factors contribute to successful project completion, and what hinders progress? The present study approaches this question by exploring in depth how students participating in the Imagine Tomorrow competition work on projects in out-of-class settings, working without the structural support they may be used to. Project-based curricula often strive to give students more authentic frameworks for learning and applying new knowledge and skills, by introducing them to real-world problem scenarios. Determining how much and what kinds of scaffolding and direction students actually need and what competencies they may or may not acquire in class may be informed by better understanding of what they are capable of outside of the classroom walls.

## Literature Review

One way to pursue the question of how high school students complete a collaborative design project outside of the classroom is to review what is known about similar project-based experiences in classroom settings. An overview of research in this area is presented in the section Project-Based Learning.

**Project-Based Learning.** The goal of the Imagine Tomorrow competition is to foster or sustain student interest in STEM fields through collaborative project-based experiences where they design solutions to real-world problems, specifically in the area of “green” environmentally-friendly technologies and practices. The premise is that such experiences have positive effects on student learning, motivation, and interest, and better prepare them for professional occupations, especially in STEM fields. Research on project-based learning is used to elaborate these ideas and frame the present study of how students successfully complete a competition project in out-of-classroom settings.

The challenge of creating engaging and meaningful learning experiences for students was well articulated by Jerome Bruner in *The Process of Education* (1960/2003):

“The best way to create interest in a subject is to render it worth knowing, which means to make the knowledge gained usable in one’s thinking beyond the situation in which the learning has occurred. (...) Somewhere between apathy and wild excitement, there is an optimum level of aroused attention that is ideal for classroom activity. What is that level? Frenzied activity fostered by the competitive project may leave no pause for reflection, for evaluation, for generalization, while excessive orderliness, with each student waiting passively for his turn, produces boredom and ultimate apathy. There is a day-to-day problem here of great significance. Short-run arousal of interest is not the same as the long-term establishment of interest in the broader sense.” (pp. 31, 72).

Stemming from Dewey’s (1959) work on learning through hands-on inquiry, project-based and problem-based learning (PBL) refers to problem, project, or question-oriented,

collaborative experiences aimed at optimizing student learning, motivation, and interest. PBL approaches to formal, classroom-based teaching and learning, and the out-of-classroom Imagine Tomorrow projects share some common features. Highlighting the major aspects of PBL instruction helps identify the features of Imagine Tomorrow projects that may be important to consider in developing a framework for analyzing how students work on such projects.

A useful preamble for describing the design principles behind PBL models is to consider some of the discontinuities between the mental activities that characterize in-school and out-of-school experiences. Drawing on ethnographic studies in real-world work settings, Resnick (1987) outlined “four broad characteristics of mental activity outside school that stand in contrast to typical school work” (p. 13). These characteristics are summarized in Table 1 below.

Table 1

*Characteristics of Mental Activity (Resnick, 1987)*

<b>In School</b>	<b>Outside of School</b>
<b>Individual cognition</b> <ul style="list-style-type: none"> <li>- independently performed and evaluated mental activity</li> </ul>	<b>Socially shared cognition</b> <ul style="list-style-type: none"> <li>- inter-dependent mental and physical tasks</li> </ul>
<b>Pure mentation</b> <ul style="list-style-type: none"> <li>- thought unaided by cognitive support tools (notes, textbooks, calculators) emphasized during testing</li> </ul>	<b>Tool manipulation</b> <ul style="list-style-type: none"> <li>- tool-mediated thought enabling more sophisticated performance and decision-making</li> </ul>
<b>Symbol manipulation</b> <ul style="list-style-type: none"> <li>- symbol-based learning that may be disconnected from symbolized objects or events</li> </ul>	<b>Contextualized reasoning</b> <ul style="list-style-type: none"> <li>- manipulation of material objects embedded in a context aids effective performance and goal achievement</li> </ul>
<b>Generalized learning</b> <ul style="list-style-type: none"> <li>- difficulty in transferring and applying general, abstracted knowledge problems in specific situations</li> </ul>	<b>Situation-specific competencies</b> <ul style="list-style-type: none"> <li>- ability to customize general knowledge into specialized routines to perform specific tasks in work and life situations</li> </ul>

PBL approaches are aimed to address the discontinuities between in-school and out-of-school mental activities and practices by helping students better understand what they are learning, to transfer and apply the new skills and knowledge to novel problems, and to develop or sustain interest in a subject. The PBL literature spans instruction in many subjects and describes different flavors of the model, such as project-based learning (Krajcik & Blumenfeld, 2006; Thomas, 2000), anchored instruction (Cognitive and Technology Group at Vanderbilt, 1992), project-based science (Krajcik, et. al., 1998; White and Frederiksen, 1998), and problem-based learning (Hmelo-Silver, 2004). The approaches differ in some respects, including characteristics of the learning challenge (complexity, ambiguity); structure and duration of the problem-solving, design, or inquiry process; the teacher’s role; patterns of group work; tools and representations; and the intended outcomes. At the same time, PBL models have much in common. They tend to be defined in terms of the features of the learning environment that they

share. In a synthesis of research on the topic Krajcik and Blumenfeld (2006) identify the following common features of PBL learning environments:

- Starting with driving question or problem
- Engaging students in authentic, situated inquiry (processes that characterize expert performance)
- Collaboration between students, teachers, and community members aimed at solving the problem
- Scaffolding the inquiry process using learning technologies that push students to develop their abilities
- Creation of tangible, publicly accessible products or artifacts that address the problem

Similarly, Thomas (2000) outlined five criteria for projects in project-based learning models:

- PBL projects are central, not peripheral to the curriculum.
- PBL projects are focused on questions or problems that "drive" students to encounter (and struggle with) the central concepts and principles of a discipline.
- Projects involve students in a constructive investigation.
- Projects are student-driven to some significant degree.
- Projects are realistic, not school-like. (pp. 3-4)

To summarize, PBL projects may be described as “complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations” (Thomas, 2000, p. 1). Other key features of the PBL approaches include student teamwork and a reconfiguration of the teacher’s role from a source and standard of knowledge, to a facilitator or guide in the construction of meaning with students. Importantly, the teacher is also responsible for laying out the basic structure of the learning process – ensuring that projects meet certain guidelines, providing feedback, and grading.

There are different ways of doing research on the effects of project-based learning experiences on students, teachers, and schools. Evaluation and intervention studies can answer questions about the effects of specific PBL models or particular aspects of these models on outcomes of interest, compared to alternative models or “control” curricula (e.g., Gallagher, Stepien & Rosenthal, 1992; Moore, Sherwood, Bateman, Bransford, and Goldman, 1996). Such research is possible and useful when the content and form of the PBL curriculum are pre-designed and known; when the researchers or instructors have substantial control over the implementation process; and when the intervention is implemented in a relatively bounded environment with certain established norms. Studies of this kind enable inferences that changes in the outcomes were the product of the intervention, thus informing further refinement of the PBL curriculum. However, research in this form becomes problematic when the “intervention” is a spontaneously conceived, student-initiated project, which neither the instructor nor the researcher has direct control over or knows much about. Also, while specific technology and curriculum design changes are viable means of fine-tuning instructor-led PBL experiences, such changes may not be feasible in an environment of scarce and opportunistically utilized resources, as may be the case with Imagine Tomorrow projects conducted “under the school’s radar.”

Implementation studies represent an alternative approach to analyzing PBL experiences, by addressing the “how” and “why” questions that help to contextualize and explain the outcomes associated with the implementation of a particular PBL model. This is accomplished by examining the challenges that the teachers and students had faced in the planning or enactment of a particular PBL model. For example, Krajcik et al. (1998) examined how several seventh graders participated in group work to carry out project-based scientific inquiry activities. They found that while the learners were able to take into account experimental control conditions

and sampling issues as well as plan investigations and organize data collection, they were less capable in considering the scientific merit of their chosen questions, align experiments with questions, and logically support their claims.

Edelson, Gordon, and Pea (1999) identified a number of challenges students encountered when working on projects designed to foster inquiry-based science learning using computer technology visualization and modeling tools. The challenges involved lack of: motivation for meaningful learning; the technical skills for generating or analyzing data-intensive visualizations; background knowledge for generating research questions, planning investigations and interpreting findings; the ability to organize inquiry activities over time while navigating time and other resource constraints. In a study by Achilles and Hoover (1996) of PBL activities implemented in middle and high schools, the teachers reported students struggling with working well in groups, due to a lack of teamwork skills and etiquette.

Conclusions from research on student-related challenges with PBL curricula emphasize the need to support teachers through carefully designed technical, logistical, content knowledge, and process support tools and scaffolding strategies that would allow them, in turn, to help students gain the appropriate skills, knowledge, and motivation to effectively engage in PBL experiences (Krajcik & Blumenfeld, 2006).

Other investigators have focused on challenges that teachers experience when attempting to plan and enact PBL curricula. Citing a program of research on developing and implementing problem-based science curricula by Marx, Blumenfeld, Krajcik, Blunk, Crawford, Kelly, & Meyer (1991) and Marx, Blumenfeld, Krajcik, and Soloway (1997), Thomas (2000) summarized several problems commonly confronted by the teachers that surfaced in those studies:

*Time.* Projects often take longer than anticipated. In addition, difficulties that teachers experience in incorporating Project-Based Science into district guidelines are exacerbated by the time necessary to implement in-depth approaches such as Project-Based Learning.

*Classroom management.* In order for students to work productively, teachers must balance the need to allow students to work on their own with the need to maintain order.

*Control.* Teachers often feel the need to control the flow of information while at the same time believing that students' understanding requires that they build their own understanding.

*Support of student learning.* Teachers have difficulty scaffolding students' activities, sometimes giving them too much independence or too little modeling and feedback.

*Technology use.* Teachers have difficulty incorporating technology into the classroom, especially as a cognitive tool.

*Assessment.* Teachers have difficulty designing assessments that require students to demonstrate their understanding. (pp. 26-27)

Although some of these factors may be less relevant for out-of-class projects (e.g., classroom management, control), others (e.g., time, support) suggest topics that may be worth exploring.

Studies may also address the classroom, institutional, and community-related factors which could mediate the implementation of the PBL model in a particular case. Findings from such studies may help uncover interdependencies among the components of the PBL curriculum, or between the curriculum and student, teacher, or contextual limitations, as well as unintended outcomes that could be overlooked by evaluation research. For instance, Marx et al. (1994, 1997) discuss a link between teachers' classroom-level difficulties with PBL, and school-level factors, noting that some challenges may be ameliorated by a supportive school environment where teachers have the ability to iteratively reflect and seek feedback on their practices.

The detailed findings in studies of school-level constraints and challenges with implementing PBL curricula are less relevant to the present research, since they tend to focus on practical aspects specific to the formal in-school learning. Examples of such issues include

district curricular policies, class size, technological and scheduling issues (e.g., Edelson, et. al., 1999; Blumenfeld, Krajcik, Marx, & Soloway, 1994). At the same time, they illustrate how seemingly idiosyncratic, teacher or classroom-related challenges may signal deeper discontinuities or tensions between a particular form of teaching and learning activity, like PBL, and broader contextual factors, such as school rules or professional and cultural norms. For example, Ladewski, Krajcik, and Harvey (1991) described several “dilemmas” that one middle school teacher confronted when enacting a project-based science curriculum. These dilemmas centered on finding the appropriate balance of teacher control and student autonomy in the inquiry process – for instance, meeting state content standards on one hand, and on the other hand, allowing students to pursue their own investigations. While this may be interpreted as a conflict between one teacher’s deep-seated beliefs and the demands of a particular instance of PBL enactment, it may also indicate tensions that involve school, district, and other professional norms and commitments. Overall, research indicates that student, teacher, and contextual factors associated with implementing PBL curricula are interrelated and complex, suggesting that inquiry in this area would benefit from an integrated perspective that could account for these dynamic relationships.

**Summary.** Many of the projects students do as part of STEM competitions, including Imagine Tomorrow, are completed outside of class, not as part of PBL curricula. The PBL literature provides reference points for comparing and distinguishing competition projects from formal project-based curricula, and highlights possible challenges that students and team advisors might face along the way. The planning and implementation of such projects may be ad-hoc, with little control or prior knowledge about the project topics, goals, settings, or tools that may need to be employed in the design process. It may be difficult to reliably measure the

effects of such projects on student learning, or to differentiate internal project activities from external “mediating” factors.

There are currently few in-depth studies of how high school students go about developing a competition project without the classroom constraints or a traditional teacher-figure, and in what areas of project work they tend to succeed or fall short. The available research on student competitions includes steps in this direction (e.g., Khorbotly, 2010; Mitchell, Dori, & Kuldell, 2010), but the majority of studies remain focused on in-class projects. On the other hand, *in situ* research on distributed cognition and collaboration in out-of-school settings illustrates what problem-solving might look like when individuals work on complex tasks or issues over periods of time. However, these studies typically involve experts or outstanding designers (e.g., Cross, 2004; Cross & Clayburn Cross; 1998; Lawson, 1994), or novices acting in relatively stable (albeit potentially distributed) environments such as scientific labs (e.g., Goodwin, 1997; Nersessian, 2005). The factors associated with successful execution of a collaborative design project by high school students in loosely bounded, out-of-class settings are not well defined and understood. If little is known about the limits of what students are capable of if left to their own devices, the picture of their zone of proximal development (Vygotsky, 1978) where context is accounted for remains incomplete. The systems perspective leveraged in this study contributes to such understanding, by considering the social and contextual dimensions of project-based collaboration.

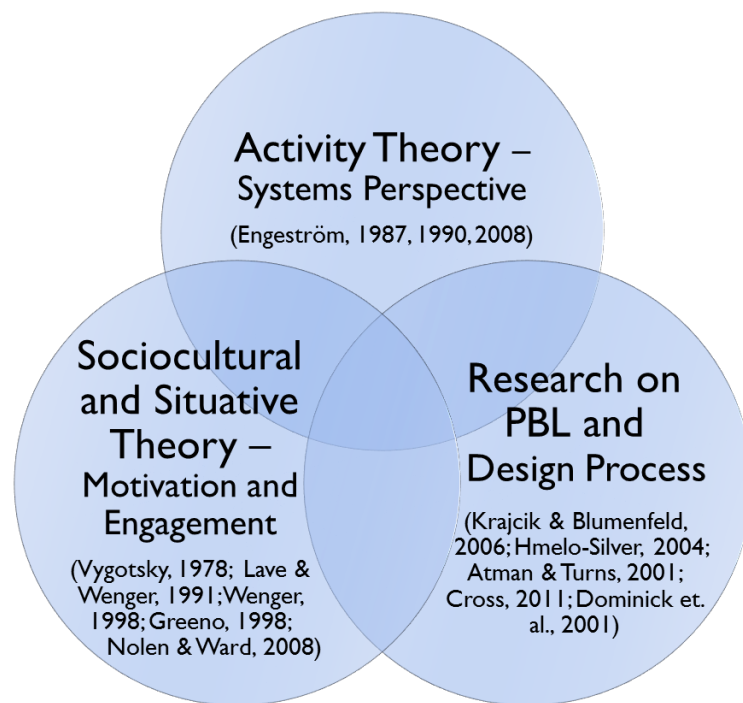
## Chapter 2: Theoretical Framework

The type of student project that is the subject of this study differs from projects executed in PBL curricula in one major way, namely, a developmental trajectory not merely in the solution to the problem that the project entails, but in the process of solving the problem. This is so because project-related activity of the team is not directed by the structure of the unit as taught by the teacher. Rather, it may be hypothesized that the team must carve out its own “project space,” and come up with *a way of doing the project* over time, as the team’s goals and tasks become more concrete, and as students accumulate experience of tackling different tasks and working as a team, taking on specific responsibilities, performing different roles, and staying motivated to work on the project in the self-driven, “deregulated” out-of-class atmosphere.

It is also likely that as time goes on, the students identify and make use of the opportunities and resources which may be available to them, or which they identify and secure in the environment where they operate. Presumably, the team also has to adapt to various internal (team-related) and external (existing regardless of the project) limitations which shape their work practices and expectations regarding the outcomes. Thus, such project activity blends two features: an emergent process internal to the team, and a process by which the team adapts to while also repurposing and adapting to its needs, the context within which it organizes the project work.

The notions of the development of organized project-related collaborative activity, and a dynamic relationship between this activity and the broader context of the project warrant theoretical elaboration. The sociocultural theoretical perspective is used to frame these ideas and to foreground an overview of activity theory, which guides the analytic approach of the study. A

related issue of what motivates students to engage with and complete the project is explored with the help of the situative approach to the study of motivation and engagement in and across complex and changing learning environments. Figure 1 shows the three areas of research forming the foundation for this study.



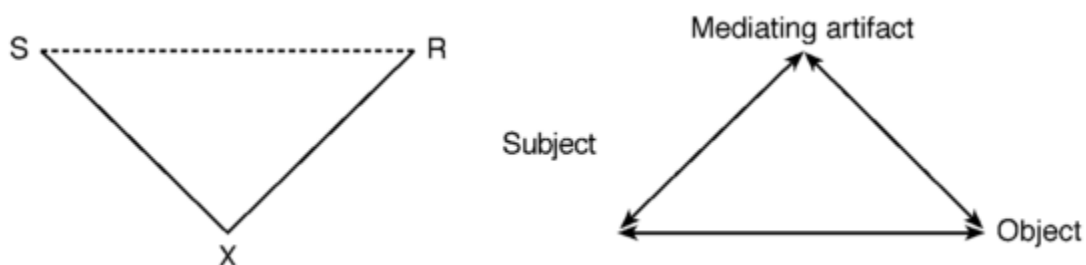
*Figure 1.* Three areas of research forming the foundation of this study.

The activity theory developed by Yrjö Engeström (1987) is used as the basis for the conceptual and analytic approach in this study. Engeström's theory is well suited for the study of student competition projects. First, the theory is consistent with and complemented by the sociocultural and situative theoretical perspectives. These perspectives offer fruitful ways of thinking about how high school students succeed in completing an open-ended, complex, collaborative design project in out-of-class settings. Second, activity theory provides a way of representing and linking some of the key topics in this study: object-oriented activity, as

students' project-related collective design work; activity system (and its elements), as context for the work; tensions, contradictions, and disturbances, as sources and manifestations of challenges for the team; and innovation or expansion, as a way of thinking about strategies students might use to address their challenges. Finally, the theory offers several organizing principles which are helpful in developing a holistic perspective on the topic of interest. An overview of the background and central ideas of the theory is provided in the following sections.

### **Sociocultural Foundations of Activity Theory**

Activity theory (Engeström, 1987) provides a framework for a holistic, systematic analysis of the practices of a team of students as they work on their project for the competition. Activity theory stems from cultural-historical psychology developed by Vygotsky, Leont'ev and Luria in the first half of the 20<sup>th</sup> century. It is rooted in Vygotsky's notions of mediated action and the zone of proximal development. Mediated action is the idea that learning and development emerge in one's interaction with the surrounding environment which is mediated by tools and artifacts, including physical objects and language (Vygotsky, 1978). Vygotsky's (1978, p. 40) model of "a complex, mediated act," may be represented as a triangle of subject, object, and mediating artifact (Figure 2).



*Figure 2.* Vygotsky's model of mediated act and its common reformulation (adapted from Engeström, 2001, p. 134).

Another key concept in activity theory is the *zone of proximal development* (ZPD). Vygotsky (1978) introduced the concept of the zone of proximal development in an effort to provide a more comprehensive account of the “dimensions of school learning,” and particularly the role of formal learning in schools in the process of children’s mental development. A major reason for advancing this theoretical framework stemmed from his appreciation of “a well-known and empirically established fact [...] that learning should be matched in some manner with a child’s developmental level” (Vygotsky, 1978, p. 85). The notion of ZPD reflects Vygotsky’s perspective on children’s mental development. For Vygotsky, mental development was *not* merely characterized by what a child can achieve by him/herself at a given point in time; in his view, such measures revealed one’s “actual developmental level,” which “defines functions that have already matured, that is, the end products of development” (p. 86). Rather, a key characteristic of mental development at a given time was the individual’s future developmental potential. Hence, “the state of a child’s mental development can be determined only by clarifying its two levels: the actual developmental level and the zone of proximal development” (Vygotsky, 1978, p. 87). He, therefore, defined the zone of proximal development as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p. 86). The important implication of ZPD for activity theory is that it reflects a more fundamental argument, which according to Cole, Hood, and McDermott (no date), was “that the child’s abilities were to be discovered not just within the child, but in a system which included the child and the structured environment provided by adults and peers” (p.31). The use of the concept of ZPD in activity theory differs from its application in research on teaching:

In North America, the concept of ZPD is frequently referred to as a pedagogical tool to justify instructional strategies in classrooms. In these applications, it is often separated from the CHAT [cultural historical activity theory] perspective and instead referred to as an artifact or in some cases as a variable that educators can manipulate. However, ZPD from a CHAT perspective is a conceptual tool for understanding the complexities involved in human activity while individuals engage in meaning making processes and interact with the environment. (Yamagata-Lynch, 2010, pp. 18-19)

Stemming from the work of Vygotsky, sociocultural theory considers learning, motivation, and self-regulation as elements in an inherently social developmental psychological process (Pressick-Kilborn & Walker, 2002). Vygotsky's work gave rise to a pivotal theoretical claim that cognition is a cultural process, a comprehensive understanding of which can only be achieved by supplementing experimental research with investigations of its workings within real-world, "everyday" situations and contexts. Such thinking was also associated with the recognition, going back at least 30 years, of the limited ecological validity of laboratory-based experimental research that sidestepped the dynamic and bidirectional nature of meaning-making and learning in everyday life (Cole, Hood, and McDermott, no date). More contemporary scholars have sought to bridge the theoretical gaps they saw in the experimental research-driven findings of traditional cognitive psychology by using ethnographic methods, which were more sensitive to the social dynamics of environments where cognitive activity actually takes place (e.g., Cole, Hood, & McDermott, no date; Nasir, 2005; Ochs, et.al., 1992). Some of these efforts have focused on describing individual and group cognition in real-world contexts by conceptualizing cognition as a component of culturally determined systems (e.g., Hutchins, 1995a). In his book, *Cognition in the Wild*, Hutchins (1995a) states:

Culture is not any collection of things, whether tangible or abstract. Rather, it is a process. It is a human cognitive process that takes place both inside and outside the minds of people. It is the process within which everyday cultural practices are enacted. (pp. 354, 373)

An important outcome of such thinking is the reformulation of the concept of culture from a collection of artifacts and forces that act upon an individual to a more dynamic relationship where the individual has agency in maintaining a culture by perceiving, interpreting (negotiating meaning), and *acting* within a community that shares this culture. Language, as well as other tools and artifacts, are seen as key enablers of these activities, and meaning-making through social interaction as the engine for the transmission and historical continuity of culture. In this way, sociocultural theory acknowledges that individual and collective identity, knowledge, competence, values, interests, and motivations are dynamically and continuously co-constructed through participation in the practices of communities (Lave & Wenger, 1991).

As a member of a community, the individual is seen as adopting, repurposing, and contributing to its semiotic tools, artifacts, and activities which collectively constitute the very contexts that mediate interest and motivation (e.g., in classroom settings – see Pressick-Kilborn & Walker, 2002; Walker, et. al., 2004). Within this framework, the meanings and functions of individuals’ activities and social interactions are explored at different levels of analysis. These levels may include small groups or whole classrooms (e.g., Walker, et. al., 2004), homes (McCaslin, 2004), as well as consideration of “multiple, overlapping communities of practice” (Pressick-Kilborn & Walker, 2002). In line with these notions, I believe that collaborative design activity in the context of the Imagine Tomorrow competition may be meaningfully analyzed at the level of a group project. But how is a “project” to be interpreted – as a sum total of individual mental processes and physical actions, as manifestation of interpersonal interactions among the project team members, or as a design exercise in achieving the project objectives under rigid external constraints? In the next section I describe how activity theory may be leveraged to examine the issues of interest at the project level.

## Activity Theory

The ZPD-inspired sociocultural view of the dynamic relationship between individual and context, which activity theory adopts, represents a middle-ground approach between two alternative positions. One is a “standard cognitivist view [which] identifies the given problems and knowledge domains – or the given individual’s mental modes and cognitive structures – as the context of problem solving, thinking and learning. This view excludes the societal and cultural aspects from its notion of context” (Engestrom, 1990, p. 77). The other includes “various phenomenological and ethnomethodological analyses [that] focus on dyadic interaction, attempting to define contexts as social situations, as spaces of interactive experience or as fields of discourse. [...] This makes contexts look like something that can be created at will by two or more persons in interaction, as if independently of deep-seated material practices and socio-economic structures of the given culture” (Engeström, 1990, p. 78). As Lave (1988) reflected on these opposites, “one has system without individual experience, the other experience without system” (p. 150). It is reasonable to assume that neither the individual cognitive processes of Imagine Tomorrow project team members, nor their project-related exchanges explain how and why a team manages to complete a project. Other responsibilities, existing relationships, past experiences and future plans might frame the ways in which students do or do not engage with their project-related tasks and with each other.

An out-of-class project is not fully contained, as if in a bubble, within a particular “external” context, either. According to Engeström (1990), “For activity theory, contexts are neither containers nor situationally created experiential spaces. Contexts are activity systems. An activity system integrates the subject, the object and the instruments (material tools as well as signs and symbols) into a unified whole” (pp. 78-79). In this way, a student project itself

becomes a context and an activity system, emerging as part of participation in the competition where certain rules and norms are enacted, relationships formed, tools employed, and activities carried out.

Activity theory has been revised over time. In its present third generation, the theory enables analysis of interaction among networks of activity systems. In this current state, the theory is characterized by five principles, representing aspects of studied phenomena that should be taken into account (Engeström, 2001). These principles help organize the thinking about the topic of interest in this study and are leveraged to structure the overview of the activity-theoretical framework in the sections that follow, as well as guide the analytic approach.

**Activity System as Primary Unit of Analysis.** The concept of *activity* is central in an activity-theoretical conceptualization of an *activity system*. A key distinction in activity theory is between activity and action. Engeström's definitions are based on those of Leont'ev, a Soviet psychologist who closely collaborated with Vygotsky. Leont'ev used an example of a primeval collective hunt to show how division of labor leads to apparent disassociation between the direct result, or object, of what an individual does, and the final outcome, or motive for the doing: "Processes, the object and motive of which do not coincide with one another, we shall call 'actions'. We say, for example, that the beater's activity is the hunt, and the frightening of game his action." (Leont'ev, 1981, p. 210, quoted in Engeström, 1987, p. 84). According to Leont'ev (1978, 1981), social connections and the collective activity provide the basis for individual actions, by connecting these actions and their direct result, or object, with their indirect motives, that is, the object and outcomes of collective activity. By the same token, although personal needs may motivate individual activity (e.g., participating in the hunt), the meaning of individual actions, and their object, can only be understood by considering the object of collective activity

within which they are situated. Individual motives might overlap or become subsumed by the larger socially shared motive which includes the direct object (e.g., the animals killed in a successful hunt) and its associated outcomes (e.g., food, clothing, and hence survival). Based on Leont'ev's (1978) framing of activity as object-oriented, productive, agential, collective human practice, Engeström (2008) characterized activity as follows:

“collective, systemic formation that has a complex mediational structure. Activities are not short-lived events or actions that have a temporally clear-cut beginning and end. They are systems that produce events and actions and evolve over lengthy periods of sociohistorical time.” (p. 26)

Figure 3 depicts Engeström's elaboration of a model of the collective activity system and its mediational structure.

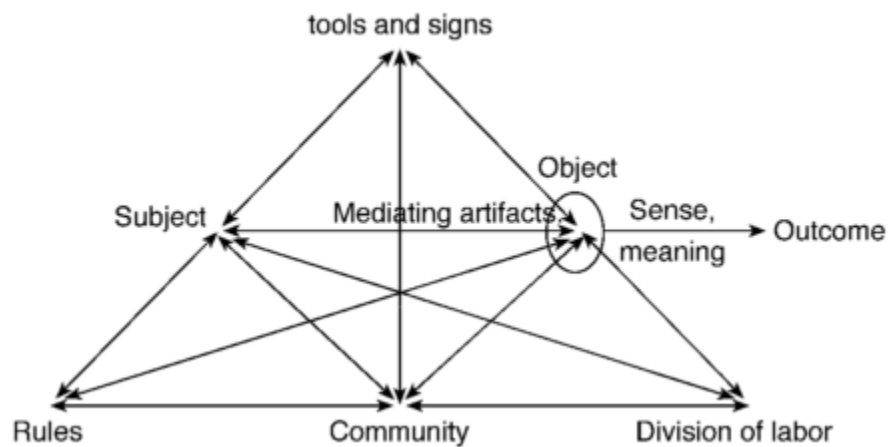


Figure 3. The mediational structure of an activity system (adapted from Engeström, 1987, p. 78; Engeström, 2001, p. 135).

Engeström (1990) provided the following description of the components of the activity system:

“In the model, the *subject* refers to the individual or sub-group whose agency is chosen as the point of view in the analysis. The *object* refers to the ‘raw material’ or ‘problem space’ at which the activity is directed and which is molded or transformed into *outcomes* with the help of physical and symbolic, external and internal *tools* (mediating instruments

and signs). The *community* comprises multiple individuals and/or sub-groups who share the same general object. The *division of labor* refers to both the horizontal division of tasks between the members of the community and to the vertical division of power and status. Finally the *rules* refer to the explicit and implicit regulations, norms and conventions that constrain actions and interactions within the activity system.” (p. 79)

Thus, Engeström conceptualized activity as a complex, changing, dynamic system involving several components. This view suggested an expansion of Vygotsky’s (1981) proposal of using tool-mediated action as the unit of analysis of behavior. Engeström (1987) recognized that tool-mediated action does not enable analysis of activity as a *collective* system of goal-directed work where the practices and structural arrangements of work might be transformed in new, innovative ways “from below:”

Tool-mediated action in no way solves the problems of motivation, emotion and creation. To the contrary, it seems that both meaning and tool-mediated action are formations of the same structural level. This is the level of goal-directed individual cognition, the 'rational level' of human functioning. The problems of motivation, emotion and creation seem to be unanswerable on this level. They belong to a higher, collective and - paradoxically - less conscious level of functioning. (p. 81)

Thus, in analyzing activity, the *activity system* also becomes the primary unit of analysis. This does not prevent analysis from being based on episodes of discourse recorded through observation of work activity such as conversations between coworkers on a television broadcast team (Engeström, 2008), or researcher interviews with individual subjects such as physicians in a hospital (Engeström, 1990). As Engeström (2001) pointed out, “Goal-directed individual and group actions, as well as automatic operations, are relatively independent but subordinate units of analysis, eventually understandable only when interpreted against the background of entire activity systems” (p. 136). Thus, particular modes of activity, especially those central to the attainment of the object by the subject within the system, constitute valid lower-level units of analysis, or nested units of analysis. A key issue for activity-theoretical analysis of a

phenomenon is to integrate the inferences from analyses based on such embedded units or episodes into a more comprehensive whole, with implications for the overall activity system.

**Multi-Voicedness and Historicity.** The principles of multi-voicedness and historicity are integrated here as they have complementary implications for the present study. According to Engeström (2001),

An activity system is always a community of multiple points of view, traditions and interests. The division of labor in an activity creates different positions for the participants, the participants carry their own diverse histories, and the activity system itself carries multiple layers and strands of history engraved in its artifacts, rules and conventions. (...) Activity systems take shape and get transformed over lengthy periods of time. Their problems and potentials can only be understood against their own history.

In the Imagine Tomorrow competition, the students are free to come up with their own ideas for the project. Perspectives contributed by the project team members would be informed by their unique past experiences, knowledge, and skills. These individual and collective perceptions might change over the course of project work, and might also converge or diverge from the advisor's sense of the project. These multiple voices of the subjects, as well as the community stakeholders who might control relevant information or resources, might need to be reconciled in order to complete the project.

The components of an activity system suggest that activity systems possess another important property – historical continuity, or historicity. The tools, rules, community, and other aspects of an Imagine Tomorrow project activity system do not appear from nowhere when an activity system is formed. Neither are they re-created from scratch in interaction each time a team meets to work on the project. The students and their teachers (who often serve as project advisors) are provided with resources from the competition's organizers, including deadlines for certain activities (e.g., registration; final presentations), suggested topics and categories for project entries, a scoring rubric, and guidelines for structuring the presentations at the

competition event. The project advisors must abide by the university, district, and school policies in planning the teams' trip to the competition. In schools that repeatedly enter the competition, the current cohort of participants might "inherit" resources, best practices, and even on-going projects from prior participants.

**Contradictions and Expansive Transformations.** The historicity of activity systems means that a given activity system does not only involve internal connections among its various components, but is also enmeshed in interactions with other activity systems. Although an activity system might persist through time in a relatively stable form, exhibiting certain properties and relationships, this does not mean that it is inherently stable. According to activity theory, all activity systems are characterized by inner *contradictions*. According to Engeström (2001), contradictions are:

sources of change and development. Contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems. (...) Activities are open systems. When an activity system adopts a new element from the outside (for example, a new technology or a new object), it often leads to an aggravated secondary contradiction where some old element (for example, the rules or the division of labor) collides with the new one. Such contradictions generate disturbances and conflicts, but also innovative attempts to change the activity. (p. 137)

Certain contradictions are inherent in activity systems – for instance, Engeström (2001) describes the "primary contradiction" between use value and exchange value of commodities in capitalism. This fundamental or *primary contradiction* propagates through all of the components (nodes) of the activity system, and surfaces in two ways: as *tensions within each component*, and as *secondary contradictions between components*. In the activity system of a student competition project, the primary contradiction within the solution (object) might be expressed as an inherent tension between designing a solution that effectively addresses a real environmental

problem (use value), and presenting a project in a way that earns high scores from the judges and wins an award (exchange value).

Besides the inherent primary contradictions, secondary contradictions arise when changes are introduced into any of an activity system's components, as these components often represent junctions in activity system networks. An out-of-class collaborative design project is not an immutable structure from the time the team registers for the competition to the day of final presentations. Changes in team membership (subject), the available resources (tools), member roles (division of labor) and project goals (object) might disrupt the order of things. In a study of work of a professional television broadcast team, Engeström (2008) called such disruptions "disturbances," which represented "deviations from the normal scripted course of events in the work process, normal being by plans, explicit rules and instructions, or tacitly assumed traditions" (p. 24). Other terms used to describe such disruptions include "troubles," "discoordinations," and "breakdowns" (Engeström, 1990, Ch. 4, pp. 83-93). These phenomena may be detected in analyses of particular forms of activity, such as doctor-patient consultations, or conversations between members of a television show production crew. Identifying such issues which arise as a consequence of tensions and changes in activity systems helps identify hypothetical internal contradictions which may interfere with the subjects' (e.g., a student team's) ability to attain the object (e.g., to complete a design project). On the other hand, tensions and contradictions may also provoke attempts by an activity system to adaptively change itself, by *innovating* its way out of the "double binds" that occur when subjects in the activity system are faced with conflicting demands (Engeström, 2001, p. 137).

An activity system may either exhibit rigidity by privileging practices intended to maintain the status quo in the face of changing circumstances (e.g., Engeström, 2008), or it may

flexibly adapt to change by developing innovations in practice, such as new or modified rules, tools, community connections, ways of dividing labor, and so on (e.g., Engeström, 2008; Yamazumi, 2009). The capacity of activity systems for development through innovation relates to the activity-theoretical principle of *expansive transformation*. Engeström (2001) describes the principle in the following way:

Activity systems move through relatively long cycles of qualitative transformations. As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from its established norms. In some cases, this escalates into collaborative envisioning and a deliberate collective change effort. An expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity. (p. 137)

In the context of *Imagine Tomorrow*, the notion of multiple overlapping or joined activity systems enables thinking about an out-of-class collaborative design project as a semi-stable arrangement with potential for innovation in the way its collective activity is organized. Rather than falling into disarray and failing to coordinate and carry out the necessary project-related tasks without the familiar boundaries of teacher-directed classroom activity, a student team might be able to survive or even thrive outside of the classroom, by maneuvering within and across the boundaries of in and out-of-school contexts to carve out an “activity setting” for itself, which “provides the context in which [project-related] activities take place” (Yamagata-Lynch, 2010, p. 25). Research on “nomadicity” in group work, conceptualized as an aspect of collaborative activities across physical locations, suggests that such work involves complex coordination of strategies, tools, spatial practices, and places in order to support engagement in collaborative design practice (e.g. Rossitto & Eklundh, 2007). From an activity-theoretical perspective, this “nomadic” project-related activity setting would exist in a dynamic relationship with other activity settings where students engage in their daily practices, like academic

coursework or other extracurricular activities. To better understand how such symbiosis might be achieved, it is necessary to develop a more precise understanding of practices that might be important in an out-of-class project activity system.

### **Activity as Collaborative Design Practice**

How might the focal activity in the activity system of an out-of-class design project team be defined? In this study, this activity is conceptualized as collaborative design practice (CDP). To unpack this term, it is helpful to consider the sociocultural notion of practice and the STEM-related notion of collaborative design process. Below, I develop a view of collaborative design practice that bridges the broad Wengerian notion of “community of practice,” and the more structured, narrower model of design endemic to engineering education research.

**Practice as Community Engagement.** The following definitions from Wenger’s (1998) social theory of learning provide grounding for the term practice as it is employed in the present study. Within Wenger’s (1998) framework, knowledge is conceptualized as “a matter of competence with respect to valued enterprises; knowing, as “a matter of participating in the pursuit of such enterprises;” practice, as “a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action,” and community, as “a way of talking about the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence” (pp. 4-5). Extending these concepts, Wenger (1998) defined learning by individuals, as “an issue of engaging in and contributing to the practices of their communities,” and learning by communities, as “an issue of refining their practice and ensuring new generations of members” (p. 7). Knowledge is regarded as that which possesses social value, the community as an arrangement where this value is negotiated, and practice as collective action aligned with

community values. If completing a project is a key aspect of the “valued enterprise” of a design and problem solving competition, the focal activity within the project activity system may be formulated as collaborative design practice. Broadly defined, such practice involves arrangements, productive activities, and interactions that contribute to the project’s completion. In other words, participation in collaborative design practice means doing things that help complete the project. In turn, because project completion and creation of deliverables that reflect the scope and meet the constraints of the design problem are important aspects of successful engineering practice, IT project work may also be considered aligned with and authentic to the relevant disciplinary standards and values.

**Practice as Design.** The notion of collaborative design practice as anything that helps complete a project may be considered too broad. The design process, especially in STEM fields, tends to be regarded as fairly predictable, organized, and systematic, especially in engineering disciplines, and in engineering education in particular (Moore, Atman, Bursic, Shuman & Gottfried, 1995; Eastman, McCracken & Newstetter, 2001; Christiaans, Cross & Dorst, 1996). Sample models for teaching and evaluating the engineering design process are presented in Figures 4 and 5.

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"><li>1) Problem Definition</li><li>2) Information Gathering</li><li>3) Generation of Alternative Solutions</li><li>4) Analysis / Evaluation</li><li>5) Selection</li><li>6) Implementation / Communication</li></ol> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Figure 4.* Steps in the engineering design process, based on a content analysis of seven engineering textbooks for college freshmen (adapted from Moore, Atman, Bursic, Shuman & Gottfried, 1995).

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Identify need	Identify basic needs (purpose, reason for design)
Problem definition (PD)	Define what the problem really is, identify the constraints, identify criteria, reread problem statement or information sheets, question the problem statement
Gather information (GATH)	Search for and collect information
Generate ideas (GEN)	Develop possible ideas for a solution, brainstorm, list different alternatives
Modelling (MOD)	Describe how to build an idea, measurements, dimensions, calculations
Feasibility Analysis (FEAS)	Determine workability, does it meet constraints, criteria, etc.
Evaluation (EVAL)	Compare alternatives, judge options, is one better, cheaper, more accurate
Decision (DEC)	Select one idea or solution among alternatives
Communication (COM)	Communicate the design to others, write down a solution or instructions
Implementation	Produce or construct a physical device, product or system

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*Figure 5.* An expanded ten-step engineering design process model with brief descriptions of each step, used to evaluate design activity for research purposes (adapted from Atman, Cardella, Turns & Adams, 2005).

Research on design is especially robust in the field of engineering education and professional engineering practice. In educational settings, design competence is typically analyzed in terms of the individual or collective ability to consider certain types of factors, or design constraints, or follow certain steps presumed to be important elements in the design process (e.g., Atman & Turns, 2001; Cross, 2001). In engineering education, the design process takes the relatively uniform appearance of a step-by-step process not because most design activity happens that way, or because it is the best way of doing design, but because structuring a complex process in this way enables its systematic teaching and evaluation in formal learning environments. Unlike formal PBL environments, in settings where a team of novice designers tackles an open-ended design challenge with relatively little scaffolding by the advisor, the design process is likely nonlinear and emergent, developing as the students learn to work as a team, balance multiple priorities and goals, and coordinate project objectives, tasks, and roles (e.g., Gilbuena, Kirsch & Koretsky, 2012).

Findings from design studies indicate that neither novices (such as undergraduate college students), nor all expert engineers or designers in various disciplines perform design activities in a strictly sequential fashion, or follow the same process models or frameworks (e.g., Atman, Adams, Cardella, Turns, Mosborg & Saleem, 2007; Mosborg, Adams, Kim, Atman, Turns & Cardella, 2005). On the opposite, design in real-world settings, especially among the highly successful innovators in various disciplines, settings tends to be intuitive, idiosyncratic, and opportunistic, with design thinking typically consisting of parallel and iterative, loosely structured, temporally dispersed activities (Cross, 2011; Lawson, 2005). In addition, the use of external symbolic representations such as diagrams, sketches, and models, as well as verbal and written communication, coordination, and collaboration across individuals and teams are essential and pervasive features of productive design work (Cross, 2011; Christiaans, Cross & Dorst, 1996; Dominick et al., 2001). Consequently, insights into the quality of the design process are not only gained from evaluation of the properties of the final product, or whether certain procedures were followed and steps completed; they may also come from analysis of the wider range of practices which comprised the process of completing a project, including relationships, communication patterns, and strategies used to address issues or mitigate conflict. As Engeström (1990) noted, “An activity system incorporates both the object-oriented productive aspect and the person-oriented communicative aspect of the human conduct. Production and communication are inseparable” (pp. 78-79).

These observations carry two implications for the present study. First, although design activities – especially when carried out by novice designers like high school students, and occurring in out-of-class settings – may resonate with models of design process applied to classroom-based engineering design practice, they do not need to be conceptually defined by

such models. Second, conceptualization of “collaborative design practice” (CDP) benefits from a framework that foregrounds the collaborative aspect of design. Identifying some possible dimensions or elements of collaborative design practice is essential for making sense of how it is *coordinated* within the project activity system rather than whether, in what order, or how frequently the specific design activities are performed. In the Analytic Approach section I consider one such framework, proposed by Dominick et al. (2001), for analyzing different strategies a team might use to make progress on their project. On one hand, such framework narrows the view of CDP from anything that helps to complete the project to activities associated with the design process in learning contexts. On the other hand, it illustrates how project-related activities diverge from the commonly recognized elements of the design process.

### **The Role of Motivation and Engagement**

An account of how a project activity system comes together and functions successfully is incomplete without consideration of the forces that push students to sign up for the competition, join a team, and persevere to complete a project. Why would a handful of student volunteers commit to working for extended periods on projects of dubious academic relevance and unpredictable outcomes? An important aspect of completing a team project outside of class has to do with what motivates students. According to Engeström (1987),

“...the concept of activity is necessarily connected with the concept of motive. Under the conditions of division of labor, the individual participates in activities mostly without being fully conscious of their objects and motives. The total activity seems to control the individual, instead of the individual controlling the activity” (p. 84).

Addressing the issue of motivation in activity systems, Engeström (2001) contrasted the activity-theoretical perspective with the approach of situated learning theory, recognizing certain limitations of the latter:

For situated learning theory (Lave & Wenger, 1991), motivation to learn stems from participation in culturally valued collaborative practices in which something useful is produced. This seems a satisfactory starting point when we look at novices gradually gaining competence in relatively stable practices. However, motivation for risky expansive learning processes associated with major transformations in activity systems is not well explained by mere participation and gradual acquisition of mastery. (p. 142)

This statement suggests that mere participation in activity systems in ways that sustain “business as usual” is less important from an activity-theoretical perspective than understanding how a system might transcend the established norms and develop or reconfigure practices in ways that expand the range of what is possible for the system to accomplish – what Engeström (2001) referred to as “a collective journey through the zone of proximal development of the activity” (p. 137). Engeström (2001) proposed that expansive transformation stems from explicit recognition of acute tensions and contradictions within the activity system. He cited the intervention research by the Boundary Crossing Laboratory where researchers helped uncover the problems caused by the contradictions between the components of the activity systems in the organizations they studied, thus prompting innovations in activity.

Within the activity-theoretical perspective, exploring the potential tensions and contradictions within the activity system of an out-of-class design project seems critical to understanding the mechanism of innovation, or at least successful disturbance management, in such a system. Innovations in activity may be necessary in order for students (the subjects) to complete their project (attain the object) as they learn to function in flexible, loosely constrained work arrangements characterized by self-defined goals, plans, and work patterns. Activity theory suggests that analyzing the substantive activity itself may yield insights into the nature of the relevant tensions and contradictions. However, the nature of *motivation* for innovation as a way of mitigating or resolving such tensions in the absence of targeted intervention by the researchers is unclear.

Engeström (as quoted above) suggested that “motivation for risky expansive learning processes associated with major transformations in activity systems” might not be adequately explained by situated learning theory in cases when the activity system under investigation is not characterized by established norms, values and standards for mastery. These elements are likely to be ambiguous for an out-of-class project where the performance criteria are unfamiliar and less rigorously enforced in the absence of a traditional teacher figure; the “activity setting” (Yamagata-Lynch, 2010, p. 25) has to be improvised, unlike in a typical classroom or workplace, and the team has substantial autonomy in organizing its collective activity. The *situative* theoretical perspective on motivation and engagement provides some guidance for understanding motivation in this case. In the following section, I review some key concepts of this perspective, and discuss its implications for investigating the role of motivation in the process of completing a project in the context of the Imagine Tomorrow competition.

**The Situative Perspective.** Establishing some working concepts is useful for clarifying the notion of engagement as seen through the situative lens. The following definitions from Wenger’s (1998) social theory of learning are applicable to the sociocultural and situative views of engagement: knowledge, as “a matter of competence with respect to valued enterprises; knowing, as “a matter of participating in the pursuit of such enterprises;” practice, as “a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action;” and community, as “a way of talking about the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence” (pp. 4-5). Extending these concepts, Wenger (1998) defined learning by individuals, as “an issue of engaging in and contributing to the practices of their communities,” and learning by communities, as “an issue of refining their practice and ensuring

new generations of members” (p. 7). This fundamental understanding of knowledge as possessing social value, the community as an arrangement where this value is negotiated, and practice as mutual engagement in action suggests that participation in socially valued practice – in this case, the Imagine Tomorrow competition – may be represented as a process of *collective* engagement.

Hickey and Granade (2004) drew upon Vygotsky’s (1978) interpretation of cognition as a cultural process and Wenger’s epistemic assumptions about the nature of knowledge and learning to elaborate a “stridently sociocultural” theory of motivation and engagement. In this framework, they argued, “knowledge can’t actually be located in the minds of individual knowers. From this perspective, to be learning is to be participating in the meaningful use of knowledge practices” (pp. 229-230). Hickey and Granade (2004) further stated:

From our perspective, collective and continuing participation in the co-construction of standards and values means that they are constantly being negotiated in learning contexts. If so, the standards and values seem more appropriately characterized as residing alongside the knowledge practices in the contexts where they were constructed. In situative terms, this implies that the context becomes attuned to the standards and values of the collective participants who define that context rather than the other way around. This fundamentally contextualist assumption seems to have profound implications for any educational research that is concerned with learning in complex social contexts. (pp. 231-232)

By the same token, engagement in collaborative design practice may be thought of as *learning to complete a project*. Furthermore, the design process which takes the project from idea to final presentation or implementation may not only be thought of as performance of design activities by individuals, or participation by individuals in specific valued practices of a given community (e.g., Greeno, 1998; Greeno, Collins & Resnick, 1996), but as *object-oriented collective practice* where attainment of the object might entail transformation of the community through revision of

existing (or introduction of new) valued practices. Such reframing is consistent with Hickey and Granade's (2004) observation that "viewing motivation as engaged participation in knowledge practices places the burden for motivating engagement on those practices, rather than the environment (in a traditional behaviorist view) or individuals (as in a modern cognitive view)" (p. 232). This does not imply that individual cognition and affect should be omitted from the analysis; on the contrary, these properties provide a window into understanding the collective practices, and vice versa.

One way to reconcile the individual and social levels of analysis is to treat individual activity as "wholly coregulated because it involves the use of socially defined concepts, tools, standards, and values" (Hickey & Granade, 2004, p. 239). I believe that a fundamental view of engagement as a property or component of social practice is compatible with analysis of social configurations which in lieu of their design and structure call for coordinated, collaborative interaction, and recognize it as valuable and worth pursuing. In the context of a competition where participants form teams to work on projects, the "community of practice" may be appropriately defined as the *project* carried out by a single team. In this sense, consistent with activity theory, a project may be conceptualized as an *activity system*, which anchors and provides a setting for collaborative design practice.

In broad terms, the sociocultural perspective contributes a concern for the relationship between the interpretations, values, and goals of the individual and the meaning-making practices, values, and cultural norms of a community or group, against the background of which the individual is positioned in the analysis. Such framing tends to reflect what has been referred to as "person-in-context" theoretical stance (Nolen & Ward, 2008). In the present study the sociocultural approach calls for consideration of individuals' (self-reported) interpretations,

values, and goals associated with their involvement in the competition, and of how these interpretations, values, and goals might be reconciled through coregulated activity.

Studies on distributed cognition (e.g., Hutchins, 1995b), collaborative scientific inquiry (e.g., Engle & Conant, 2002; Herrenkohl & Guerra, 1998), problem solving (e.g., Barron, 2000), and design (e.g., Stevens 2000; Kolodner, et. al., 2003) illustrate how the setting, tools, representations, and patterns of interaction tend to structure and shape the problem-solving process, and mediate its effectiveness. These studies also underscore the importance of examining *in situ* collaborative activity for understanding how explanations, solutions, and designs evolve. Similarly, a study of collaborative design practice from an activity-theoretical perspective needs to couple practitioners' accounts with examination of practice-in-context. In line with the activity-theoretical approach, the situative perspective contributes a system-level analytical stance, primarily aimed at explaining the functioning of systems of activity in which ostensibly individual behavior and cognition are an important, though not a focal element. In this view, individuals are viewed as contributors to the processes and structures which represent activity systems; individual-level phenomena are of interest to the extent that they inform theoretical explanation of the system. In this way, motivation is also treated as a property of the system rather than just individuals, or just contexts. The situative perspective champions a concern for "principles of coordination in interactive systems" (Greeno et. al., 1998, p.9). Research in the situative tradition tends to be longitudinal and conducted *in situ*, and is oriented toward uncovering developmental changes or regularities which may be characterized as "trajectories" of social participation of individuals. It is built on a vocabulary of "attunement" of individuals to "constraints and affordances," representing regularities or coherent patterns of social practice (Greeno et. al., 1998, p.8). In situative terms, project-oriented engagement is

represented by structural components and mechanisms (i.e., the “constraints and affordances”) of an activity system within which individuals dynamically interact with each other across settings and through different activities and representations. In this sense students do not *engage in* a project, but are *engaged by* it, through opportunities to participate in certain practices. Here, a “project” signifies not the final outcome, or even the chain of activity leading up to it, but an activity system; in turn, engagement refers to motivated activity as part of such system.

Discussing the notion of engagement from the situative perspective, Nolen, Ward and Horn (2011) state:

In sociocultural or situative theory, learning and identity development occur in social worlds or activity systems. [...] The individual does not disappear in such an analysis, but is studied as part of the larger system or “figured world” (Holland et al., 1998). Such worlds include the individuals, tools, and artifacts of activity and their ongoing and shifting relationships. Words, actions, identities, ideas and practices take on meaning from this organized social system, rather than from any essential, individual quality. Motives and goals arise through the interaction of elements of the social system over time (including both people and objects). (pp. 112-113)

Since the team working on an out-of-class project does not have the luxury of operating within a ready-made activity system, such a system must be improvised, worked into, and reconciled with other existing activity systems. The affordances and constraints of the project activity system might therefore originate in other existing activity systems and settings. This suggests that students’ motivation to become involved in the competition and to participate in certain ways might be rooted in their past experiences, relationships, and identities. Likewise, the development of and attunement to the affordances and constraints of the project activity system might entail active jostling for positions with respect to the team members’ goals, expectations, and priorities. It might also involve positioning at the junctions between the project activity system and other systems or communities of practice, like those of in-school

courses, after-school extracurricular activities, and the policies of the schools and school districts.

To summarize, as Nolen and Ward (2008) have observed:

Situative approaches to motivation are necessarily complex, involving an analysis of the social meaning systems in which motivation arises. Situative researchers take individuals to be part and parcel of their social contexts, and social contexts to be activity systems, meaning systems, or figured worlds continually co-constructed and negotiated by their members. This does not imply that individuals cannot be studied or contrasted, only that such study must include an analysis of the meaning system or systems in which those individuals exist. We agree with Greeno (2006) that this cannot be adequately accomplished through self-report data alone, but that interactions in the social contexts of interests must also be studied. (p. 455)

The situative perspective privileges consideration of the processes of meaning negotiation, co-construction, and reconciliation in situations where individuals find themselves straddling different contextual boundaries and activity systems (Nolen & Ward, 2008; Nolen et al., 2007; Nolen, et al., 2009). Activity theory suggests that although activity systems are enacted by humans, historically speaking, in the day-to-day life the systems tend to take over, determining individual motives and activity. The situative perspective presents a more dynamic model, with individuals (especially in learning contexts) continuously positioning themselves, interpreting and co-constructing the meaning, standards, and values of their activity. In this sense the competition participants would not merely absorb the motivation from the project activity system (or other relevant systems), but would, through their participation, collectively negotiate and *figure out* what motivates them. With regard to the present inquiry, the situative perspective suggests that understanding the role of motivation framing students' participation, persistence, and innovation within an out-of-class collaborative design project would be informed by the project participants' self-reports concerning relevant past experiences and relationships; analysis of interaction during project-related collective activities such as team meetings; as well as

interaction with those outside of their team, such as family members or community members both in and out of school. In other words, the situative perspective tells where to look for motivation, pointing where to train the analytic lens and look for evidence of motivational processes.

## **Research Questions**

This study is aimed at examining and explaining activity systems that emerge and develop over the course of the work on complex projects in loosely structured settings in the context of the Imagine Tomorrow competition. Understanding how those systems work should provide insights into (1) the lessons students learn from participating in a design competition, and (2) the ways for supporting student engagement from the start of project work to the project's successful completion. The specific research questions are:

1. What tensions characterize high school students' collaborative project work in out-of-school settings?
2. How do teams navigate these tensions in order to complete the project?
3. What role do the team meetings play in the collaborative design process?
4. a. What types of valued outcomes are associated with students' participation in the Imagine Tomorrow competition?  
b. How do these outcomes intersect with the team's ability to complete a project?

### **Chapter 3: Methodology and Research Design**

This section foregrounds the methodological considerations for this study and describes the research design. First, I give an overview of the Imagine Tomorrow (IT) competition to describe the general framework within which the projects analyzed in this dissertation were carried out. Next, I discuss activity systems analysis and its compatibility with case study design. Then I discuss the specific type of case study design used for this study. Finally, I describe the study participants, the process for selecting the focal cases, and the data collection methods and procedures.

#### **Context: The Imagine Tomorrow Competition**

Competitions may be broadly characterized as socially organized activities intended to provide opportunities for students from diverse backgrounds to explore their interests, build subject matter knowledge, and develop complex skills and abilities important to their future academic and professional success in a variety of fields, and especially in science, technology, engineering, and mathematics (STEM).

The IT competition is an annual design and problem-solving competition for high school students, organized by Washington State University. According to the IT mission statement,

“At the outset, the competition asks teams of Washington high school students to address a topic—this year, energy sustainability—by answering any of four challenges: technological, behavioral, design, or multidisciplinary<sup>20</sup>. With these challenges, we aim to invite collaboration among leaders of today and tomorrow, enable students to realize how much they can achieve, and drive innovation that changes lives.”

The competition runs from Fall into Spring during the academic year. Students from Washington high schools form teams, select one of the four challenges, and create projects that

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<sup>20</sup> Additional information about each challenge category is available at <http://imagine.wsu.edu/how/topic.aspx>.

represent a solution or approach for addressing this challenge. The teams are often supervised by teachers who play the role of project advisors as required by the competition rules. At the end of the competition, in late May, the teams converge on WSU campus to present their projects.

There the students have an opportunity to interact with and have their projects evaluated by the judges who are typically adult professionals recruited from public and private sector companies and organizations representing regional industries such as aerospace and defense (e.g., Boeing), software (e.g., Microsoft), natural resources (e.g., Weyerhaeuser), energy (e.g., Puget Sound Energy), and architecture (e.g., McKinstry).

At the day-long competition event, the projects are evaluated during two judging sessions using a scoring rubric which includes five dimensions: Objective, Creativity, Inquiry, Thoroughness, and Presentation (Appendix B).<sup>21</sup> Awards are given based on the overall project score calculated by adding the scores on five dimensions. Monetary prizes are awarded to top-scoring teams and schools in each challenge category; a grand prize winner is also selected from the top-scoring projects. In addition to scores on the rubric, a set of nominal awards that do not include monetary prizes are awarded based on judges' and advisors' votes in the following categories: Advisors' Favorite, Most Innovative, Most Likely to Succeed in the Marketplace, Global Impact Award, and Community Impact Award. Besides the competition event itself, WSU sponsors various activities for students in advance of the competition to increase the value of their campus visit. The university covers on-campus room and board for the duration of the typical 2-3 day stay for students and their advisors and chaperones, and encourages visitors to become familiar and take advantage of university facilities and resources.

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<sup>21</sup> The complete evaluation criteria are available on the IT website at <http://imagine.wsu.edu/how/judging/criteria.aspx>.

## Activity Systems Analysis

Activity systems analysis (Engeström, 1987; Yamagata-Lynch, 2010) is the overarching strategy for data analysis in this study. As described in the Theoretical Framework section, this strategy is grounded in five organizing principles of activity theory:

1. The whole activity system represents the *primary unit of analysis*, with focal object-oriented activity and related processes as secondary units.
2. Activity systems possess *multi-voicedness*, with different participants contributing unique points of view that are considered in analysis.
3. Activity systems possess *historicity* – they develop and persist over time, gaining certain properties that help make sense of their internal processes and interfaces with other activity systems.
4. Activity systems are characterized by internal *tensions and contradictions*, which may be manifested through disturbances in activity as a result of changes in their components or interaction with other activity systems.
5. Activity systems undergo *expansive transformations* in response to changes and disturbances, with innovations in activity enabled by revision of the established norms or redefinition of the object and motive of the activity.

The research design of this study enables incorporation of these principles in order to answer the research questions. In particular, the qualitative case study method is proposed, using multiple-case research design with embedded cases.

Activity systems analysis should seek to uncover ways in which collective practices are made meaningful by way of socially negotiated meaning-making, as well as individual interpretation by the *subjects* responsible for carrying out the object-oriented activities. Thus, such investigations may proceed on different planes, or levels of analysis. One illustrative example of such studies in activity theory is Barab et al.'s (2002) examination of multiple forms of collaborative student activity in an undergraduate astronomy course. The authors analyzed episodes of student interaction as micro-level, nested activity systems, tracing how the focal

*object* being acted upon in one episode of activity may be transformed into a representational *tool* in another episode, facilitating dynamic transformation of the *object* of activity. In turn, paying attention to activity at the interpersonal level informed assertions about the inherent tension within the whole-class activity system between the activities of computer modeling astronomy concepts and of developing deep conceptual understanding of these concepts. Similar multi-level analysis is possible in studies concerned with change in individuals. For instance, Martin (2000) undertook his analysis of mathematical identity of African American students on four levels, which he termed sociohistorical, community, school, and intrapersonal. Similarly, Cobb, Gresalfi, and Hodge (2009) utilized two of these levels – school and intrapersonal – to analyze the identities students develop in mathematics classrooms. The *school* level of analysis focuses on the negotiation of classroom norms, or “microcultures;” the *intrapersonal* level focuses on the perceptions and attitudes of individual students. In the present study, analysis at the level of the overall activity system of the project captures structural relationships and tensions analogous to what Martin (2000) termed the “community” level. The analyses of team-specific norms and practices and the individuals’ activities and perceptions are comparable to Cobb, Gresalfi, and Hodge’s (2009) “school” and ‘intrapersonal’ levels, respectively.

The qualitative case study method grounded in the naturalistic inquiry paradigm is used as the model for research design. According to Yamagata-Lynch (2010), case studies are particularly suitable for activity systems analysis. The main reason for compatibility between activity-theoretical research and the case study method is that case studies accommodate analysis at different conceptual planes – personal, interpersonal, and community-institutional:

The individual is the subject of activities that take place in the personal plane. The subjects of activities that take place in the interpersonal plane consist of groups of individuals engaging in collaborative initiatives. Community-based collective global

activities are the subject of activities that take place in the institutional/community plane. Each of these planes can help identify object-oriented activities and goal-directed actions into units of bounded systems. In activity systems analysis, the object-oriented activities under investigation still remain to be the unit of analysis, but the subject of that activity can be an individual, group of individuals, or an organization. (...) from an activity theory perspective, when investigators are studying object-oriented activities as a bounded system, the system can be characterized from a personal, interpersonal, or community/ institutional planes of analyses (Yamagata-Lynch, 2010, pp. 25, 79).

The case study is an appropriate research method for the present study because answering the research questions involves analysis on multiple planes. The personal plane is represented by the individual project participants (student team members and their teacher-advisor) whose goal-directed actions comprise the collective project-related activities. The interpersonal plane is represented by the student team as the unified “subject” whose object-oriented activity (the collaborative design process) is the central activity of the system. Finally, the community-institutional plane is represented by the overall project activity system which is characterized by internal contradictions, bound by the emergent activity setting, and interacts with other activity systems. In the Analytic Approach section, I discuss the analysis carried out for each research question. Table 2 maps the issues that address each of the questions across the three planes of analysis.

Table 2

*Issues addressing the research questions across the three planes of analysis*

<b>RESEARCH QUESTIONS</b>	<b>Project Activity System (institutional / community plane)</b>	<b>Project Team (interpersonal plane)</b>	<b>Individual students &amp; advisor (personal plane)</b>
1. What types of tensions characterize high school students' collaborative project work in out-of-school settings?	General structural tensions, contradictions, discoordinations	Relationship between tensions and elements of CDP (e.g. based on project quality criteria)	Relationship between goals, CDP activities, and discoordinations
2. What types of strategies do teams use to navigate these tensions in order to complete the project?	Impact of strategies on project completion	Types of strategies used as part of CDP; impact of strategies on team as a whole	Impact of strategies on individual team members
3. What role do the team meetings play in the collaborative design process?	Meetings as sites of CDP where inner contradictions in the activity system might be manifested as discoordinations	Types of strategies that emerge or are enacted in meetings as part of CDP to address discoordinations in the activity system	The role of meetings in individual team members' project-related activities; impact on goals and motivation, and vice versa
4. a. What types of valued outcomes are associated with students' participation in the Imagine Tomorrow competition? b. How do these outcomes intersect with the team's ability to complete a project?	Outcomes related to project completion, and their role in potential tensions and contradictions in the activity system	Within-team negotiation of expected outcomes of participation in the competition; role of CDP in development of shared outcomes	Relationship between outcomes of collective activity and students' personal goals and trajectories of participation in the competition

## Case Study Model

To understand a phenomenon conceptualized as a system of social interaction within a particular context, qualitative approaches are often recommended (Miles and Huberman, 1994; Patton, 2002). This study employs a qualitative comparative case study method to address the stated research questions. This method belongs to the interpretive tradition of inquiry.

Undergirding this tradition is the proposition that meaning is inseparable from its context, and is continually evolving. The data which serve as evidence for interpretive claims and inferences within this tradition are gathered from observations, artifacts, and interviews with participants in the relevant contexts. Such evidence may take the form of narratives or records of the process and products of action and interaction of the participants. The position of the observer in this tradition is acknowledged and accounted for in the analysis, while leveraging the observer's "closeness" to the data and the context of observation (Merriam, 2009, p. 214).

The broader aim of the interpretive approach is to generalize to theory based on the findings from a detailed, focused analysis of specific contexts. Methodologically, this is accomplished by generating inferences based on analysis of activity and events, and the ways in which social actions are exhibited and interpreted *from the perspectives of those involved* (Erickson, 1986). In the present study, the analysis involves determining what the student team members do in relation to their project, why and how they go about doing these things, how they make meaning of these activities, how they position themselves in relation to these activities, and how collective activity is mediated by other factors.

A case study involves collecting longitudinal data through direct observation and other techniques in the natural setting, which represents the focus of research (Yin, 2006; 2010).

Consistent with the conceptual framework, an embedded case study approach is used. The main

level of analysis which defines the case in this study is a project which high school students work on and present to the judges at the competition event. The *project* is conceptualized here as an activity system, conceptually represented by the conceptual model developed by Engeström (1987) in his elaboration of activity theory. The student members of the project team, as well as the team advisors, represent the individual sub-units within the project-cases.

Individual contributions to the project, including the goals, activities, and the various constraints and affordances associated with them help explain and interpret the team practices involved in project work. On the personal plane of analysis, individuals' views and interpretations inform the understanding of project-level activities. Therefore, the individual participants (students and advisors) represent the sub-units which, along with the main units of the project activity systems, comprise each of the cases used in this study.

### **Confirmatory Two-Case Embedded Design**

An important consideration in selecting the sites for this study is that the competition attracts a broad range of projects in terms of disciplinary focus, scope, advisor involvement, team composition, available resources, and other factors. Consequently, the patterns of participation in a given project may be extreme compared to other projects and settings. As a result the *interpretation* of the data is constrained in uncertain ways (e.g., by the project's topic, the participants' particular attitudes, the format of the team meetings, the attitude of the team advisor, the uniqueness of the school in which the project is nested), thus limiting the study's theoretical generalizability.

To reduce the uncertainty stemming from high potential variability across cases, a *confirmatory, multiple-case, embedded case study* research design with *two cases* was used (Yin,

2010). This design is based on the logic of “literal replication,” the purpose of which is to confirm whether the same phenomenon is replicated across similar cases (Yin, 2010, p. 54). In this study, two key considerations drive the sampling of project-cases. First, because this research is concerned with the process of completing a project, it is important that the selected teams actually finish their projects. According to Yin (2010), “Selecting such cases [that are believed to be literal replications] requires prior knowledge of the outcomes, with the multiple-case inquiry focusing on how and why the exemplary outcomes might have occurred and hoping for literal (or direct) replications of these conditions from case to case” (p. 59). Since it cannot be ascertained in advance that the selected teams will be able to complete their projects (or receive average or higher scores from the judges), the history of successful past participation in the competition by the schools and advisors was considered in identifying the potential school sites and teams for the study. Second, because this research concerns projects completed outside of class, it is important that teachers acting as advisors to the teams do not impose a similar structure or exert the degree of control characteristic of typical in-class PBL experiences. Thus, the schools’ track record with IT awards, and the number of teams pre-registered for the competition in the current year was taken into account during sampling.

Studying more than one project helps uncover regularities in practice or relationships between concepts, thus enhancing the robustness of evidence for theoretical generalization (Yin, 2010). Cross-case comparison suggests common features, and may hint at regularities which could be generalized to a wider pool of similar projects. The impetus of extrapolating the findings across projects as opposed to individuals is consistent with the theory-building objective of explaining project-related activity in particular conditions, as opposed to predicting effects on individuals. In this study, the concerns for literal replication and analytic generalization were

balanced with the limited resources and the significant logistical demands of data collection for multiple cases, to settle on a two-case study design. According to Yin (2010), “To begin with, even with two cases, you have the possibility of direct replication. Analytic conclusions independently arising from two cases, as with two experiments, will be more powerful than those coming from a single case” (p. 61). Limiting the research to two project cases is predicated on two additional practical factors. On one hand, a two-case design halves the risk of “putting all eggs in one basket” associated with a single-case design. Even if one of the two teams fails to complete a project or drops out of the competition, the study could be converted into a “theoretical replication” design exploring the reasons behind contrasting results (Yin, 2010, p. 54). On the other hand, a study with more than two cases, despite strengthening the reliability of the findings, would be unfeasible considering the potential scheduling conflicts during data collection without additional resources dedicated to the study.

### **Case Selection**

**Schools.** In making the sampling decisions, the projects were considered nested within schools. The schools themselves were not regarded as cases, but rather, as contexts framing the project cases to some extent. The competition rules allowed up to eight project teams per school in a given year. On one hand, using teams from the same school would have helped to ensure that comparison between teams is not confounded by school-level factors. At the same time, such teams would likely have shared the same advisor, which would preclude treating the two project-cases as independent. This study does not aim to estimate the effects of certain factors while controlling all others, which remains a challenge when random assignment of participants to conditions is not feasible. Rather, the goal is to explain *why* certain factors matter for successful project completion – what factors constrain or disrupt a project activity system, and

how such disruptions are managed. A sampling strategy using independent cases that are comparable (but not identical) in terms of certain conditions helps ascertain the theoretical relevance of these conditions and the robustness of the conceptual model.

To reduce unnecessary variability in systemic factors that could differentially influence project work, I selected demographically similar schools – schools of similar size, serving similar demographic groups, and with comparable records of student achievement as indicated by standard measures. I focused on public schools as such schools represented the majority (about 95 percent) of schools that historically have participated in the IT competition. Two “convenience” sampling factors also played a role: geographic location that would permit the researcher frequent and quick access to the site (roughly within a 40-mile radius of a major city in the Pacific Northwest), and the advisors’ and students’ willingness to volunteer for the study.

Besides school-level demographic information, I considered a number of factors associated with the *historicity* of the project activity systems – in particular, previous experience with IT – which could differentially impact advising or teamwork dynamics. The following criteria were identified as theoretically relevant to the study:

1. Advisor or students participating for the first time or not – past experience with Imagine tomorrow may increase the likelihood of successful repeat participation in IT.
2. The number of projects entered in the competition – advisors might exert less control over any one team if multiple teams from the same school participate.
3. Awards received in previous years of the competition – high awards-to-teams ratio is likely to signal atypical or “extreme” successes and might reflect a relatively more structured, hands-on advising style, or vastly more experienced teams.

4. Integration of the competition with the curriculum – projects that were integrated into formal coursework interfere with the questions raised in this study and were not considered.

I obtained historical data about the IT competition from the organizers at WSU and used it to pre-select schools based on the above criteria.

From about 30 high schools that had pre-registered for the IT competition in the year this study was conducted, I identified six schools that met the demographic, geographic, and IT-related criteria for inclusion in this study. I contacted the teachers at these schools who had advised IT teams in the past, to introduce myself and the study, learn about the format for participation in IT (in-class or out-of-class), and to gauge their willingness as potential participants. The teachers at all six of these schools expressed initial interest. From this set, I short-listed two schools where (a) the teachers had confirmed their interest when I re-contacted them at a later time; (b) IT participation was conducted in out-of-class settings, and (c) regular hands-on project work was unlikely to have started before I was able to enter the sites. I then contacted the principals of these schools, and following their approval, secured further approval from the respective school districts. The research also had been reviewed and approved by the UW Institutional Review Board (IRB), Human Subjects Division.

The schools that were selected for the study were Emerald High School (EHS) and Malachite High School (MHS).<sup>22</sup> The school demographics are presented in Table 3.

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<sup>22</sup> The school names used in this study are pseudonyms.

Table 3

*Student Demographics at Emerald and Malachite High Schools*

	Emerald HS	Malachite HS
<i>Demographic Indicators</i>		
Total enrollment	About 1,500	About 1,700
White	70.61%	78.98%
Hispanic	12.01%	13.2%
Asian/Pacific Islander	7.54%	4.11%
Black	5.11%	1.22%
American Indian/Alaskan Native	1.79%	1.22%
Transitional/Bilingual	5.94%	2.52%
<i>SES Indicators</i>		
Free or reduced price meals	40%	23%
On-time graduation rate	85.8%	91%
Extended graduation rate	91%	95%
<i>Performance Indicators (met standard)</i>		
Reading	75%	84%
Math	40%	45%
Writing	83%	90%
Science	51%	50%

The schools were similar on most indicators, with the exception of students who qualified for free or reduced price meals. The proportion of such students at Emerald was almost double of that at Malachite (40 percent and 23 percent, respectively). The Emerald teacher, who was also the IT advisor, mentioned in an interview that the actual proportion of students qualifying for free or reduced price meals may be higher, based on the rates at the feeder middle schools and the under-reporting bias:

My kids...this is very low-income...lots of transient population that may be based downtown...lot of housing projects are up just there, so...yeah I mean what about...just below 50% are free and reduced lunch, but our feeder middle schools are at 67% free and reduced, so we think there's a kind of a social status that happens in high schools so kids just don't sign up for it, because it should stand to reason that if 67% coming in are free and reduced then we should be as well. (Emerald / Amy advisor interview 1)

It is equally likely that the proportion of students qualifying for free or reduced price meals at Malachite were also under-reported. The data I had collected contained no evidence that any differences in how the case study teams approached their projects could be attributed to either school-level or individual SES factors.

The characteristics of the two schools with regard to participation in IT are presented in Table 4. To summarize, both schools had previous experience with IT though the advisor at Emerald had more experience compared to the advisor at Malachite (three years and one year, respectively). Both schools had several projects registered for the current year. The need to distribute attention across multiple projects reduced the chances that the advisors would be too hands-on in his or her approach with the teams. Emerald also had a team win an award in their project category two years earlier. However, the relatively low awards-to-teams ratio (one award for six total teams), and the fact that no awards were received in the following year, suggested that an especially strong “winning orientation” toward IT by the advisor was unlikely. Finally, as noted earlier, neither school had integrated IT into its formal curriculum, so the majority of project work had to be carried out by the students on their own time.

Table 4

*Competition-related school selection criteria*

Competition-Related Criteria	Emerald HS	Malachite HS
Past participation in IT	3 (previous) years	1 (previous) year
Number of projects pre-registered for this year's competition	3	4
History of awards received	Two years earlier one project won an award in its category	No awards
Awards-to-teams ratio:	1/6 – the winning team was one of six total teams that participated in previous competitions	0/1 – only one team attended the competition in previous year, and did not receive an award
Integration of the competition with the curriculum	Not part of curriculum, out-of-class	Not part of curriculum, out-of-class

**Participants.** The participants in the study were the student members of the project teams and the two teachers who advised the teams and coordinated participation in the competition. According to the competition rules, up to eight teams consisting of two to five students in grades 9 through 12 may be entered per school. One project team was recruited from each of the two schools identified as potential research sites, for a total of two teams. Although each teacher advised several teams the year when this study was conducted, only one team was selected as a focal team for purposes of each research from each of the schools (see Figure 6).

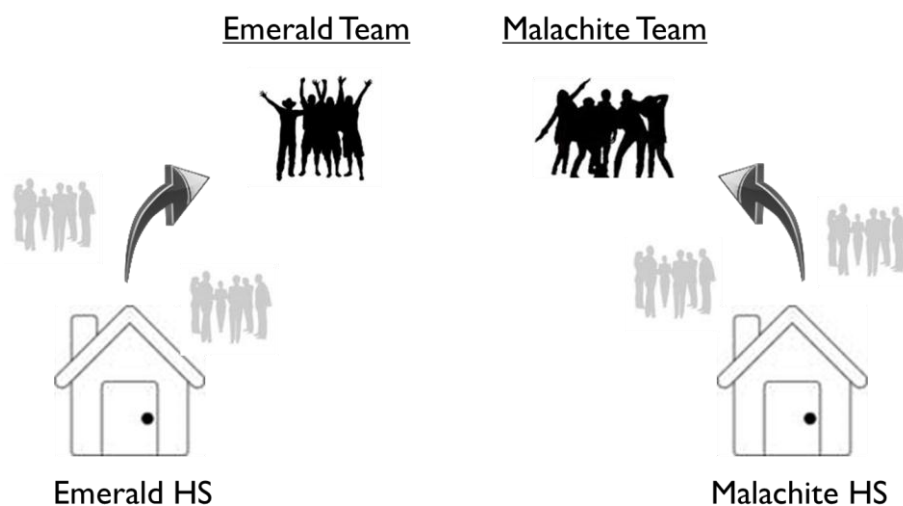


Figure 6. Selection of the focal teams for the study.

The teams were selected based on student preference to participate in the study, as well as similarities between the teams' IT project topics and IT categories. The focal team at Emerald consisted of four students: one senior (Kara), two juniors (Seth and Ben), and one sophomore (Will).<sup>23</sup> Kara was the only girl on the team. This year was the team's first-time IT experience. Their advisor, Amy, was a female teacher with about 10 years of teaching experience, who taught upper-level AP and Honors chemistry. The focal team at Malachite consisted of four sophomore girls, Molly, Gillian, Dana, and Becky. Three of the students had participated in IT in the previous year. Their advisor, Nils, was a male early-career teacher who taught lower-level physical science classes. Both advisors and all students in this study were White, with the exception of Kara on the Emerald team, who was Asian. English was the primary language for all participants. Table 5 summarizes basic participant information organized by school project team. Additional information about the students and advisors is provided in Chapter 4, "Project Case Profiles."

<sup>23</sup> The student and advisor names used in this study are pseudonyms.

Table 5

*Basic Information about Study Participants by School (Team)*

Participants	Emerald HS Team			Malachite HS Team		
	<i>Name</i>	<i>Year in School</i>	<i>Time participating in IT</i>	<i>Name</i>	<i>Year in School</i>	<i>Time participating in IT</i>
Teacher / Advisor	Amy	n/a	4 <sup>th</sup>	Nils	n/a	2 <sup>nd</sup>
Student 1 / Team leader	Kara	Senior	1 <sup>st</sup>	Molly	Sophomore	2 <sup>nd</sup>
Student 2	Seth	Junior	1 <sup>st</sup>	Gillian	Sophomore	2 <sup>nd</sup>
Student 3	Ben	Junior	1 <sup>st</sup>	Dana	Sophomore	2 <sup>nd</sup>
Student 4	Will	Sophomore	1 <sup>st</sup>	Becky	Sophomore	1 <sup>st</sup>

The students' prior experience with the competition may be associated with different constraints and affordances for engaging with the projects, and seemed worth contrasting between the cases. Some of the differences in how the teams approached project work, addressed in the Findings chapter, did appear connected to their extent of prior experience with the competition, or lack thereof.

**Projects.** The conceptual framework of this study does not account for subject matter-related factors in project completion. At the same time, the IT challenge categories (Technology, Design, Behavior, and Multidisciplinary) are also not defined in terms of specific disciplines (not even as “engineering,” or “science”). As a result, many of the projects ended up having multidisciplinary components, requiring the application of various kinds of knowledge and skills. Nevertheless, since different project categories may contribute to differences in project work processes, I tried to match projects on their IT challenge categories. If more than one team at a given school fit the category of interest, project topics were used to select the focal teams. In the end, the teams selected for the study pursued almost identical competition topics of *designing*

*composting programs for their schools.* The result was a close fit between the issues the students had to address as part of the design work, which facilitated cross-case comparison and synthesis.

At the competition event, the Emerald team's project scored an average of 19.7 points, and the Malachite teams' project scored an average of 17.5 points out of 25 total points. Thus both projects ended up receiving above-average scores from the judges based on the scoring rubric, and may be regarded as successfully completed projects as defined in this study. Detailed breakdowns of each team's project scores as rated by six competition judges, along with the judges' written comments, are presented in Appendices B.1-B.3. Additional details about the projects are provided in Chapter 4.

## **Data Collection**

**Overview.** The general data collection strategy for the present study is to investigate converging lines of evidence to develop a model of an out-of-class Imagine Tomorrow competition project as an activity system characterized by internal tensions and contradictions, collaborative design practice as its driving activity, and strategies addressing the discoordinations in the system. Data from four sources were collected: interviews with the student participants; interviews with team advisors; observation and video-recording of project team meetings; and analysis of documents or presentation materials employed in the course of project-related activities. The study was conducted on-site at the schools and other locations where research interviews or the team project meetings were arranged. Table 6 summarizes the data collection procedures. A timeline of the data collection events in relation to the competition event is provided in Appendix F.

Table 6

*Competition-related school selection criteria*

Methodology	Sources	Procedures
Student Interviews	Two group interviews with members of each of the two focal teams  One individual interview with each member of focal teams	Audiotaped and took notes during semi-structured interviews, then transcribed for analysis
Advisor interviews	Three individual interviews with the advisor of each team	Audiotaped and took notes during semi-structured interviews, then transcribed for analysis
Meeting Observations	Five meetings by the Emerald team and three meetings by the Malachite team in different settings (classroom, public library, student home)	Videotaped and took notes, then transcribed for analysis
Project Artifacts	Advisor's documents related to IT competition and trip logistics disseminated to students  Student-created documents (write-ups and visuals) as part of project work, as components for the presentation displays  Final presentation displays	Collected and reviewed advisor and student-provided materials, photographed finalized projects at competition event, used as illustrative examples to elicit elaboration and confirm meaning in interviews

**Converging Lines of Evidence.** In line with the research questions, the embedded case study approach should enable triangulation of evidence based on data from multiple sources. One such source is the goals, values and standards the individual participants bring to the project, as reflected in project-related attitudes and interpretations. Also, ethnographic research (e.g., Wenger, 1998; Hutchins, 1995a) suggests that evidence of collaborative processes may be represented by the participants' overt behavior and interaction, such as communication in group meetings, as well as by representations used to objectify, transmit, and interpret meaning in the context of the project – what Wenger (1998) referred to as reification, observable as both a process and a product of instantiation of meaning.

**Interview Data Collection.** Overall, the interviews with the project team members and advisors were intended to collect data about the teams' processes for completing the projects, as well as how the participants positioned themselves in relation to the competition and to the projects. Based on the theoretical perspectives, which frame social practices in reference to systemic factors and the related contextual affordances and constraints, I grouped interview questions into four categories, or *interview themes*: advisor support, project context, collaborative design practice, and student participation. The Analytic Approach section provides additional details on these themes. The interview questions and their mapping to the themes are provided in Appendices C and D.

**Interviews with Students.** Three semi-structured interviews were conducted with students who were working in teams on projects which represent the cases in this multiple-case study. For the first and second interviews conducted before the competition, students' limited availability was taken into account, and the interviews were conducted in a group setting with the available students present. These two group interviews were conducted in the weeks leading up

to the competition deadline, in late April and early to mid-May, when the teams were actively working on the projects (while this was the case with the Malachite team, the Emerald team was just getting ready to narrow down their project idea and seriously engage with their project). The third interview was conducted individually with each student within three weeks following the competition.

I originally planned to synchronize the student interviews with different time points over the duration of project work: the early (brainstorming) stage, the mid-point (active, focused work) stage, and after the conclusion of project work. This worked in case of the Emerald team due to that team's later start on hands-on project work. In contrast, the Malachite team began working on their project several weeks earlier, but the interview was delayed due to scheduling constraints. These differences in timing did not appear to impact the quality of the data for two reasons. First, the overall timeframes for project work on both teams were relatively brief, spanning just over 3 months, from February to the third week of May. Also, student-reported estimates of time spent working on their projects during the early brainstorming stage were very low (on the order of 1-2 hours per week), with the bulk of project work (e.g., online research, stakeholder meetings, surveys, data analysis, and write-ups) carried out in the 4-6 weeks before the deadline. Nevertheless, to compensate for the timing discrepancy, I customized the questions for each team to ensure that they were appropriate for the team's level of progress in their work. I also prioritized the historical aspect of project work in the interviews, by including several of the questions in multiple interviews, paying attention to changes in students' perspectives over time. As part of the semi-structured interview protocol, I also incorporated additional questions based on what I was learning from the preceding interviews and team observations. These follow-up probes aided analysis and interpretation by verifying meaning and eliciting elaboration

on the salient aspects of project work. Such triangulation across time and participants increased the reliability of the data and the analysis findings.

**Interviews with Advisors.** The interviews with the team advisors were intended to collect data about each advisor's perceptions of the project and his or her relation to it, as well as their interpretations of the work of the student team as a whole. Three semi-structured interviews were conducted with each advisor. The first round of interviews was conducted early in the competition timeframe (December 2010). Their purpose was to gather information about the contextual features of the school environments where the teams pursued their projects, as well as prior advising experience with Imagine Tomorrow. The second round of interviews was conducted approximately mid-way through the competition timeframe, to describe the advisors' specific roles and ways of involvement in the current year's projects, as well as their perceptions of the process the teams used to work on the projects. The third round of interviews was conducted within 3 weeks following the competition event, allowing the advisors to reflect on their teams' experiences with the competition. Similar to the student interviews, protocols for the second and third rounds of interviewing were tailored based on the data collected during the first round of interviewing and the team observations. Also, several questions were repeated across the interviews to look for changes in advising approach over time, and follow-up questions were used to verify meaning, elaborate salient themes, and facilitate interpretation.

**Small Group Meeting Observations.** The main purpose for meeting observations in this study was to understand how contradictions within the project activity system might be manifested and managed in team meetings. As sites where discoordinations in CDP might surface, team meetings helped to identify certain norms as well as contradictions within the emergent project activity systems. Capturing real-time group interactions also helped to identify

representative episodes of discoordination-management strategies. I also expected the meeting data to enable triangulation of the data from the interviews, looking for evidence of the analytically derived contradictions in the project activity systems, as well as checking for disconfirming evidence of the participants' self-reported interview data, as well as my interpretations and inferences based on these data.

I had initially assumed that, regardless of the nature of the projects, the students would meet face to face on a regular basis to work on their projects. Based on informal conversations with advisors I had interacted with in the past, I expected that meetings would typically take place in schools (e.g. in a school library) and on occasion outside of school. Because the competition was approached as an extracurricular activity at the focal schools, the “dedicated” project meetings were scheduled during out-of-school time (after the last period), and were not part of regular classroom activities.

Videotaped observations were conducted during the four weeks leading up to the competition, beginning roughly at the time of the first round of group interviews, and ending with the design of the presentation displays the day before the teams departed for WSU. I observed a total of five meetings of the Emerald team and three meetings of the Malachite team. I found out later from the interviews that both teams had other meetings as well, both during and after the school day. Examples of such meetings at Emerald were the advisor-organized meetings with all of the participating teams, which were scaffolded by the advisor to accomplish specific objectives or obtain the information she needed from the students. For the most part such meetings had taken place during the early brainstorming phase of the design process, before I gained entry to the research sites. At Malachite, such meetings included several (bi or tri-weekly) Science Club meetings, also organized by the advisor, as well as a number of student-only

meetings at the public library or at a student's home. In addition, students on both teams also took advantage of numerous occasions for brief, "informal," opportunistic check-in meetings when they intersected at the school during the day. In the Analytic Approach section, I discuss several implications of these practices for how I used the meeting data in this study. I also talk in detail about the role of the different types of meetings in Chapter 5, in particular in discussion of RQ3.

My default role in the team meetings was that of a non-participant observer though in two of the meetings I had responded to student questions about the competition, acting as observer-as-participant (Merriam, 2009). I made myself available as someone familiar with the competition event, having judged at the event in the past. My intention was to provide some value for the teams to compensate for their time in the interviews and the inconvenience my presence may have imposed at the meetings. Each of the teams had taken me up on this offer during one of their meetings, asking several questions about the competition format and the judging process. The information I shared was also available on the IT website and focused on general presentation tips and the layout of the presentation displays. Because three of the four students on the Malachite team had attended the competition in the previous year, they had fewer questions and seemed familiar with much of the information I provided. The Emerald students were interested in my general presentation tips and impressions from the flow of the judging session although I did not detect any major changes in their preparation based on my feedback. Therefore, I believe the impact of my temporary "participant observer" role was not significant.

**Project Artifacts.** Several kinds of project artifacts were obtained and utilized in the course of this study. Three categories of the artifacts emerged: materials prepared or disseminated by the advisor to the teams, student-created artifacts that were parts of the

presentation displays and the finished presentation displays, which represented the completed projects at the IT competition event. I describe the uses of these materials in the Analytic Approach section.

### Analytic Approach

This section discusses the approach for addressing the research questions in this study, with sub-sections organized in the order of the questions. This approach provided the initial direction for data analysis while allowing enough flexibility for additional and unexpected analytic categories, themes, and relationships to emerge from the data. Figure 7 presents a general depiction of an Imagine Tomorrow project as an activity system based on Engeström’s (1987) activity-theoretical framework, with draft labels attached to the nodes. The figure helps situate and visualize the elements of the model and their mediational structure in the general context of a project.

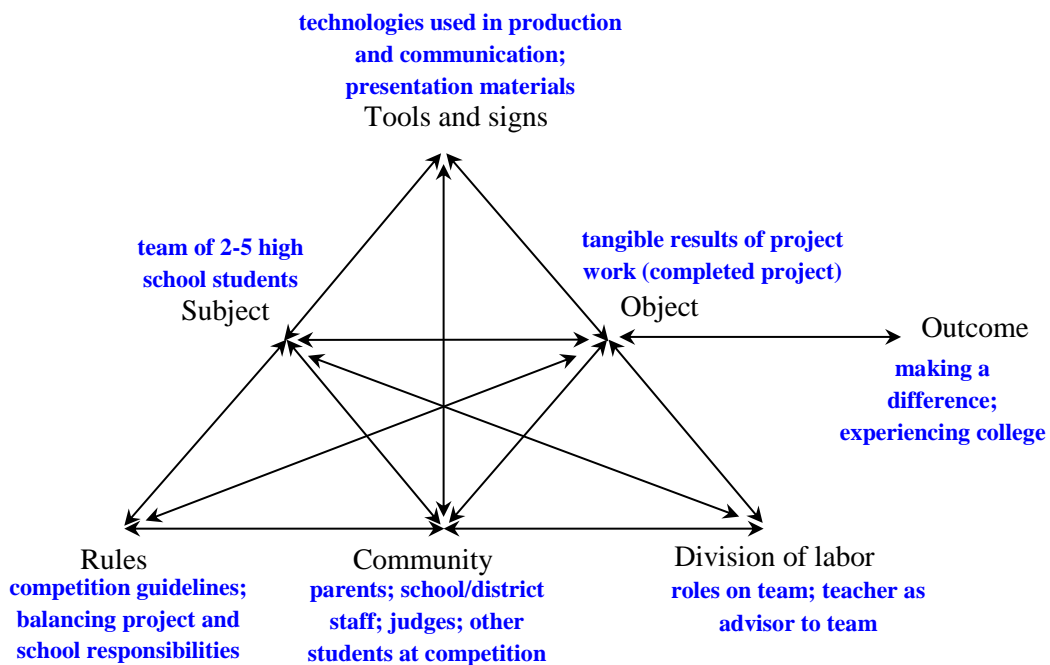


Figure 7. An Imagine Tomorrow project as an activity system.

**Overview of the Analysis Process.** Grounded theory development (Glaser & Strauss, 1967), activity systems analysis (Yamagata-Lynch, 2010), and thematic analysis (Charmaz, 2006) which enable triangulation and integration of assertions across the occasions and sources of data, were used to explore converging lines of evidence for addressing the research questions. Coding of the data related to project work activities was guided by the conceptual model and the analytic questions, but all analyses began with open coding, followed by focused coding, to allow for the salient categories and themes to emerge (Strauss & Corbin, 1998; Emerson, Fretz & Shaw, 1995). Data reduction proceeded iteratively through identification of recurring categories and themes, mapping of data to the analytic themes (described below) and the emergent categories, and by consolidating codes into categories and eliminating redundant codes. This process was informed by the initially proposed structural tensions in the activity system, aspects of collaborative design practice, and strategies for addressing contradictions and discoordinations. However, the analysis remained sensitive to alternative accounts of key processes and relationships in the project activity systems, resulting in changes to the initially hypothesized analytic framework. In this section I describe the analysis methods, the initial conceptual frameworks, and how they were modified to produce the final analyses.

### **Analysis of Student and Advisor Interviews**

The group student interviews mainly address RQ1 and RQ4, focusing on the process and context of project work and the circumstances and outcomes associated with participation in the competition. The interviews also cover RQ2, seeking to develop a more detailed account of team practices. In addition, several questions relate to RQ3, eliciting students' perspective on the role of team meetings in their project work. The individual student interviews address primarily RQ1, RQ2, and RQ4, focusing on students' individual and collective competition experiences

with emphasis on students' unique individual perspectives on the projects, teamwork, and the competition experience in general. The interviews also briefly address RQ3 regarding the role of meetings in project work.

The primary purpose of advisor interviews was to address RQ1 and RQ4. This was achieved by focusing questions on the advisor's approach to the competition and his or her students' projects, as well as the circumstances and outcomes of students' participation in the competition. The secondary purpose of these interviews was to address RQs 2 and 3, by exploring the advisors' perspectives on student project-related activities. This should yield insights into and help triangulate interpretation of potential tensions and strategies associated with the students' CDP. These RQs are addressed indirectly in the first interview, by referencing other teams' experiences with IT in previous years, and more specifically in the second and third interviews, referencing teams' projects in the current year when this study was conducted.

I used a two-pronged approach to coding the interview data. One strategy involved top-down category development based on the interview themes, research questions, theoretical framework, and transcription of the corpus of the data. The other strategy involved bottom-up, fine-grained coding. I used these strategies in parallel, using one to inform the other and enable a systematic method for inference building.

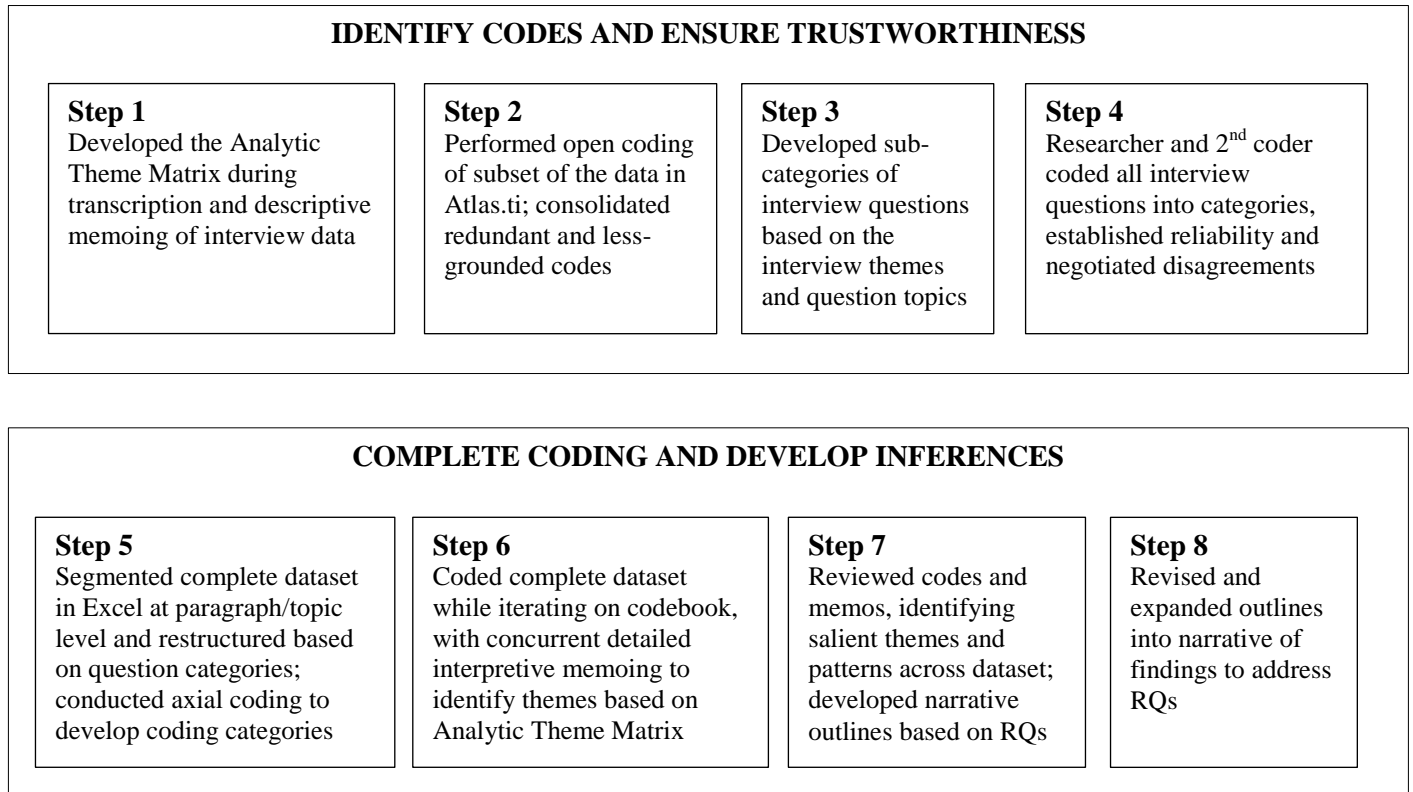
As one strategy, to stimulate thematic analysis of the interview data, I developed a conceptual tool called the Analytic Theme Matrix (see Appendix G). The Matrix further specifies and operationalizes Table 2, which maps the research questions to the three planes of analysis (institutional-community, interpersonal, and individual). I realized that the table, although useful on a conceptual level, was ineffective for guiding the coding and interpretation

of the interview data because it did not directly tie the research questions to the components of the project activity system. To address this issue I remapped the research questions to the four organizing themes of the interview questions: project context, advisor support, CDP (team design process), and student participation. This created analytic “buckets” for concepts. The Matrix provided a way to organize the nascent coding categories which began to surface during open coding, thus helping to better understand how the RQ topics relate to the interview themes. The notes in the coding matrix describe some potential properties, dimensions, and patterns derived from the theoretical framework, as well as memoing in the course of data collection and transcription. In the end, this framework became a useful reference, and helped organize my thinking about the highly nuanced, case-specific data on a higher analytic plane. This also facilitated cross-case synthesis of the findings.

The other strategy was based on the grounded theory development method (Strauss & Corbin, 1998; Charmaz, 2006) as well as activity systems analysis methods (Yamagata-Lynch, 2010). In particular, I adapted the analysis process outlined by Yamagata-Lynch (2010, pp. 89-91) to organize the analysis steps (Figure 8). I describe this process below.

**Steps 1-2. Open Coding.** I conducted open coding using Atlas.ti and Microsoft Excel software. I used Atlas.ti for line-by-line open coding (Strauss & Corbin, 1998) of a subset of the data (an advisor and a student interview from each project case). I took advantage of the software features that improve the robustness of the emergent coding framework. First, the software allowed attaching codes to individual phrases or sentences (similar to the commenting function in Microsoft Word). This helped keep the codes grounded, and prevented their premature interpretation and abstraction, thus reducing the likelihood of misalignment of codes with the

data from the start. This step resulted in about 150 uncategorized codes. A sample screenshot from this coding process is shown in Figure 9 below.



*Figure 8.* Interview Analysis Process Diagram, modified based on the diagram in Yamagata-Lynch (2010).

Atlas.ti also generated real-time tallies of how many times each code was assigned, in other words how many instances of each code were found in the data, thus revealing which codes were less grounded (scarcely represented in the data). This facilitated iteration on the codebook, i.e. gradual consolidation of redundant and less-grounded codes, and revision of code labels.

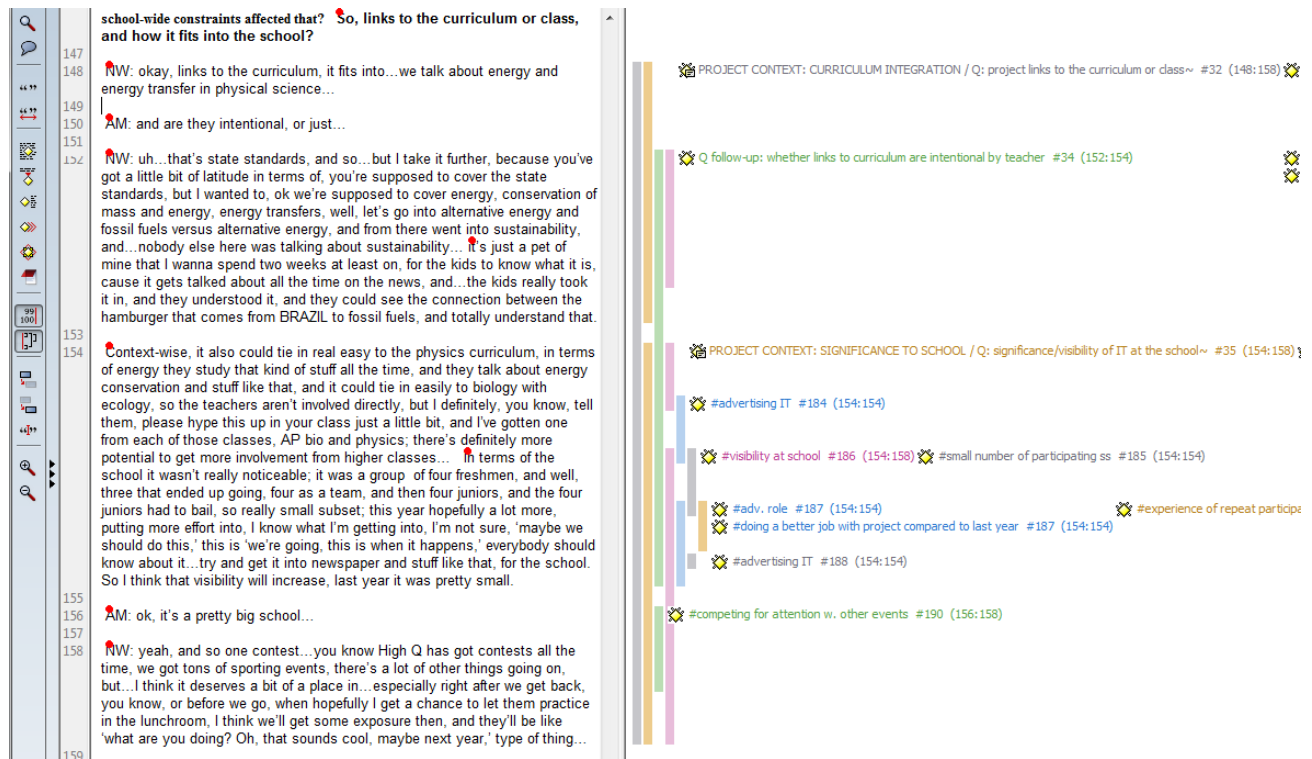


Figure 9. Screenshot of open coding using Atlas.ti software.

**Steps 3-4. Further Categorization of Interview Questions and Themes.** The initial open coding called for a way to organize the detailed codes in order to develop categories as part of data reduction process. I examined the interview questions more closely for ways to cluster the participants' responses with more specificity than what was afforded by the four interview themes. I sub-categorized the questions to better understand how the responses might be clustered based on the main ideas or topics raised by the questions. I developed thirteen initial categories for the questions (the questions themselves, not the responses), then worked with another coder to double-code all questions across all interviews with reliability of 78.5% (discrepancies were negotiated to agreement). I then coded the responses for each question with these categories. Tables 7-9 provide the mapping of the interview themes and question sub-

categories where “x” indicates which detailed categories apply to questions under each interview theme.

Table 7

*Mapping of the interview themes and question sub-categories; “x” indicates combinations that were reflected in the actual questions (22 total)*

Interview Question Categories	Interview Themes			
	ADVISOR SUPPORT	PROJECT CONTEXT	CDP	STUDENT PARTICIPATION
Approach/Activities/Progress	x		x	x
Changes	x		x	x
Meetings			x	
Tools/Resources	x		x	
Challenges			x	
Competition Event		x		
Constraints		x		
External Perspectives		x		
Outcomes			x	x
Pathways	x			x
Quality of Experience			x	x
School/Curriculum		x		
Topic/Scope		x	x	

Table 8

*Definitions of the interview themes*

Interview Theme	Brief description
ADVISOR SUPPORT	Advisor’s background, teaching, and his/her support of the Imagine Tomorrow teams/projects (for example organizing participation in IT, advising role, approach or strategies).
PROJECT CONTEXT	Anything that is not within the project team but is somehow related to project, part of the context of project work (for example the organizations/structures/contexts within which project work happens, individuals who provide feedback that informs project work, etc.).
CDP	Collaborative design practice – the process of working on the project, including the project topic, students’ goals, roles, and tasks specifically related to the project and how they make progress on it; any other project-related activities or strategies.
STUDENT PARTICIPATION	How students end up participating in IT or as members on a particular team/project (“pathways”), how participation relates to their goals/interests/skills, what they get out of participation/project work, identity factors/trajectories relevant to participation in IT.

Table 9

*Definitions of the interview question categories*

<b>Interview Question Categories</b>	<b>Brief description</b>
Approach/Activities/Progress	Approach to working on the project, activities directly related to the process of completing or making progress on project, including goals, roles, and project management tasks and strategies.
Approach/Activities/Progress - Changes	Same, but focusing on <i>changes</i> in approach, strategies, or activities directly related to project work process.
Approach/Activities/Progress - Meetings	Same, but focusing on team or advisor-team <i>meetings</i> , including activities in meetings or related to preparing/organizing meetings.
Approach/Activities/Progress - Tools/Resources	Same, but focusing on tools or resources that students or advisor might use that directly relate the process of project work – may include technology, information, presentation, funding, meeting space, or anything else directly related to project work.
Challenges	Challenges / difficulties / issues that students faced individually or as a team that complicated their project work / progress / completion, or required extra attention/effort.
Competition Event	Impressions regarding the context of the project at the competition event, such as comparisons in relation to projects of other teams/schools.
Constraints	Constraints/factors that impacted project work process or outcome.
External Perspectives	Perspectives/comments of those who were not directly involved in project work.
Outcomes	Actual direct results/accomplishments of working on project, as well as indirect or related outcomes that participants have (or believe they have) achieved as a result of project work, or from participation in IT overall (as opposed to hypothetical statements of goals/reasons for participating in IT) .
Pathways	How participants became involved in IT, including how they find out about it, and join or form teams; also factors that contributed to decision to participate in IT and involvement in specific team/project.
Quality of Experience	Experiences during the process of project work, or related to the IT trip, campus visit, and event that made an impression on students and contributed to a more positive (enjoyable, interesting, fun) or less positive quality of their experience of participation in IT.
School/Curriculum	Role or extent of integration of project work or participation in IT in formal school curriculum (specific class or subject area), as well as any formal recognition of participation in IT at the school.
Topic/Scope	Participants' understanding of what the project is about, including the topic or problem being addressed and the scope and feasibility of the project idea or plan; includes the development and changes in the project topic or how the participants understand it.

**Steps 5-6. Final Coding and Memoing.** For these steps I used Microsoft Excel to segment the interview transcripts into paragraph-units. During the semi-structured interviews, I frequently asked follow-up questions to clarify the participants' responses and confirm meaning. This produced answers that were very complete and detailed, with most answers consisting of several paragraphs. I pre-segmented the responses into paragraphs during transcription, using the breaks to denote transitions between main ideas in the responses. The inter-connectedness of details in the responses suggested that a paragraph represents a more meaningful unit of analysis than a single phrase or sentence, and allows more accurate interpretation and inference development. The paragraph-segments of each response were coded in two ways. First, I assigned to each segment the corresponding question category code (inductive coding, using categories in Tables 7-9). I then restructured the dataset to cluster similar questions together within each interview and coded the complete dataset using codes based on the open coding in Atlas.ti with additions or revisions as necessary. Such structuring helped focus the coding and facilitated the development of coding categories through axial coding (Strauss & Corbin, 1998). The final code list is included in Appendix H.1-2. The version that was used for coding includes definitions and examples for each code. Multiple codes could apply to each segment; for the full dataset, the count of codes per segment ranged from 1 to 13, with an average of 2.9 codes per segment. Such coding enabled systematic description of each paragraph and facilitated analysis of major factors such as goals, strategies, and constraints in the project activity system. Parallel with coding, I did extensive memoing, writing descriptive and interpretive notes for *each* paragraph-segment (total n=910 segments). In the notes, I also referenced the Analytic Theme Matrix, to see whether and how the findings were connected to the analytic themes.

**Steps 7-8. Identifying Themes and Outlining Narratives.** In the last steps of the analysis, I reviewed the coding notes and memos, identifying the dominant themes and patterns across the interviews, participants, and projects. I prioritized cross-case analysis, identifying similarities and differences between the two teams. Finally, I developed outlines based on the themes, then revised, and expanded these outlines into narratives of the findings addressing the research questions.

### **Analysis of Meeting Observations**

I have transcribed all of the meeting video and audio recordings, then re-read the transcripts and related fieldnotes and added descriptive and interpretive notes to document emerging patterns of collaborative design practice, as well as similarities and differences in approach between the project teams. Close examination of the interview data allowed me to identify contradictions, strategies, and other key processes in the project activity systems. The interview data indicate that the team meetings that were captured in the course of the study do not reflect the full spectrum of project-related interaction among the team members. Not all team meetings were recorded. Also, in addition to pre-arranged meetings, the teams used a variety of opportunities to share ideas and status updates. These meetings took many forms, including quick chats and check-ins during school day among students, or between team members and the advisor. Addressing RQ1 and RQ2 based primarily on the meeting transcripts would yield an incomplete account of contradictions in the project activity systems. The advisor and student interviews contain questions about these interactions, and I have relied on them to generate inferences about particular aspects of CDP (e.g. adaptive strategies). Therefore, the interviews were used as the primary source for in-depth coding and analysis of the research questions.

I carried out the coding parallel with extensive interpretive memoing, supplementing codes on *each* segment with detailed notes. This helped to see connections between the responses of individuals within teams, as well as across the project cases. As a result of this approach, most of the findings are applicable to both teams, and although examples from only one of the two teams may be cited, cross-case applicability may be assumed for the findings unless noted otherwise. I then used these constructs as signposts for further triangulation and verification using the available meeting transcripts, looking for both confirming and disconfirming evidence of the participants' accounts. To this end, I have used fragments of the meeting transcripts to provide additional insight as needed, to further illustrate the narrative.

### **Analysis of Project Artifacts**

The advisor and student-created artifacts such as the trip agenda, project plans, and the materials used for the presentation displays played a supplemental role in the analysis. The advisor-created materials were used as illustrations or accounts of some of the advisors' activities as part of their role in coordinating students' participation in the competition. These included advisor-compiled packets of information about IT, itineraries of their planned activities for the trip to Pullman, and documents they shared with the students to inform their project work (such as the judging rubric). Most of these documents were created or provided to me after the competition was over and illustrated what advisors meant when they had mentioned them in the interviews.

The student-created artifacts consisted of text documents, surveys, and graphical illustrations (charts and sketches) that students had prepared as part of their projects, as well as the completed presentation displays. These artifacts had an anchoring role in the analysis. In general, the focus of the study was not on these artifacts *per se*, but on the activity systems that

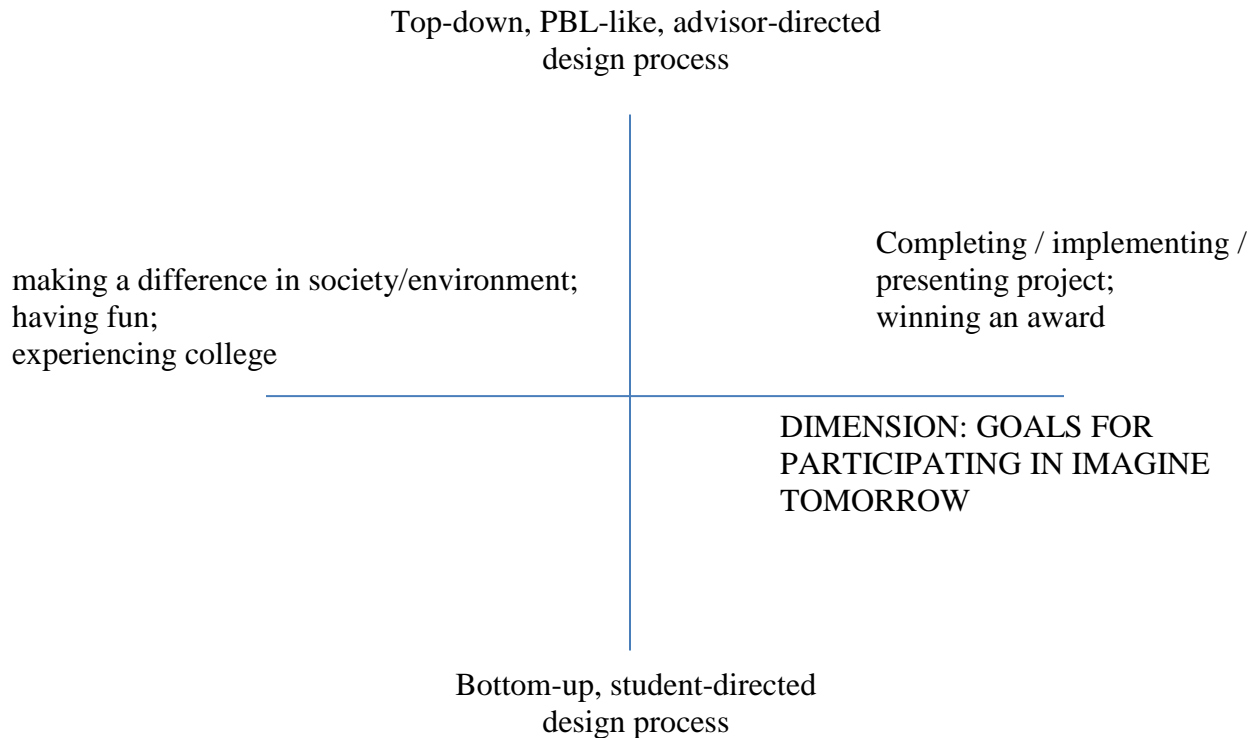
produced them. The artifacts were only useful for explaining the teams' practices if other data were available that linked these artifacts to the teams' practices, ideas, challenges, resources, and so on. Thus, the primary use of these artifacts was as a tool in the data collection process, helping to elicit insights about the processes which helped bring them about. For instance, I used an iPad tablet to photograph student presentation displays at the competition event. During follow-up interviews, I showed these digital photographs to the interviewees, using particular elements of the presentation displays to reference and illustrate their responses. In this way, these artifacts served as concrete examples which helped to elaborate meaning during student and advisor interviews and triangulate inferences about the project activity systems.

### **Examining tensions and contradictions in project activity system (addresses RQ1)**

Research question 1 explores the sources of the tensions that surface in the course of working on the project, as well as conditions that may give rise to these tensions within the project activity system. The framework illustrated below (Figure 10) provided a starting point which I used for identifying the tensions and contradictions which might characterize the project activity system. The hypothesized dimensions of tensions were revised as the analysis progressed, based on the emerging dominant themes.

The tensions and contradictions in the project activity system might be pervasive, manifesting throughout the period of working on the project. Alternatively, the participants might change their practices in response to explicit or implicit recognition of these tensions. For instance, the advisor might change his or her approach to working with the team, or the students might adapt their practices to the advisor's style or revise their goals and priorities based on time or resource constraints.

## DIMENSION: CONTEXT/FORMAT OF DESIGN PROCESS



*Figure 10.* Initial framework for analyzing tensions in the project activity system.

The vertical dimension is based on the assumption that high school students have more experience with group projects in classroom-based PBL settings than outside of class. This resonates with an observation that balancing teacher control and student autonomy sometimes presents a "dilemma," or contradiction for teachers implementing PBL curricula (e.g., Ladewski, Krajcik, and Harvey, 1991). A similar dilemma might signal contradictions within the project team, with students' confidence in their ability to autonomously organize the project outpacing the skills for doing so. This might reveal a tension between a role for the advisor that is deemed appropriate based on the team's expectations within the context of the competition and a role that helps the team complete their project.

The horizontal dimension contrasts activities that directly correspond with the goal of completing the project with goals that may be pursued, or even achieved without finishing and presenting a project. In activity system terms, these latter goals represent ways of working toward *outcomes* (consequences of participation in the competition) that may result in side-stepping or downplaying the importance of achieving the *object* (a completed project). This dimension is based on the expectation that students have multiple goals for participating in Imagine Tomorrow. Moreover, as mentioned in the introduction, about one-third of the teams that register for the competition eventually drop out. I hypothesize that one of the reasons for this might be different goals or relative priorities attached to the goals for the competition. The goals or motives that spark initial interest in the competition might differ from those that help to finish a project. In other words, different goals for participating in the competition may be associated with differential level of commitment to the project, expressed in students' motivation to translate ideas into action.

The issue of different goals or motives is directly related to potential discoordinations in collaborative design practice. Although the joint enterprise of the project might influence general motivation for helping with the project, what motivates students to participate in the competition or to produce a successful project may not be what motivates them to perform specific day-to-day activities. In particular, differential goals and priorities of the individual team members could determine the perceived importance or urgency of various project-related activities, leading to discoordinations in CDP.

### **Navigating contradictions in project activity system (addresses RQ2)**

To address research question 2, I analyzed the strategies that were used to address contradictions within the project activity system. These are the strategies that the project team

and the advisor used to keep the project on track when contradictions in the project activity system created discoordinations in activity, or when such discoordinations could be anticipated. In this analysis, I use the term “strategy” broadly, to denote activities that emerge from the interaction of the individuals with the context in the project activity system.

To identify the strategies or practices that facilitated project completion, I initially planned on using the design process framework by Dominick et. al. (2001) where the authors link steps in the engineering design process with the skills and tools associated with these steps (Appendix E). This framework seemed applicable to my analysis because it emphasized the collaborative aspects of the design process (e.g., the “communication” and “collaboration” skill areas). Initially, it had broadened my view of the practices or “moves” that might characterize CDP. However, from the early stages of data analysis it became clear that the framework in its original form did not add explanatory power or structure to describing the flow of activities on the focal teams for purposes of the present study. The issue was that most of the steps in the design process (in the left-hand column of the table) involved multiple practices across all four skill areas that were associated with different design steps. For instance, defining the problem involved research and brainstorming (decision making skill area), active listening and seeking feedback (communication skill area), as well as group formation and ensuring equal participation (collaboration skill area). Most importantly, such categorization did not inform research question 2 in terms of explaining how different design activities were enacted *in situ* in the two focal project activity systems and how they were adapted to (as a result of being facilitated or impeded by) the affordances and constraints of these project activity systems. It was also unclear how such analysis could inform practical recommendations for IT advisors and student teams while taking into account the unique challenges of out-of-class project work.

On the other hand, thematic analysis of the interviews and team meeting using grounded theory methodology and activity systems analysis revealed patterns of activities within the project activity systems, which I refer to as strategies that could be grouped into distinct categories and linked to contradictions and tensions in these activity systems. This analysis is integrated into the response to research question 1 and is presented in Chapter 5 section “RQ 1 and 2: Tensions and Strategies.”

As part of this analysis, I identified specific strategies, which I refer to as *adaptive* strategies, which appeared effective in negotiating the contradictions in the project activity system and facilitated project completion. These strategies are “adaptive” in that they represent adaptations of the activities or conditions framing the project work. I considered strategies “adaptive” if they satisfied two criteria: (a) enabled project completion, i.e. the achievement of the *object* of collective activity in the project activity system, and (b) did so with no apparent detriment to the participants in the project activity system, in particular the students and their advisor, with regard to their competition experience. I determined whether particular strategies were detrimental or not by checking interview and meeting data for evidence of negative outcomes, perceptions, or emotions exhibited by the study participants. When a strategy facilitated project completion, but did so at the expense of the quality of the competition experience for the individual or team, I considered such strategy “borderline adaptive” to signify the trade-off, which likely rendered such strategy unsustainable. Finally, I used the label “maladaptive” to denote activities or conditions which appeared to impede project completion, regardless of the impact on individual or team. Figure 11 graphically represents these analytic categories. Two questions were addressed: (1) what types of adaptive and maladaptive strategies may be identified in relation to facilitating or impeding project completion, and (2) how the

project cases compare on these strategies. That analysis is presented in the Chapter 5 section “Research Question 2 Supplement.”

The strategies were identified based on the interviews and meeting observations. Analyzing the data for evidence of strategies that could be mapped to either quadrant in Figure 11 implied intentional search for disconfirming evidence related to the different activities and conditions making up the project activity systems, thus validating and strengthening the analysis of research questions 1 and 2 methodologically.

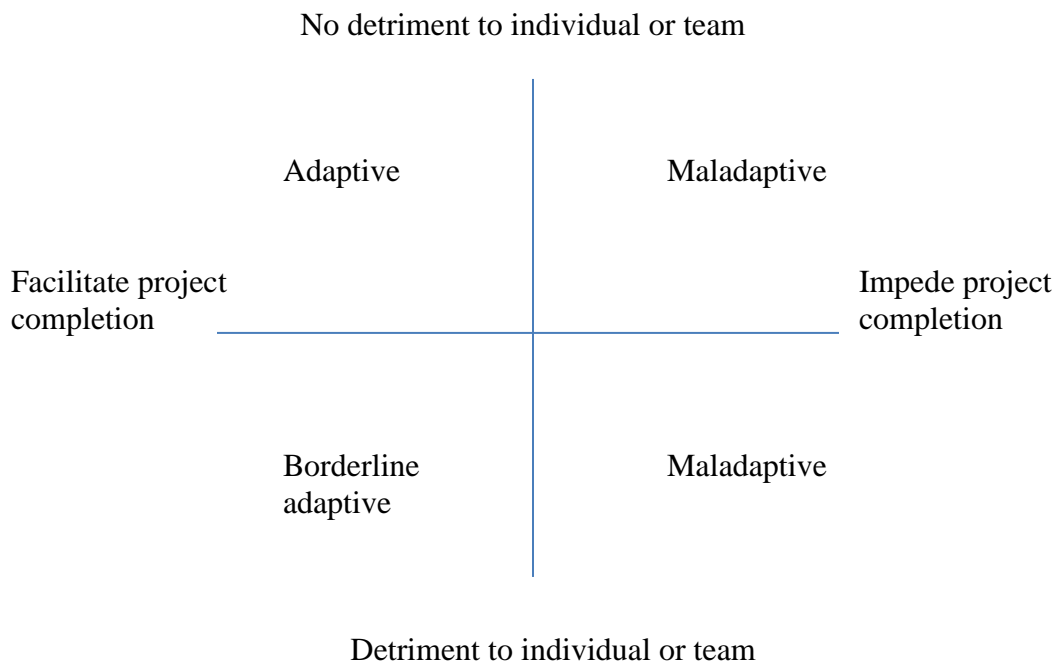


Figure 11. Framework for categorizing discoordination-management strategies.

I also leverage one particular feature of the framework by Dominick et. al. (2001), namely, the four “skill areas” involved in all phases of the design process. These skill areas are represented by the vertical columns in the model diagram -- decision making, project management, communication and collaboration. The framework lists specific skills corresponding to each category and design step (e.g., “active listening and probing skills” as part

of the communication process during problem definition). Although the exact mix of the skills and tools within each skill area depends on the disciplinary context and structure of the design process under study, the skill areas themselves help in describing the collaborative aspects of design. Therefore, I used these four skill areas to develop working definitions of four overlapping dimensions of the strategies which the teams might use to make progress on their projects:

**Decision making:** *Analysis methods and standards-focused* – the kinds of information and other factors (e.g., resource constraints) considered in making decisions and the methods used to arrive at decisions.

**Project management:** *Organization and structure-focused* – the activities and strategies of significance to the project as a goal-oriented, joint enterprise, characterized by controlled movement toward the project's completion.

**Communication:** *Information transmission-focused* – the practices through which information is exchanged, including the methods for how information is collected, shared, attended to, documented, and represented.

**Collaboration:** *Individual and team-focused* – the expression, awareness, and accommodation of individual and shared attitudes, patterns, and norms of conduct.

These definitions inform my discussion of decision making, project management, communication, and collaboration as part of CDP in the Findings chapter.

### **The role of team meetings in the collaborative design process (addresses RQ3)**

Research question 3 looks at the ways in which team meetings contribute to project work; the kinds of activities carried out in the team meetings; the challenges that stem from these activities; and the challenges that such activities aim to resolve. According to activity theory, changes in activity systems may unsettle the established routines and lead to discoordinations in activity. I hypothesized that team meetings shape the team's approach to the project by actively

involving students (and possibly advisors) in collaborative work where goals are clarified, member roles negotiated and enacted, and tools and resources leveraged in productive ways. Conversely, modifications in activity systems, such as changes in team membership or roles, might influence meeting activities.

In general, meetings are a form of project-related activity where discoordinations might be manifested, and thus represent potentially important sites for observing the development of CDP, especially breakdowns and innovations in activity. Meetings may also yield insights into whether teams engage in *masking* the discoordinations through actions aimed at suppressing anticipated conflicts (Engeström, 2008). I have explored the role of team meetings in reference to strategies aimed at addressing the contradictions within the project activity systems.

#### **Outcomes associated with participation in the competition (addresses RQ4)**

Research question 4 addresses the valued outcomes associated with working on, completing, and presenting a project, as well as the sources of these outcomes, and the extent to which project completion is aligned with these outcomes. The individual and shared goals related to the project and the competition as a whole might either help to facilitate coordination on the team and the achievement of valued outcomes or become a source of discoordination on the path to project completion. As part of this analysis, I examined the relationship between attainment of the *object* of the project activity system (a completed project presentation) and the associated *outcomes* of individual and collaborative activity. Depending on the alignment between the standards and values of the competition participants, project completion may to a greater or lesser extent enable perceived success in the competition. Student and advisor interviews were the primary sources of data for the analysis, permitting synthesis of the participants' perspectives.

## Chapter 4: Project Case Profiles

Drawing upon the interviews, this chapter profiles two project cases which are the subjects of this research. This allows the reader to become familiar with each case and sets the stage for an analytical treatment of the cases in the Findings chapter, which addresses the research questions.

Each project profile is organized in several sections: advisor background, Imagine Tomorrow context, the project team, and the project itself. Substantial attention is given to the advisors because their approach to overseeing the teams provided constraints and affordances for the way project work progressed, both in terms of what the advisors did and what they did not do. The advisor background section describes the advisor's relevant teaching experience, the experience of participation in IT, and the personal factors which frame each individual's advising approach. The IT context section describes the links between IT and the school curriculum and the process for recruiting participants at the school. The project team section offers basic information about the student members and the student who acted as the team leader. Finally, summaries of project topics, work processes, and timeframes are given in the last section.

### Emerald HS Project Profile

#### Advisor Background

**Teaching Experience.** Amy had degrees in biochemistry and education, and was in her 10<sup>th</sup> year of teaching at EHS. She has been teaching Advanced Placement (AP) and Honors chemistry for the past 7 years, and really enjoys her work. Because Amy's classes are not required, her students tend to be interested in science and college-bound. She considers her students highly capable and creative, and she is passionate about providing them with

opportunities to express their interests and talents. The IT competition presented a way to do this. Talking about her professional goals, she noted:

I'd wanna write a curriculum that was designed for project-based learning in science. I mean, my God, the kids can plan a ball six months in advance, and it's to a tee, they had everything done, and it's like God, it's what science is, but just not with THAT outcome...so if they can do THAT, they can do this other stuff; they just don't have the opportunities presented for them. (Emerald / Amy advisor interview 1)

**IT Experience.** Amy has participated in IT continuously since the competition's inception several years earlier, with the current year being her fourth year advising and taking teams to the competition. She took one team in the first year and two teams in the second year. In her third year she had over thirty interested students but "ended up taking only fourteen." One of her teams had won first prize in their category. In the current year she advised three teams. Her track record of involvement in IT garnered her nomination for a teaching award by her district supervisor.

**Personal Factors.** Amy had attended WSU as an undergraduate. She did not view IT as a chance to attract students to WSU in particular but to give them an opportunity to see a different part of the state and a college campus that they might otherwise not have a chance to visit:

So I wanna try promote WSU to these urban kids who don't get a chance to go, many of them have never been over the mountains, and it wasn't because I want them to prefer WSU over the U or any other schools, I just wanted to give them an opportunity to see another school...so that's how I first got started kind of on an interest of I'd really like these kids to see what's over there. (Emerald / Amy advisor interview 1)

Also, as a student at WSU, Amy took part in an undergraduate research experience where she presented her research to a professional audience. She believed that participating in IT would help prepare her students for these types of experiences in college.

Finally, Amy repeatedly stressed the importance of using data as evidence in the scientific inquiry process and saw the competition as an opportunity for students to practice applying the scientific method by having to collect, analyze, and interpret primary data as part of their projects. Earlier IT experience revealed that students lacked the skills to work with data, producing a feedback loop that informed Amy's teaching:

Last year that's what our teams lacked; I kept telling them, that you know, numbers say everything – you need to have numbers in your project; [...] I saw kids had no idea how to collect data, no idea. So part of my personal goal, at least in my AP class this second semester is, hey, you are collecting data and you're doing all the interpretation on it; we've done enough synthesis, we've done enough controlled environments so that you can do chemical processes; well now, test it, collect it, interpret it, graph it, everything. (Emerald / Amy advisor interview 1)

### **Imagine Tomorrow Context**

**Curriculum Integration.** As a rule, the students at EHS do not receive credit or take a class to participate in IT, and all project work, meetings, and advising happens outside of class time and is voluntary. When asked whether IT was integrated into the school curriculum, Amy responded, "It's completely stand-alone." However, a couple of students – one of whom became the leader of the focal team – have been able to align IT project work with school graduation requirements, in particular the Culminating Exhibition (CE) performance assessment completed during the senior year. Such dovetailing appears to be ad-hoc, such that a student's environment-related CE project may lead to participation in IT, or vice versa. The requirements, timeframe,

and deadlines of CE projects differ from those of the IT competition, however. Also, CE work is individual for each student whereas IT projects require collaboration.

**IT Recruitment.** Amy advertised IT through posters and announcements in her classes, in her building (where mostly science classes are held), and school-wide through the morning PSAs. Students also learned about the competition through word-of-mouth from friends and past participants. Almost all students who signed up for the competition had Amy as a teacher in one of their science classes. Here is how she described students at their school who typically participated in IT:

I would categorize the kids that are normally into this as very kinda out there, they are not confined by any social structure at all, they are very artistic, very bright, some of them may not necessarily have the academic record to prove their intelligence because they are kind of...they are beyond that in their own...they feel like they don't need to prove it to the man, so but they are extremely intelligent kids, and they got wild ideas that are I mean tremendous, and...yeah so they kinda tend to be that kid, someone very (...) and they take a lot of science classes, and they kinda have that...creativity...some of them are very order-focused, some of they are very ingenuity-focused. (Emerald / Amy advisor interview 1)

After enough students expressed interest in participating in IT, Amy held meetings where students wrote their tentative project ideas on the board, and self-selected into teams – a process typically driven by common interests and social ties.

## **The Team**

**Team Members.** The focal team consisted of four students: two male juniors (Seth and Ben), one male sophomore (Will), and one female senior (Kara), who became the team leader. All four students were taking Amy's classes when they formed a team. The two juniors, Seth and Ben, heard about the project from their friends who had gone before and enjoyed the

competition. They came up with the original project idea. Kara joined the team during a meeting organized by Amy where students interested in the competition shared their ideas and self-selected into teams. Will initially joined a different team with his friends, but that team never managed to solidify its project idea. He was looking to switch teams when Seth, who he also knew, invited him to join their team. Although Will participated in a number of meetings, around late April he unofficially dropped off the team under pressure from his parents in order to refocus on academic commitments and did not attend the competition.

All four students were first-time IT participants. They may be described as highly capable and outgoing, heavily involved in school-related and other extracurricular activities. Besides taking Amy's classes, all four were involved in the school's competitive music group and numerous other activities. Ben and Seth were on one of the school's sports teams. Seth also held positions on various school committees, and in the current year, he was elected as the PR representative for the school's student government. He enjoyed serving in leadership roles and had been taking a leadership class for a number of years. Will was a member of two competitive music groups at the school, was taking AP coursework above his grade level, and was involved in some early admission college prep programs (attending institutes, taking practice SAT, etc.). All four students were college-bound.

**Team Leader.** Like her teammates, Kara was very active in school extracurricular activities. She was in the school's competitive music group, a sports team, and volunteered for a national honor society. Prior to Kara joining the team, Seth was the originator of the project idea and de-facto leader. In contrast to Seth, whose leadership ability was evidenced by a track record of leadership roles, Kara's experience was rich in participation but not leadership. She may be described as "the incidental leader" on her IT team, landing into the leadership role by

the assumption of her teammates. In the post-competition interview, she described how “the leadership thing happened:”

AM: Has your role changed from what you initially thought, and if so in what ways, as the team was working on the project?

Kara: I...I didn't expect to be the leader, at first, I thought I was just being... a part of the project that...none of us had ever done before, then the leadership thing happened...and then...I became...I didn't think I'd be the contact person either, since I was the least sociable in the group, I feel like...since Seth and Ben were used to talking to people and texting and all that, I didn't think I'd be...[chuckles] the contact person, but since I was the leader and since I was the most organized, and had already done some emailing, they said to keep it from getting confusing, let's just have me be the contact person. (Emerald / Kara interview)

A comment by Seth also shed light on the antecedents of Kara's becoming a leader:

AM: How about other challenges? What do you think presented issues or had to be overcome?

Seth: Yeah I would say the best would be for me just to list them, and then you can...let me know if I need to explain them more. [...] I would say the leadership in the group, was...Kara has this as her CE project, her senior project, so it was important for her to be the leader of the group, and I could understand that, and I kinda took a more laid-back presence than I would've normally done in a group setting...[...] She's a very quiet and shy person by nature, and I think if she would've been more...leadership style, I would say, or just experience...she may not have as much experience in leadership roles. (Emerald / Seth interview)

To summarize, for Kara, taking the leadership role preceded actually acting in that capacity. She was made the team leader in lieu of being organized, having done some emailing on behalf of the team, and on the assumption that leading the team would be a plus for her senior project. She then had to learn by doing, that is, by stepping up to the tasks such as continuing to serve as the focal contact for external stakeholders and organizing team activities and meetings. She also sought feedback from the advisor and her CE mentor.

## **The Project**

**Topic.** The team's project focused on instituting a composting program at their school and using educational presentations within the school to change the behavior of the student body so that the program would work. The students also developed a plan for an inter-school student environmental council that would oversee environmental initiatives across the high schools in the district. At the time of the IT competition their accomplishment was to have laid the groundwork for instituting the program by securing sponsorship of school leadership and key stakeholders at the district level, drafting some of the needed documentation, and designing an organizational structure intended to ensure program sustainability. The actual implementation of the program was presented as a potential future plan. The presentation visuals included planning documents and survey research findings. The planning documents consisted of council charter and letters of support from school and district leadership. The research findings consisted of graphs and PowerPoint slides on the results of a survey of the student body regarding composting behaviors. The project fell in the Multidisciplinary category of the competition.

## **Process and Timeline**

**Team formation.** Seth and Ben formed their team in November – December of the current academic year when Amy was recruiting students to participate in IT. Kara expressed initial interest in the competition to Amy in late fall, then joined Seth's and Ben's team in late January – early February. Will was the last to join in late February.

**Idea Revision.** The project originated from Seth's and Ben's idea of redesigning the school to be more "green." One element involved redesign of the school facilities in accordance with Leadership in Energy and Environmental Design (LEED) green building certification

standards. Another element involved turning the school toward more environmentally friendly waste management policy and practice. After adding Kara and Will to Seth's and Ben's team and further brainstorming and research, the initial broad idea of making the high school more environmentally friendly was focused on ways to introduce a composting program. The composting idea emerged after the team met with the school district maintenance department staff and learned about the district's ongoing energy and waste management initiatives:

Kara: There's the one project that Mike [member of the local school district maintenance department staff] was working on with [ ] Elementary, and that was food waste, and paper waste -- they're combining those -- and having [the local waste management company] take the compost stuff waste, and that was time-saving and...[...] money-saving and...but then they were only looking at elementary schools. So we thought it'd be great if we could get that program into high schools too, and so...I guess we went from a more general view of things to specifically recycling food and paper. (Emerald group interview 2)

The idea for the environmental council also emerged from meetings with the advisor and the district staff. The students considered the council idea innovative and presented it as such at the competition. In general, meetings with the stakeholders such as the district staff were useful in helping the students generate feasible project ideas. The students then proceeded to substantially elaborate these ideas through further brainstorming, information gathering, and analysis in order to organize the relevant information and present recommendations for how these ideas could be put into practice.

**Major Activities.** The team's major activities included stakeholder interviews with school principal and district staff, a cost study of contracting with a commercial composting service provider, survey opinion research with students at the school, and creation of presentation materials. The presentation included planning documents and survey research findings.

**Timeline.** Seth and Ben formed the original two-person team in Oct-Nov 2010 after deciding to participate in IT based on friends' positive feedback. Initial brainstorming sessions took place around December and January, during meetings organized by the advisor. After Kara joined, she became the team leader. Team activities until April involved mostly brainstorming and refining the project idea and plans during the weekly after-school, all-teams meetings organized by the advisor. Besides some initial Web research, very little individual project-related work was done up to that point. In late April and early May, the students had several meetings with external stakeholders, developed the council idea, and gathered survey data from the student body. In early May, Will dropped off the team to refocus on his academic commitments. In the weeks leading up to the competition, the team held several additional meetings to draft and revise the presentation materials. Their last meeting was the day before they had to depart for WSU, during which they worked on finalizing all of the presentation materials and creating the poster. Although the poster was not quite finished, Seth and Ben considered the work mostly done and left, arguing the work could be postponed until the ride over to Pullman or the evening upon arrival. Kara had a different opinion about the amount of time needed to complete the project and worked independently later that evening to finish the poster. It may be said that the project was completed late on the night before departure. The team did not have time to practice presenting their project before the competition.

### **Malachite HS Project Profile**

#### **Advisor Background**

**Teaching Experience.** Nils was in his second year of teaching physical science to several classes of freshmen at MHS. In his classes, he covered “chemistry, physics, a little bit of astronomy.” He had degrees in zoology and education, and a year and a half of teaching

experience prior to coming to MHS. In his first year at MHS, he re-started the school's Science Club (SC), which had been around for several years but was inactive at the time of his arrival.

The same year he also found out about Imagine Tomorrow. He described the flow of events as follows:

I started [the Science Club] back up because I had the idea of you know making a human-powered bicycle generator, and I didn't really know these existed and were so common on the Internet, but I thought of the idea, I was like I bet you that would work, and I looked into it a little bit on the Internet and I wanted to get some kids involved, and then once I started you know plugging that idea with kids that were pretty science geeky, you know they were really into it, then I thought well this is a club type thing, this should be tackled by a club. We never did manage to make that - far too many parts and costs, but we threw around the idea for a long time, and it started science club, really...and from there somebody got me a poster or information about [Imagine Tomorrow], I don't remember how, but once I learned what it was about I was pretty interested in it, and I just drug along the kids a little bit in terms of pumping it up. (Malachite / Nils advisor interview 1)

The SC membership nearly doubled from about a dozen members (mostly freshmen) in the first year to about twenty students in the current year, including several upper-classmen. Club meetings were held in Nils's classroom every other week after school. The meetings lasted about an hour and consisted of socializing, club organization, and fun hands-on science-related activities of Nils's and the students' choosing (e.g. making a non-Newtonian fluid, "oobleck").

**IT Experience.** Nils participated in IT for the first time during the previous year when he began teaching at MHS and re-started the Science Club. He advised and was planning to take two teams, but one had dropped out due to a family emergency for one of the team members. The other team consisted of four students. The students had difficulty managing their extracurricular activities with project work, procrastinated, and nearly dropped out. In the last days before departure to WSU, Nils stepped in and helped students identify a feasible hands-on

project of making a prototype model of an alternative energy device, which they were able to complete in the nick of time and present at the competition. Although the project did not receive an award, the students, nevertheless, had a good time and enjoyed the competition. Both Nils and the students came away from that experience with lessons learned about how to better track and manage project work. In the current year, Nils advised two teams, both of which were able to attend the competition.

**Personal Factors.** Like Amy, the advisor of the EHS team, Nils was also a WSU alum. Also, like Amy, he did not participate in IT because WSU was his alma mater. He described his goals as follows:

I knew that just getting to Wazzu [WSU] would be a huge thing for a lot of these kids; they might not get to a college campus, and just being on a campus might let them realize, hey this is doable, I can manage to get here and be part of this kind of thing sometime...so, my role... I wanted to get them to Wazzu, not because I went there, but because it's a university, and I think students from this area need to get that exposure, I think that's important. (Malachite / Nils advisor interview 1)

Familiarity with WSU allowed Nils to act as “part tour guide,” arranging a number of unique campus experiences for the students, such as a meeting with a Biology professor and a visit to the university bookstore.

Another characteristic that appears to have contributed to Nils's involvement in IT is that it aligned with his personal interests – as a science teacher, but also as a tinkerer, especially when it involved concepts or technologies related to environmental science and alternative energy.

This alignment is reflected in his emphasis on environmental topics in his teaching:

We talk about energy and energy transfer in physical science [...] but I take it further, because you've got a little bit of latitude in terms of, you're supposed to cover the state standards, but I wanted to, ok we're supposed to cover energy, conservation of mass and

energy, energy transfers, well, let's go into alternative energy and fossil fuels versus alternative energy, and from there went into sustainability, and...nobody else here was talking about sustainability... it's just a pet of mine that I wanna spend two weeks at least on, for the kids to know what it is, cause it gets talked about all the time on the news, and...the kids really took it in, and they understood it, and they could see the connection between the hamburger that comes from BRAZIL to fossil fuels, and totally understand that. (Malachite / Nils advisor interview 1)

Compared to Amy's "methodological bend" regarding the role of IT projects in students' learning of the scientific inquiry process, Nils appeared to connect with the competition through a personal interest in issues of environmental sustainability and design.

### **Imagine Tomorrow Context**

**Curriculum Integration.** The IT competition was not integrated into the formal curriculum at MHS. Participation was voluntary, and project work happened outside of class. At the same time, the after-school SC meetings served the dual purpose of carrying out regular club activities, and giving the teams an opportunity to gather in one place at the same time, to check in about their projects, and interact with Nils in a somewhat structured, though less formal context.

**IT Recruitment.** The IT completion became a natural choice for channeling Nils's and some of his students' scientific interests, and his role as coordinator of the Science Club made the club a natural place for sourcing students for IT. Besides recruiting through the club, he also tried to advertise the competition school-wide using posters and morning PSAs. In addition, he enlisted the help of other science teachers:

Context-wise, it also could tie in real easy to the physics curriculum, in terms of energy they study that kind of stuff all the time, and they talk about energy conservation and stuff like that, and it could tie in easily to biology with ecology, so the teachers aren't involved directly, but I definitely, you know, tell them, please hype this up in your class just a little bit, and I've gotten one from each of those classes, AP bio and physics;

there's definitely more potential to get more involvement from higher classes...(Malachite / Nils advisor interview 1)

Students that were initially interested in the competition self-selected into three teams, based on friendships and class level. One of the teams, which included upperclassmen, dropped out due to scheduling conflicts. Advisor's meetings with the remaining teams were integrated into the SC meeting time.

### **The Team**

**Team Members.** The focal Malachite team initially included three girls, Molly, Gillian, and Dana, all sophomores and friends. They were also in the SC, and had participated in *Imagine Tomorrow* under Nils's guidance the year before. Gillian had worked on the project during the previous year, but had to miss the competition event for family reasons. She remained committed and rejoined the team for the second time, confident that she would be able to make it this year (she did). A fourth girl, Becky, joined after the initial team had been formed and the project topic selected though early enough to be involved in all substantive aspects of the work. She was Molly's friend, the team leader, who pulled her into the team after realizing that she had been helping in an "unofficial" capacity by contributing knowledge regarding the project topic. Becky was the only team member who was not in the SC and did not already know Nils, which made her slightly uncomfortable and hesitant about becoming involved in IT. It represented a different pathway into the competition whereby it was not a result of general interest in the competition, membership in the SC, being in the advisor's class, or friendship, but it was mostly due to her expertise in the project's topic.

All four girls on the team may be described as academically oriented, interested in science, and college-bound. Besides Science Club, three of them were also involved in

extracurricular activities: Dana was on a school sports team; Molly was in the school's competitive music group; and Becky had a management role in the school arts program. These responsibilities substantially constrained their after-school availability.

**Team Leader.** In addition to being involved in the school's competitive music group, Molly was also the President of the Science Club. At SC meetings she presented the club agenda, coordinated club activities with Nils, solicited input from members, and generally attended to the club business. At one of the team meetings, the students jokingly picked titles for their roles: Gillian was the "Serf;" Becky was the "Compost Master;" Dana was the "Artist;" and Molly was the "Dictator." Although Molly had nominated herself, it may be said she was a democratically elected dictator because the other girls supported her self-nomination. Her leadership on the team may have been preempted by her role in the Club, but it appears that the primary reason was that she possessed the qualities needed to lead the team. She was highly organized and adopted a proactive approach toward coordinating the project from relatively early stage by stepping into the leadership vacuum to take charge of planning, assigning, and tracking the project tasks as well as communicating with the advisor.

## **The Project**

**Topic.** Like the EHS team's project, the project of the MHS team came from an observation that the school's waste management strategy was not comprehensive and did not cover some types of waste. There was little recycling of cans and bottles, and there was no process in place for composting food waste from the cafeteria. The team eventually focused on composting and developed a three-year plan for implementing a composting program that would allow the food waste to be converted into compost on school premises. Unlike EHS team's project, this project did not involve collaboration with the school district staff or the local

compost waste company but relied on integrating the new behaviors into existing school structures and practices. Similar to the EHS team's approach, the team conducted surveys of the student body to gauge attitudes toward the proposed changes to waste management. The presented version of the project consisted of printed materials describing the three-year implementation plan, student opinion results summary, and visual aids. The project was presented in the Multidisciplinary category of the competition.

### **Process and Timeline**

**Team formation.** Molly, Gillian, and Dana planned on participating since the previous spring. Nils registered their team in late fall of the current academic year when he was recruiting students to participate in IT. Becky was formally added to the team around February after she had contributed to the project in an "unofficial" capacity for some time by sharing her composting expertise and helping Molly brainstorm ideas.

**Idea Revision.** The team decided against continuing to work on their project from the previous year, opting instead for a fresh idea. The reason was that their 2010 project topic was a necessary choice which was partly prescribed by the advisor after the team nearly had to drop out due to procrastination and failure to make progress on their project. The advisor recommended building a relatively simple model of a hydroelectric downspout, a device for converting rainwater into electric energy. The students had neither interest nor the technical skills to iterate on that project, so they decided to switch to a more interesting and relevant challenge. The idea of starting a recycling or composting program was initially suggested by the advisor, but the students eagerly took it up. They shifted the focus toward composting, capitalizing on the team members' hands-on informal experience with composting, especially Becky's knowledge of the composting process based on her experience on a small farm at home. The final idea consisted of

developing a 3-year plan for implementing a composting and education program at their high school and possibly exporting the program to local middle and elementary schools. The team went a different route compared to the EHS team's approach for contracting with another company for compost waste management as their county did not offer such services. Instead, the composting program was designed to be contained within the school. The food waste from the cafeteria would be placed into a to-be-constructed compost bin and turned periodically by students in the horticulture class. The ready compost would be used for the class's needs as well as for gardening sales organized by the school.

**Major activities.** The team's major activities included surveying the student body about attitudes toward recycling and composting, interviews with the school staff (concerning composting) and vending machine suppliers (concerning recycling), and development of the three-year plan for implementing the program and educating the students in composting practices.

**Timeline.** Molly, Gillian and Dana continued their participation from the previous year, so they were registered for IT early in the competition timeframe, in late Fall 2010. Following winter break, the team began brainstorming project ideas, and by February had settled on the composting and recycling program. Around that time, Becky began contributing her ideas and expertise, which informed Molly's ability to plan project activities. The team conducted a pilot, online survey around March, and in-person surveys with students around the school in April. Also starting January-February, Nils began to integrate check-ins with the IT teams into the Science Club meetings on a bi-weekly basis. Occasionally, these meetings were skipped, but Nils caught up with the teams through other means such as quick check-ins with team leaders around the school. By the end of April, the team had nearly completed their planning and information

gathering activities. The teamwork intensified during the first two weeks of May when the team met frequently to compile the data, discuss and refine ideas, and draft presentation materials. Their last meeting was the day before leaving for WSU. By that time, the team had finalized almost all of their presentation visuals and had gathered most of the required supplies. As a result, they were able to complete their poster design during the meeting, working collaboratively as a team over the full length of the meeting. The team's timely completion of their project suggested that they had learned their lessons from their first IT experience and modified their practice in a way that enabled timely project completion. Nevertheless, no time was set aside for practicing the presentation in advance of the competition event.

### **Summary of Project Cases**

The key similarities and differences in the project cases are summarized below (see Table 10).

Table 10

*Summary of Project Cases*

<b>Section</b>	<b>Emerald HS Project</b>	<b>Malachite HS Project</b>
<b>ADVISOR BACKGROUND</b>		
Teaching experience:	<p>About 10 years, upper-level Honors and AP chemistry</p> <p>Prioritizes learning of scientific inquiry process</p> <p>Aims to address deficiency of hands-on, problem-based learning in curriculum</p>	<p>About 3 years, lower-level physical science</p> <p>Prioritizes coverage of alternative energy and environmental sustainability issues in curriculum</p> <p>Oversees the Science Club</p>
IT experience:	<p>Continuously since inception, currently in 4<sup>th</sup> year</p> <p>One team won top prize in category</p>	<p>Continuous since last year</p> <p>Barely salvaged last year's project by stepping in with a quick-build project idea</p>
Personal factors:	Stresses importance of data as evidence in IT projects	Interested in alternative energy technologies
<b>IMAGINE TOMORROW CONTEXT</b>		
Curriculum integration	<p>Not part of curriculum</p> <p>Some conceptual links to advisor's chemistry class</p>	<p>Not part of curriculum</p> <p>Some conceptual links to classes taught by advisor and other science teachers</p>
IT Recruitment	<p>Advisor recruits in her class, also advertised through flyers in her building and morning announcements</p> <p>Students volunteered to participate and self-selected into teams</p>	<p>Advisor recruits in his classes and Science Club</p> <p>Also advertised through other science teachers, flyers outside his classroom, and morning announcements</p>

THE TEAM		
Summary	<ul style="list-style-type: none"> <li>• 1 Sophomore, 2 Juniors, 1 Senior</li> <li>• Senior the only girl and team lead</li> <li>• All enrolled in advisor's Honors or AP science classes</li> <li>• All first-time participants</li> </ul>	<ul style="list-style-type: none"> <li>• All Sophomores, girls</li> <li>• All interested in science</li> <li>• 1 first-time and 3 repeat participants</li> <li>• Repeat participants took advisor's science class</li> </ul>
Team members	<p>Kara –senior, using IT project for her CE graduation requirement, involved in competitive music group, honor societies, and volunteering, college bound with interest in elementary education, joined Seth and Ben's team, only girl on team</p> <p>Seth – junior in advisor's class, good leadership abilities and experience in leadership roles at school, PR officer in the student government organization, also involved in competitive music group and a school sports team, college-bound but undecided on major, leaning toward business</p> <p>Ben – junior in advisor's class, friends with Seth, also in competitive music group and track and field, college bound but undecided on major, leaning toward engineering</p> <p>Will – sophomore taking advisor's junior-level class with Seth and Ben, friends with Seth, highly advanced academically, interested in Computer Science, member of orchestra, college-bound through early admission to major in CS and continue to graduate school, joined Seth and Ben's team late (Feb)</p> <p>None of the students had prior IT experience</p>	<p>All four girls are sophomores, really like science, and are college-bound, although have no definitive plans for major. All girls except Becky had participated in IT in previous year</p> <p>Molly – was a student in advisor's class, involved in competitive music group, President of Science Club in current year</p> <p>Gillian - was a student in advisor's class, involved in competitive music group, friends with Molly and Dana for many years</p> <p>Dana - was a student in advisor's class, VP of Science Club, plays on a school sports team, friends with Molly and Gillian for many years</p> <p>Becky – was not familiar with Nils because took more advanced science coursework and was not involved in Science Class; involved in 4-H for many years, the 'composting expert' on team</p>

Team leader	Kara became team leader due to her senior class standing and using IT project for CE requirements. Leading the team was a learning experience. She did well overall, organizing teamwork and being the focal contact with stakeholders	Molly became the de facto team leader by taking a proactive role in planning team activities. She prioritized planning to help ensure timely progress on project, and became team's focal contact with the advisor
<b>THE PROJECT</b>		
Topic	Multidisciplinary category  Starting a composting program at EHS - laying the foundation for using commercial composting service, educating student body, and instituting a district-wide high school environmental council	Multidisciplinary category  Starting a composting program at MHS – laying the foundation for implementation of composting within the school by leveraging local resources, including building a compost bin and involving the horticulture class
Process and timeline	Team formed in late Fall of the current academic year, before Kara and Will joined in January-February  Initial idea of exploring ways to redesign the high school to be more environmentally friendly was narrowed to focus on designing a composting program and an environmental council in partnership with other schools  Winter and early spring spent mostly brainstorming and refining project idea. Research and data collection intensified in April and May. The presentation materials were finalized the day before the trip to WSU, and the poster designed by Kara late that night	Team remained since the previous competition, Becky joined in January-February of the current academic year  Previous year's last-minute idea of a technical device model was replaced with a design and three-year plan for implementing a composting program at the high school  Winter was spent brainstorming and pre-planning; in March the team piloted an online student survey, subsequently revised and re-administered offline by the team members. The survey and the interviews with project stakeholders were completed in April and early May, and the analysis and presentation design completed in the days leading up to the trip to WSU. The presentation display was created on the last day before the departure, with all team members collaborating to complete the poster with time to spare

## Chapter 5: Case Study Findings

This chapter discusses the findings from analysis of the data, organized by research question. The analysis was intended to illuminate the research questions in a manner consistent with the theoretical and analytic approach of the study by making interpretations and drawing inferences that address IT projects as activity systems within the Activity Theory framework. In particular, effort was made to retain sensitivity to the following parameters:

1. Activity system – The project conceptualized as an activity system, with focal activity (CDP) considered in relation to activity system components.
2. Multivoicedness – The interview responses of different participants are integrated in analyses of all RQs to present holistic account of issues.
3. Historicity – Both the stable and the dynamic elements of project activity system are identified by considering the development of approaches, practices and understanding of project elements over the duration of project work, and in comparison with past experiences and future plans.
4. Expansive transformations – The project activity system is examined for changes in practice, redefinition of norms or goals, or weakening of constraints which address (or have the potential to address) tensions and reduce the risk of contradictions and discoordinations.

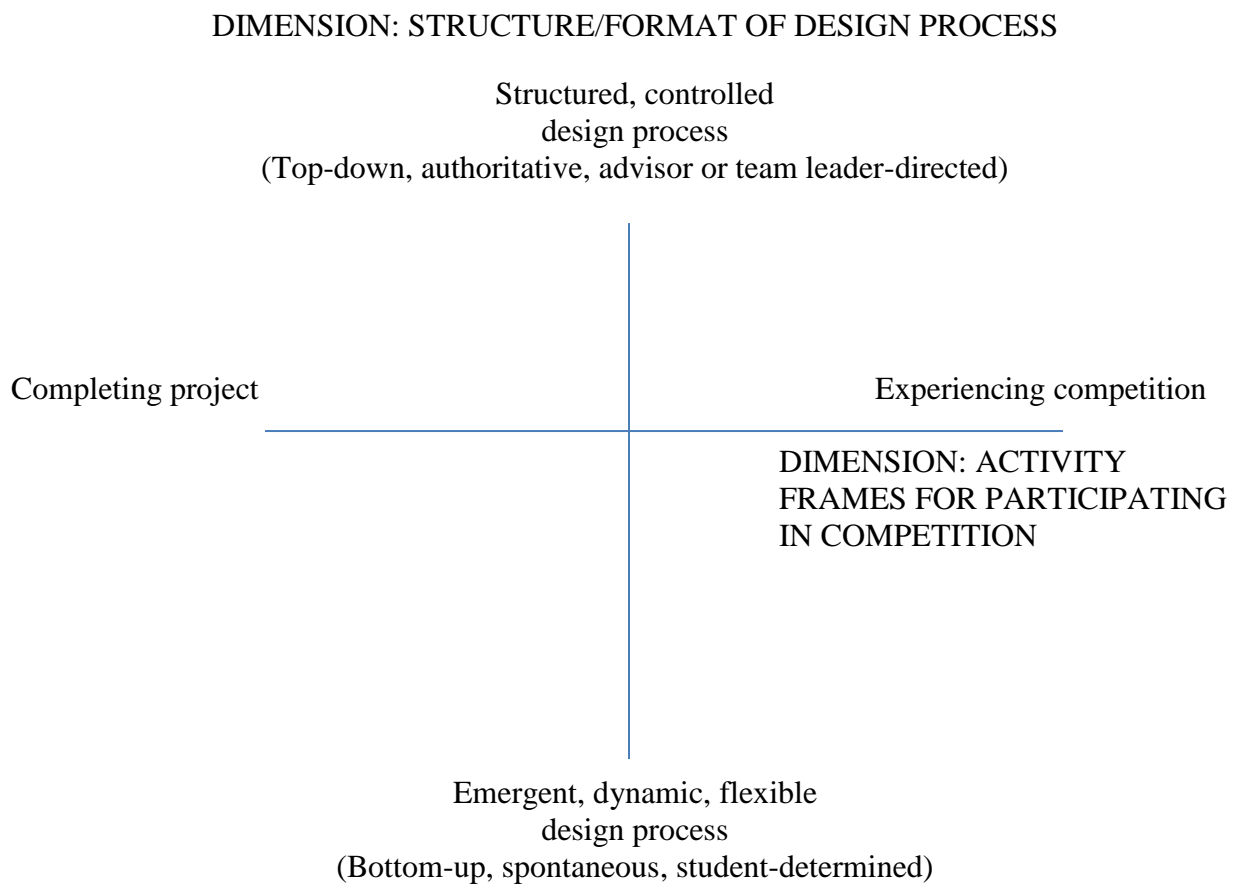
### Research Questions 1 and 2: Tensions and Strategies

Research questions 1 and 2 state:

RQ1: What tensions characterize high school students' collaborative project work in out-of-school settings?

RQ2: How do teams navigate these tensions in order to complete the project?

The tensions that were hypothesized in the Analytic Approach chapter (Figure 10) were good starting points for the analysis, highlighting issues which turned out to be relevant to the understanding of the project activity systems. In the course of the analysis, differences emerged which led to reframing of the dimensions to accommodate the range of competing factors and contradictions in the activity systems of both projects. The final framework is presented in Figure 12.



*Figure 12.* Analytically derived framework of tensions in the project activity system.

Contradictions in the activity system are manifested through the subjects’ perceptions and practices. In the narrative that follows, I discuss strategies the students and advisors have used, which may be analytically tied to managing or avoiding discoordinations in activity. In a section

specifically addressing RQ2, I summarize adaptive and maladaptive strategies with regard to project completion and compare strategy use across the two cases. I use several thematic labels to synthesize the findings. In particular, “practice trajectories” highlight emerging patterns which describe the development of the project activity system. The discussion of “gaps” in strategy use suggests opportunities for improvement in attaining the related goals.

### **Relationship between contradictions, goals, and strategies**

The discussion that follows may give the impression of one-to-one relationship between contradictions, goals, and strategies. However, in actual project work, the relationship between these elements is more complex and may change over time, as well as across teams, and in how it is perceived by the participants in a given activity system. For instance, whereas the advisors may perceive regular IT meetings in their classroom as opportunities to check in with the teams and monitor project status, the students may consider the same meetings as additional opportunities to socialize, collaborate on tasks, and get work done. As another example, narrowing the scope of a project topic may help increase project quality by concentrating attention and effort as well as catalyze the CDP by clarifying tasks and objectives. To consider such potential interpretations, I used the four interview themes as analytic lenses for examining contradictions in the project activity systems (see the Analytic Theme Matrix in Appendix G). The subtitle of each section calls out the contradiction and the theme I used to frame the analysis: advisor support, CDP, project context, and student participation (Table 8 in the Analytic Approach section above describes each theme).

The participants of both teams shared similar goals with regard to projects and used similar strategies to achieve them. Unless otherwise noted, the statements and examples are representative of both project cases.

## **Tension 1: Structured vs. Emergent Collaborative Design Process**

The first tension involves the structuring and coordination of the design process and ranges from a more rigid and controlled structure to a more emergent and spontaneous structure. This tension has to do with factors such as the nature and extent of advisor involvement in project activities and the amount of control exerted by the team leader. It reflects the range of opportunities for *agentic* student-centered practice. The notion of *agency* here is juxtaposed with the notion of *structure*, and resonates with the perspectives of structuration theory (Giddens, 1984) where it refers to sociohistorical constraints associated with following or “making use of” rules in social practice (Erickson, 2004). Here it is used in a narrow sense to denote students’ capacity to self-direct their project work. The narrative that follows is organized based on the contradictions which reflect the tension between structured and emergent collaborative design process.

### **1.a. Advisor Support: Balancing hands-on vs. hands-off involvement by advisor**

A fundamental challenge advisors face is balancing the extent of their hands-on involvement in project activities in light of two competing goals: on one hand, ensuring that students complete a project of reasonably high quality; on the other hand, not doing the project *for* the students (Figure 13).

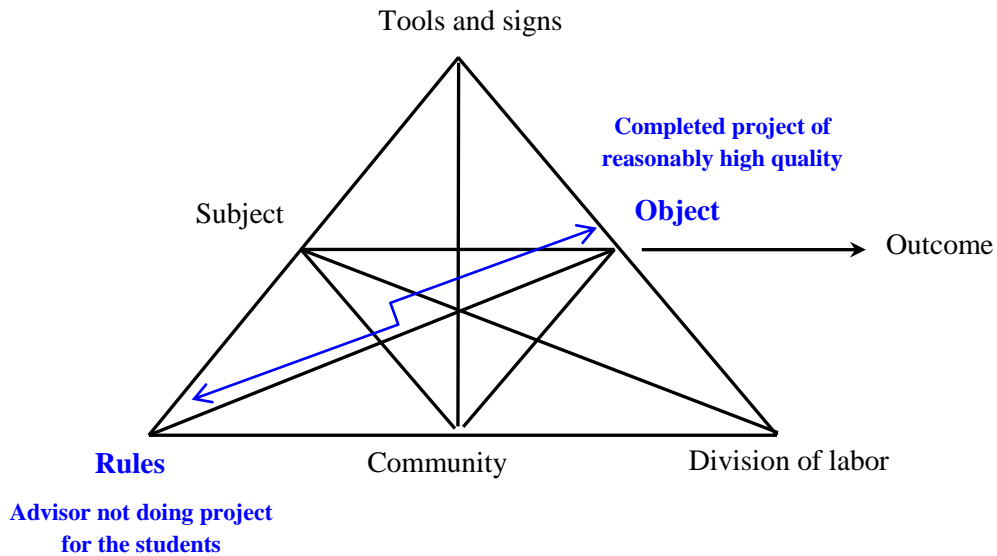


Figure 13. Contradiction 1.a. Completed project of reasonably high quality (Object) vs. advisor not doing project for the students (Rules)

Advisors have a vested interest in students' projects being completed on time, being competitive, and possibly award-worthy. Projects that are not completed result in a team's inability to attend IT. This translates into wasted time and effort on the advisors' part, related to organizing the logistical part of the trip. The administrative component adds up to considerable time investment involved in advertising IT at the school, managing the consent paperwork, making transportation arrangements, and creating itineraries of campus activities. Failure to complete projects also undermines an important goal for advisors of providing college exposure experience for their students. These factors are independent of project topics and outcomes such as community impact or winning. Attending the IT event and experiencing WSU is viewed as significant outcome in and of itself. (This helps explain why some students perceive advisors' approach as misaligned with the orientation toward winning an award, which I address later.) As

a result, advisor goals include ensuring that their students prepare well for the IT competition, that the trip is not a 'waste of time' in terms of low project quality:

I wanna make sure they are doing what they're supposed to be doing; that they've met what they've [set out]. Just like OK, I'm gonna take you to Washington State University, and they're gonna make presentations to people from all sorts of huge scientific industries, and you better know what you're talking about, so ...you better also prove to me that it's not gonna be a waste of time. (Emerald / Amy advisor interview 1)

Here Amy notes that the trip is worthwhile to her if the teams prepare reasonably good quality projects, it is not going just for the sake of going; she wants them to show some good work for it.

On the other hand, advisors recognize that their desire to see students succeed does not justify overly hands-on involvement in project work. As Nils observed:

Nils: in a perfect world if I had more time, I guess, like, but at the same time I don't wanna invest too much in their outcome, it's their thing, so I think that...what they did is fair for what they've put in, too, you know. Of course I would have loved to see them do better, and I could've helped them do better, I think, I think I could've helped them do better by...you know, pushing them along sooner, um, maybe a little bit more legwork for them, but...

AM: But would you actually...

Nils: No. [...] Coulda and woulda...coulda done a lot more, don't know that I would have, because...not my contest. (Malachite / Nils advisor interview 3)

Another comment underscores Nils's recognition that having a more hands-on role could make the project more competitive. At the same time, the comment signals an implicit trade-off, suggesting that it might violate a certain principle and shortchange the students. If winning requires more of advisor's "fingerprints" on the project, then it is not worth the trade.

AM: How would you describe your role on the team? What are your goals as an advisor, and what kinds of project activities were you involved in?

Nils: okay, yeah, so my role...I tried to keep it just as scaffolding; I didn't want my fingerprint to be on it really...to much...

AM: why not?

Nils: because I wasn't competing [chuckles] and I didn't think it was all about winning it; you know, I was trying to motivate them with the cash and all that kind of stuff, but I knew that just getting to WSU would be a huge thing for a lot of these kids; they might not get to a college campus, and just being on a campus might let them realize, hey this is doable, I can manage to get here and be part of this kind of thing sometime. (Malachite / Nils advisor interview 1)

For both advisors, participation in IT was not about producing the most competitive project and winning an award for it (although that would not hurt; another quote by Nils presented later in this section confirms that he is in fact quite passionate about seeing students produce high-quality projects). Neither was it about doing the bare minimum just for the sake of the trip. It was about striking a balance between these extremes, by helping students complete a project of reasonable quality without playing too central of a role along the way.

I interpret the above comments by both advisors as signaling their recognition that the responsibility for producing quality projects falls on the students. This is consistent with the intent and fundamental assumption of the competition that the projects that are presented reflect predominantly the accomplishments of high school students rather than their adult advisors or mentors. This confirms that advisors should play peripheral rather than central roles on the teams and in the design process. This interpretation is reflected in the conceptual representation of the contradiction between the completed project as *object*, and advisor role as related to the *rules*.

The students were also aware of aspects of project work where the teams could have used additional support. Ben, a student on the EHS team, had this to say:

AM: How do you feel about the amount of assistance you got?

Ben: I'd say it was good. Or we could--maybe a little more...A little more structure would've been nice.

AM: can you clarify a little bit? What would more structure look like?

Ben: I wish she would've given us more direction on what we should be doing...like and how to start and wher--like yeah I don't know, so we only did like...for the first couple

months we only did like monthly meetings, and then it was just like, 'Okay do you guys have any ideas for your project?' And I feel like we weren't doing anything for the longest time, and then eventually it got to where it was like a month left, and she was like, 'Okay. What are you guys doing?' and we just started going on it, because we HAD TO...so. (Emerald / Bobby individual interview)

At the same time the students recognized the flipside of greater advisor involvement:

Ben: Ms. [advisor's name] gave us some guidelines, but...she...it kind of more like 'good luck,' which I think was good because it...made it so we had to actually work for it. Cause I mean she could've done everything and handed it to us, but we had to work for it...so that I feel like...I feel more accomplished from it. (Emerald / Ben interview)

The leader of the EHS team, Kara, reflected on the extent of advisor's support as follows:

AM: [How do you feel about] how much the advisor helped with different tasks, or the [amount of] information that [the advisor] provided?

Kara: At first I was kind of...'Ehh...!' cause I felt like [the advisor] wasn't really doing much. But now that I think about it, [the advisor] did help us by not doing much. [laughs]

AM: What do you mean by that?

Kara: Oh, we--we had to think farther instead--'cause--hmm--it's...like we had to think of a...like teachers usually think of a course, like a lesson plan, and students follow. But this--with the project it was like the students thought of the lesson plan and followed it ourselves, and got the end result...and then so we learned that process, but also learned about the environment and all that. So...by [the advisor] not being there to try to guide us, we learned how to guide ourselves...yeah. (Emerald / Kara interview)

How did the advisors help structure project work without doing the work *for* the students? To reconcile this contradiction, advisors tried to navigate a middle path between hands-off detachment that risks runaway projects that don't get finished, and excessive hands-on help that risks robbing students of opportunities to learn from their mistakes and develop their skills. The advisors used a number of strategies to find the appropriate balance of involvement and detachment with projects.

## Goals and Strategies

**1.a.1. Ensuring timely progress.** One important goal was ensuring that students make regular progress on their projects. The strategies used to achieve this goal were regular status checks and meeting facilitation.

Regular status checks may seem trivial but were in fact a powerful strategy that served multiple purposes. Here is how Nils described how he went about it:

I've been more organized in terms of...keeping track, you know, sending them a note, or walking around: "Are you still participating? How's your idea coming? Make sure you come this/next science club." 'Cause even though I put announcements into bulletin, they may not hear them. So just [being] more proactive. (Malachite / Nils advisor interview 2)

Besides helping advisors stay abreast of project status, which aided the advisor's planning on the administrative side, reaching out to the teams also provided a motivational nudge. It communicated to the students that their projects mattered to the advisor, and reduced the chances that they could easily get away with little progress. Sometimes catching up with the students required a little legwork – for instance, Nils talked about how he would find out the classroom where a particular student was during a given period, and then walk over and catch them on the way to or from class. There is no evidence in the data to indicate that students were put off by such practices.

Meeting facilitation refers to the advisor arranging meetings where IT project teams could catch up with the advisor and each other regarding their projects. Here is how Amy described her planned IT meetings:

So right now we've got like 12 ideas on the board, and so once they come back from break and they have it narrowed down, they'll write their names on the board, they'll exchange email addresses and phone numbers, start communicating with one

another...and every Wednesday that we meet after that, it is more of a check-in for me.  
(Emerald / Amy advisor interview 1)

The meetings provided additional opportunities for status checks but also were an attempt to infuse some regularity and structure in the process of project work. In contrast to occasional check-ins between classes with individual students, meetings provided a warrant for all students to come together at the same time and in one place, typically the advisor's classroom. This was a precious chance, considering students' busy academic and extracurricular schedules. I discuss the role of team meetings in more detail in response to research question 3.

**1.a.2. Ensuring high standards.** Holding projects to a reasonably high standard was another priority for advisors. They accomplished this by providing feedback and invoking quality criteria.

Providing feedback refers to making suggestions that have direct and tangible impact on the project's content. Two types of feedback were observed, specific and open-ended. Specific feedback includes suggestions like ideas about project topic during initial brainstorming, edits made to a student-designed survey instrument, or edits to an email to an external stakeholder pre-drafted by the team leader. As one example, when Nils pointed out the lack of a comprehensive recycling and composting program at their school, the focal team took up the issue and gradually focused the topic on the composting aspect.

Open-ended feedback involved asking open-ended questions that oriented students toward issues, tasks, or approaches they may not have considered. Amy framed her role in this regard as follows:

I mentor in the fact that I will always ask them questions, I never want to just say, 'oh that looks great'; my job ideal, my job like a classroom teacher, I'm always questioning them about the way they compete, about how things can be done better: 'well this is a very interesting setup why did you choose to set it up like this? Did you consider this? Why not?' It's always a role of questions to lead their [...] thinking. I think that helps kids, that's how I structure my classroom I never just want to say 'you're right, let's keep moving.'

I mean all these things that they don't think about, but maybe as a \*mom\*, it's just me, I'm just this over-planner; maybe the teacher; I don't know, but I just...I identify those things that kids just don't think about. [chuckles] Yeah, the mom comes out. 'Well did you think about how this would affect this? Did you think about how this person would be inconvenienced by...?' [laughs] -- you know, I try and pose those questions in a way that they don't get intimidated, and they don't get discouraged, but in the same way they're like, 'Oh, thanks, we never did think of it that way.' (Emerald / Amy advisor interview 1, 3)

In summary, specific feedback gave students concrete details or information; open-ended feedback gave students more questions to think about. As the following comment by Nils suggests, sometimes these types of feedback were integrated in advisor's communication with the team:

I'm more just...a pesterer, you know -- "how are you doing on it," -- I'm not gonna do it FOR you, but if you got an idea, and I've seen something in the paper, I might cut it out, might hand it their way, might say 'hey did you check out this, or did you search for this term?' (Malachite / Nils advisor interview 2)

The strategy of invoking quality criteria refers to the carryover of the advisors' epistemic notions of high-quality research into project work. These criteria were not derived from the IT competition criteria (the judging rubric) but reflected the advisors' own internalized disciplinary standards for high school-level science-related projects. In this regard both advisors emphasized the importance of doing research and using primary data. This comment by Nils (referring to a non-focal team) is illustrative of his mindset concerning project quality:

I tried to send them a note with some search terms, like...[A: that's the third team?]-yeah, the third team -- building technology and stuff, things that they would wanna look up.

[A: like things to search on?]-KEYWORDS, yeah, I know it seems simple, but they may not realize things that are out there, you know - 'look this up, see what you find there, and...' - just to keep 'em rollin.' 'Cause some of it, I just...I'm dreading seeing a model city piece of crap type of thing, you know, where it's like milk jugs, and this and that making a city, and it just doesn't look like high-school super-sweet work; I'd rather see them focus on one building, is where I sort of tried to...see if they wanna focus on that, 'cause it's SMALLER, and you can do a lot of research just on that, rather than a whole city of... [...] rather than, 'here's SOME good ideas in the midst of a fifth-grade art project, you know, [laughs] with, with fake trees here, like...that's more an ART project, rather than a SCIENCE RESEARCH, build a small model of--or DRAW, JUST DRAW, don't build it-that's too hard-that's an architecture UW thing to make it look really good [refers to a high-quality model]-- but DRAW it-we've got great technology to be able to do that, and large-scale printers and stuff, it could look really flash; and that with the research to back it up could be a decent contender. (Malachite / Nils advisor interview 2)

Nils's comment surfaces another consideration that pertains to quality standards, namely, project scope. I discuss the issue of scope definition in more detail later on. The key point here is that Nils associates project quality with the ability to conduct comprehensive research by gathering information. This premise determines the feedback he provides, such as resources and information which he hopes the students will pick up and which will stimulate their thinking on the subject.

For Amy, project quality was also directly associated with the quality of the research, but she tended to place more emphasis on the role of primary data in the research process:

Last year that's what our teams lacked; I kept telling them, that you know, numbers say everything – you need to have numbers in your project; so find a way to collect data, report on it; explain why the data works, or why it doesn't work, how you would go back and do it differently, and...that's for me, last year was my eye-opening experience in that I saw kids had no idea how to collect data, no idea. (Emerald / Amy advisor interview 1)

**Gaps in ensuring high standards.** There were three apparent gaps in both advisors' approaches to ensuring high standards for project quality. First, insufficient attention was given to the formal project evaluation criteria represented by the judging rubric. Amy mentioned that she had shared the rubric with the students early in the design process. However, interviews with

the EHS team revealed a rather superficial understanding of the rubric criteria, and no evidence was found of purposeful and systematic mapping of project elements to these criteria. In turn, Nils did not appear to be aware of the formal evaluation criteria until after the competition, and interview data suggested that the MHS team had not systematically referenced the criteria as part of their project work.

Simulating the IT experience through mock presentations would have provided opportunities producing a more polished presentation. However, advance practice with presentations was not sufficiently prioritized to allow teams to work it into their project schedules. As a result, although both advisors mentioned initial plans to have the teams practice their presentations ahead of the competition, these plans failed to materialize. Both teams were at their busiest in the days leading up to the competition and finalized their presentation displays the day before their departure, leaving no time for practice.

Finally, the advisors did not seem to take advantage of opportunities to iteratively refine and improve projects through project extensions beyond the competition timeframe. Both of teams' projects featured plans for extending project work into the following school year, focusing on the implementation of the composting programs that had been designed for the current year's competition. Although the advisors were accommodating with regard to these plans, the plans had remained as such, and neither project was in fact extended and implemented during the following year. The resulting *discontinuity* in project work short-circuited the feedback-revision cycle that could have been possible if more thought was given by the advisors on ways to sustain projects from one school year to another and reinvest the knowledge capital accumulated by the teams through their competition experience.

**1.a.3. Catalyzing project work.** Certain forms of advising support also had the effect of stimulating or catalyzing project work. One such practice involved support of the teams' networking with external stakeholders and subject matter experts. (By "external" I mean adults outside of the project team, whom the students typically did not know, or had not interacted with extensively in the past.) Reaching out to such individuals tended to release the teams from a holding pattern of inaction at the early stages of project work, and set them on a productive path. Getting in touch with experienced professionals was a form of information gathering that students engaged in as part of their design activities. In particular, advisors helped students identify individuals with decision-making authority who could be impacted by the project (I refer to them as project stakeholders) as well as subject matter experts (SMEs) in the community who may serve as sources of relevant information. The facilitation ranged from giving students referrals to helping locate contact information, and to arranging meetings. The following quote illustrates Amy's approach of helping students reach out to experienced professionals:

AM: In terms of your role, can you talk about how you see yourself?

Amy: Um, I let my students know right off the bat during our idea share meetings that I am not an expert on any of these subjects, I am only an expert... "expert" – that's a loose term – in how this competition works. And I tell them that I would be happy to help them to find professional advisors out in the working world to help them with their project; [...] I just kinda provide a connection, I am a little bit of a liaison; [...] but I don't... I don't do anything except provide the organization to get them there. (Emerald / Amy advisor interview 1)

Nils also assisted students with identifying individuals who could be good sources of information. For example, when students were trying to obtain data about the amount of water bottles and cans used at the school, he sent them contact information for a vending machine supplier. In addition to providing referrals, Nils also facilitated a meeting with the school principal to ensure students had an opportunity to ask their questions:

I setup the meeting with the principal and said OK, here's we've scheduled time, he's available, let's go and talk to him, and I just...wanted to make sure I was there, so they weren't super intimidated...because it depends on the day what mood he's in...yeah he's not always consistent...so some days he's super happy go lucky, the next day he's like ultra stressed, and it comes out in his mood. So I didn't want him to take that out on students, and shoot down their idea when they had a good idea – so I just played moderator there...and it worked out well, so they were well received.

Such support of students' "networking" catalyzed project work for several reasons. The teams' ideas were usually received with enthusiasm by the stakeholders and SMEs, leaving students encouraged and motivated to persist in their efforts. Also, such interaction usually resulted in students walking away with information they had not considered before, which clarified their understanding of the issues and suggested fruitful directions for further work. This transition toward greater focus is evident in the following quote by Kara:

We had to talk to a lot of people to get to...that guy in charge of the department of maintenance and operations, and \*once we met with them\* it really kicked off, because we...at--after that meeting we really knew what we wanted to do. (Emerald / Kara interview)

The meetings with external stakeholders helped reduce the uncertainty and untangle the knot of the different "what if" ideas regarding the projects that the teams had by showing which course of action seemed most useful *to these stakeholders*. The result was alignment of the teams' agendas with the agendas of the larger systems within which the teams operated, such as the school or the school district. Conceptually, these kinds of "informational interviews" became the *tools* or *mediating artifacts* in the project activity system, positioned between the *subject* (team) and the *object* (completed presentation). This helped untie the knot of ideas and see the path to realizing the project goals. In this way, interaction with the stakeholders and SMEs may be considered an enabler of *expansive transformation* of the project activity system that may

have been stuck in hypothetical brainstorming, by aligning it with the activity framework of the larger system.

### **Summary of Contradiction 1.a. Advisor Support: Balancing hands-on vs. hands-off involvement**

The goals and strategies advisors have used to support students' project work may be placed in two categories: process-oriented and content-oriented. These categories are interrelated and overlapping and do not reflect a clear-cut division but rather the area where impact is most direct. Process-oriented goals include ensuring timely progress and catalyzing project work. These goals are associated with process-oriented strategies of regular status checks, meeting facilitation, and facilitation of networking with external stakeholders and SMEs. The goal of ensuring high standards involves the content-oriented strategy of providing feedback and the process-and-content-oriented strategy of invoking quality criteria. The predominant process orientation of advisors' approach points to indirect impact on the finished project by supporting the teams' design process rather than direct input into the production of the final product.

There are common characteristics among the goals and strategies associated with balancing the extent of advisor involvement in project activities. In general, the advisors appear to play an *enabling* support function. They focused on providing resources and information such as meeting facilities and networking leads, which helped with the "how" of project work but, for the most part, stopped short of actually doing the work for the students. The working distinction appears to be between enabling students to do things and actually doing things for them. This allowed reconciling the contradiction in question. I label this approach "enabling agency."

The enabling role of advisors may be interpreted as provision of *tools* for the project activity system where the students are the *subjects* expected to use them. The process is that of

transfer: the sharing or transferring of practices, resources, and information. The *tools* advisors transferred to the teams were the practices they considered value-adding (e.g., Amy's emphasis on scientific practices prioritizing the use of primary data). The transfer was premised on the expectation that the tools would be used – that students would take up and repurpose the practices, resources, and the information provided to them. The advisors may be characterized as hands-on in their enabling-transferring role, and hands-off in the application of the transferred tools.

**Trajectories of practice.** The advisors' approach may be characterized on a trajectory of practice in the context of the project activity system as movement from a less to a more structured process (upward along the vertical axis in Figure 12). An illustrative quote comes from an interview with Nils, who described how his approach in the current year would be different based on lessons learned from the first IT experience of the previous year:

The students, how they got it together: wait, wait, wait, wait, wait, last minute: 'oh my goodness it's gonna be next week...let's get it done,' then they finally made it happen. This year I'm gonna be pushin, pushin, pushin a lot sooner, and giving them opportunities to meet, and almost requiring them as much as I can, you know, I can't...pull them by the nose, but, 'we're meeting,' providing doughnuts, providing snacks, 'let's get together...'. (Malachite / Nils advisor interview 1)

In particular, the strategies of regular status checks and meeting facilitation, aimed at ensuring timely progress, may be considered an attempt to pull teams from the less structured, out-of-school time context closer toward the more formal, classroom-based PBL context where project work happens at regular intervals and the advisor (as teacher) is on hand to monitor and guide the work.

### 1.b. Project Context: Emergent vs. existing activity systems

Another contradiction deals with achieving structural congruence between the project activity system and other activity systems external to the project. It stems from the difficulty of completing the project without established spaces, norms, and routines for organizing project work (Figure 14).

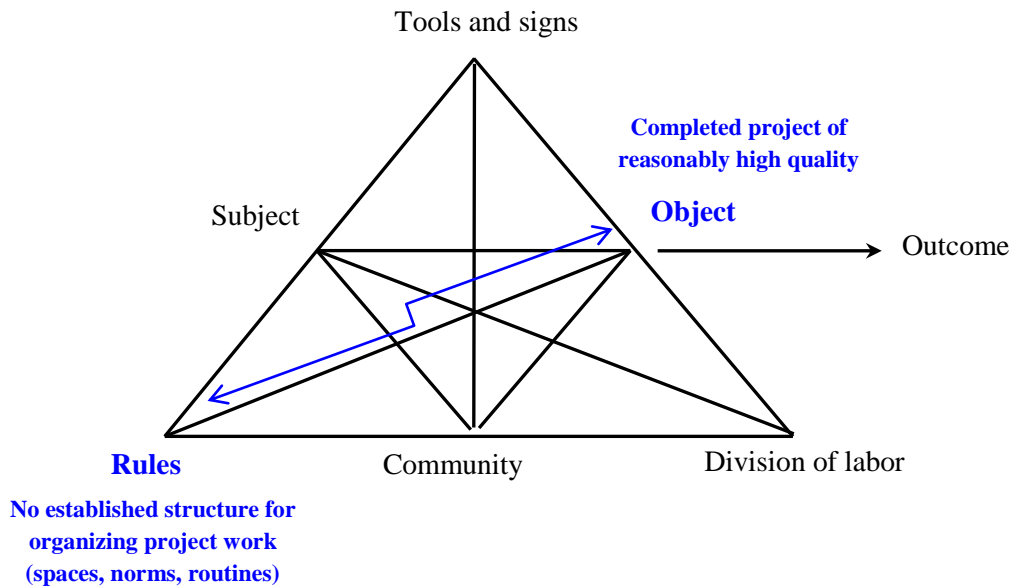


Figure 14. Contradiction 1.b. Completed project of reasonably high quality (Object) vs. no established structure for organizing project work (Rules)

The IT competition rules do not specify the structure of project work besides requiring that participants should be high school-age students, and that teams should have two to five members and an advisor. The project work may or may not be integrated into the curriculum. When students participate in IT as part of a class, classroom time is typically allocated for project work, including group work on the different phases of the design process. When there is no class associated with the competition as in this study, project work happens in out-of-school time (OST) settings. This typically means there is no pre-existing structure for how the project

work is organized: where, when, and under what circumstances it takes place. This may be viewed as a general *rule* of IT participation in OST settings: the participants need to create a new structure for project work, i.e. a project activity system. One part of this structure is project space, by which I mean the physical sites as well as administrative or other formal, norm or rule-based structural arrangements for engaging in project work. Other parts are the rules and conditions which follow from the OST format of the project work and represent constraints and affordances for how this work happens.

In the preceding section, I discussed how advisors supported the creation of emergent project structures through meeting facilitation. The various ways teams came together in meetings and the role of these meetings in structuring project work are described in more detail in the section on RQ3, below. In brief, advisors created structural scaffolds which approximated in-class, PBL-like project work by arranging regular meetings for IT participants in their classrooms. In turn, the students arranged meetings in different locations and used opportunities when they intersected in school (e.g. during a shared class or lunch period) to share ideas, give status updates, and confirm next steps. The following segment from a group interview with the EHS team reflects this practice:

AM: Where would one need to be physically present to see the interaction through which you guys make progress together?

Kara: Our group meetings...

Seth: That's the obvious one, right...

Kara: yeah...

Seth: I would say [the class for the competitive music group] we've discussed things in...

AM: You mean, before or after or...

Seth: during.

Kara: [laughs]

AM: So you find times...which happens to be [the class for the competitive music group]...

Kara: we're all in it...

Seth: We're all seated near each other kind of, so we can...

AM: touch base?

Seth: right. (Emerald group interview 2)

This example suggests that creation of a space where project work happened was not achieved through isolation or separation of project work from students' other activities and sites where these activities took place. One reason is that there was no project space to begin with; rather, it had to be created from scratch. This improvisation took place within the existing spaces such as classes, where the students saw their teammates over the course of the school day.

### **Goals and Strategies**

Creating a project activity system was an important goal for the students as well as the advisor, strategies for achieving which included adaptation of existing spaces and structures to the teams' needs and patterns of activity, and vice versa. The illustrative metaphor is not that of intrusion or carving out of one structure within another – which implies sharp delineation and contrast – but of overlaying or assimilation – flexible adaptation and alignment of the project activities alongside the existing contexts and communities in and beyond the schools. The form of such adaptation was determined in part by the project topic and scope of the solution the students proposed. A project that mostly influenced composting practices within the school (such as the Malachite team's project) was adapted accordingly to the school's structure whereas a project with broader boundaries at the district level (such as the Emerald team's project) had to be adapted to the structure of the district. In this discussion, these structures and spaces are viewed as existing activity systems.

**1.b.1. Creating a project activity system.** Both teams approached creating a project activity system by aligning team practices with existing contextual constraints and affordances, and vice versa – the accommodation of students' constraints and leveraging of their capabilities by the existing activity systems. Theoretically, constraints represent top-down structural

pressures which narrow students' opportunities for agentic activity. The affordances represent structural elements which expand opportunities for bottom-up, student-directed project work. In practice, however, a perceived constraint may become an affordance, depending on how it is used. I found this determination problematic because it risked excessive interpretation and "reading into" the data. For instance, the advisor-team meetings in the advisor's classroom may be interpreted as a constraint on project work in terms of limiting students' activities in accordance with the advisor's agenda, expectations, and classroom norms. On the other hand, these meetings may be perceived as an affordance of the school activity system, enabling project work with various resources. Thus a particular structural element may constrain or enable project work. The key is whether the team is able to leverage these constraints and affordances in ways that facilitated project completion.

An important point for this discussion is that the students were neither constrained to work in specific ways nor were they completely free to organize their work however they wanted, if they wanted to complete the project. Between these opposite poles were possibilities for structuring the work in certain ways which either facilitated or impeded effective project work. This structuring resulted in the emergence of the project activity system. I argue that the nascent activity systems that developed did facilitate project completion, and that this development was catalyzed by adaptation to and alignment with the existing activity systems.

Several examples illustrate how the IT project activity systems emerged alongside the existing school and district activity systems. Although how exactly this happened varied across the teams and advisors, the common result was the emergence of project activity systems through leveraging of available spaces, resources, and practices. By repurposing and adapting the

tools, rules, and other components of the larger, more formal and stable systems, project activity systems gained these elements and came into being.

At EHS, Kara used her IT project as part of her Culminating Exhibition (CE). This allowed her to leverage several resources which she otherwise may not have been able to access. First, she was able to use study time and classroom space during her CE senior seminar to catch up on her (individual) project-related work. In addition, students working on their CE were expected to have a mentor, typically a working professional in the community. Amy worked with another teacher to locate a mentor for Kara, who was knowledgeable in an area related to the IT project. She mentioned that when answering an interview question about her advising role in the context of IT:

[Kara's] teacher for her senior seminar who she's doing this [Imagine Tomorrow] project through during that class, has been emailing me and asking me questions to provide...together the two of us a direction that she can go in as far as, an outside mentor; your senior seminar class is taught by a teacher, but you have to find an outside professional mentor; so I believe that her mentor is in a LEED certification guild for architectural design, so she's going that route. And so once I knew that [Kara] was on the right path and working with her mentor through her senior seminar I felt good to just kind of let go a little bit and just ask them questions when I saw them in class, hey how is it going, talk with so and so, um, and they seemed to be running OK. (Emerald / Amy advisor interview 2)

When I asked Kara about the advisor's impact on the project, she also noted Amy's assistance with finding a mentor:

AM: what did [the advisor] do that had an impact on the project?

Kara: [...] finding me a mentor, a good mentor...that was...that I could reach conveniently. AM: is he local?

Kara: uhum.

AM: how did you interact with him...

Kara: um, mostly through email, and then I met with him twice, and he is right in [city where the school is located], so...that was easy to get to. [...]

AM: And in two words, who is your mentor?

Kara: He is an engineer, and a father of my friends; he works for McKinstry, it's a...I think, green company that build...or works on infrastructure and all that.

AM: So where did he come in, in what context is he your mentor? In the context of the competition or the CE?

Kara: The CE, yeah. I had to get a mentor for CE, and I had based my mentor off of the Imagine Tomorrow project; cause at first I thought we were gonna work on infrastructure, not composting, so [advisor] [...] said 'Oh Mr. [name]' -- who...his wife is a teacher at the school she is one of my favorite teachers -- she said he is LEED certified...I think...and he works with civil engineering, McKinstry and all that...[...]

AM: as a contact for the CE?

Kara: uhum.

AM: not for Imagine Tomorrow?

Kara: hmm...oh well she knew that I needed a mentor, but she knew that I wanted a mentor that would be able to help me with the Imagine Tomorrow project, or give me some assistance, so...she thought about that both and said Mr. [name] would be a good choice. And then so I talked about him to my CE teacher and she approved; it...he was a really good choice, because he...I mean he is into the whole environment thing, but he is also...he...does presentations...so...teaching and communication...he could teach me about as well...and he was...he--or he is the vice president of project managing I think...so he is also a leader, so he covered those three parts that I wanted to work on. (Emerald / Kara interview)

This example illustrates concurrent adaptation of the project activity system based on *rules*, *tools*, and *community*. The *rule* that students working on their CE projects should have mentors was adapted for the purposes of finding an external SME to help guide (in this case, through Kara) the IT project. The mentor himself became the *tool* that was reused for both CE and IT purposes. His willingness to mentor Kara in the context of CE and the IT competition represented *community* support for project activity. This adaptation was, on one hand, the result of a systemic *constraint* – the requirement to have an outside mentor for CE work. On the other hand, it was enabled by the *affordance* of the school system to allow dovetailing CE work with participation in IT.

The example above suggests one condition that was important to the emergence of project activity systems in out-of-class settings that facilitated project completion. This condition is a property of the context, and refers to the flexibility of the relevant existing activity systems to accommodate different goals and patterns of students' project-related activities. For instance, if the CE requirements were more rigid and required 100% individual project work, it would have prevented alignment between the project and the school activity system in this particular way. As a result, Kara may have been unable to participate in the competition, or to enlist her CE mentor's help in her leadership role on the IT project. Also, the final choice of somebody who ended up being a great fit for Kara may not have been possible without the commitment of her teachers (who are *subjects* in the school activity system) to adapt to *her* constraint of a locally based mentor.

An example from the MHS team illustrates another important condition for the emergence of project activity systems in out-of-class settings that facilitated project completion. This condition is a property of the individuals, in this case, the students. It refers to the students' flexibility in their ideas, practices, and goals, which enabled adjusting to the constraints, as well as identifying and leveraging the affordances of existing activity systems.

There were numerous instances where such flexibility proved essential for catalyzing and sustaining project work. Numerous extracurricular activities created busy schedules, making it difficult for all students to consistently attend team project meetings. By finding opportunities for frequent, brief check-ins during and between classes, in study periods, and at lunch during the school day, the students were able to remain up-to-date and coordinated in their activities. The students' understanding of their projects deepened, and project plans often had to be modified following meetings with project stakeholders and SMEs. Without willingness to make such

course corrections based on the experts' feedback, students would have been unable to take advantage of these resources in their schools, school districts, and local communities. For example, the EHS team's plan to create a student council was based on an idea suggested by the school district maintenance department staff. For the MHS team, meeting with the principal uncovered limitations on surveying students during classes, prompting the team to revise its approach and opt for lunchtime interviews.

One particular example from the MHS team highlights the importance of the students' willingness to adapt to the constraints of the existing activity systems. On that team, all students except Becky were familiar with their advisor, Nils as students in his class or members in the Science Club. This made Becky uncomfortable with the prospect of joining team meetings with Nils in his classroom, especially when they also overlapped with Science Club activities. Here is how she describes her experiences in this regard:

AM: Were there any interactions or relationships that you feel really shaped or had an impact on your experience of the project?

Becky: Kind of mine and [advisor]. I skipped physical science as a freshman, and he \*teaches\* physical science, and so...I never had him or knew him as a teacher before this... so I...heard about him a little bit from Molly and Gillian, but I didn't know him at all...and, um...and so sometimes there was a...I don't know...getting...to knowing him, especially cause he was like our...\*adult figure\* in this project, and he's who we got our information from and stuff, so...as far as the project I think...at first it was kind of...a little bit of a deterrent for me, cause it was a little...I don't know, you know, weird...working...working kind of under...or in this teacher's classroom who I'd never really met...

AM: whom you don't know...

Becky: yeah...and...it helped that I did a lot of...or that I was kind of...part of meetings outside of science club, or outside of [advisor's] classroom, so when I came in, like, I had some kind of like grounding and connection...but then afterwards, like I...getting to know him and stuff...I...made it...

[...] I don't know if I would necessarily have been as interested to go into the project with a teacher I didn't know...with groups I...with people I didn't know...in that club I didn't know...and so that having that -- in a project I didn't know -- so having that connection

with Molly and Gillian, and then also having already kind of volunteered information for their project, made it easier to go into that situation. (Malachite / Becky interview)

This example highlights the importance of students' proactive approach to navigating the existing activity systems – in this case, the systems of Nils's classroom and of the Science Club. Although Becky felt uncomfortable entering that project space, she was able to change her perception and step into the slightly unfamiliar territory. In her case, this move represented transitioning from semi-legitimate peripheral participation in her team's project activity system toward central participation, and paved the way for officially joining the team and participating in IT.

Although being unfamiliar with a teacher who happens to also be the team's advisor may seem like a low barrier to participation, Becky's comments show that this barrier may be higher for some students than others. This is corroborated by the following comment by Kara:

AM: Was there anything else about [advisor] that she did that had an impact on the project, how the project worked out, the process?

Kara: When I was not happy with my group, so I talked to her...she gave me a few tips...so I guess for moral...not moral support but...to help me with my own problems so that I could smoothly work with my other...team members...she kind of helped out with. She is also my science teacher, a second year with her, so I kinda...I guess...she's easy to be with. So in that sense I liked how easy going it was. (Emerald / Kara interview)

This quote indicates that for Kara having past experience with Amy as a teacher was an important factor which had an impact on her experience on the project, contributing to Kara's willingness to share concerns and seek help from Amy regarding some challenges with leading her team.

Overall, this analysis suggests that the emergence of a project activity system was not a passive endeavor but a proactive and intention process of adapting to contextual conditions. It

was a dynamic process of co-regulation and adaptation to mutual affordances and constraints between the project's participants and context. Otherwise, effective reconciliation of the top-down structural constraints and affordances of the existing activity systems with the teams' bottom-up ideas, practices, and goals would not have been likely. It may be hypothesized that gaps between these two trajectories would have created impasses in the collaborative design practice, thus stalling or delaying project completion. The next section addresses another tension in the project.

### **Tension 2: Completing Project vs. Experiencing Competition**

The second tension depicted in Figure 12 (the horizontal dimension) is associated with the constraints which frame students' activities in relation to participation in IT in out-of-class settings. Students engage in project work under a variety of constraints. Some of these pertain specifically to project-related tasks while others frame their overall approach to the competition. For instance, constraints associated with the activities of working on the project include having to make timely progress on tasks and having to meet certain competition standards. Constraints associated with the more general approach to "doing the competition" include balancing project work with other commitments, being interested in the project topic, and prioritizing tasks that one enjoys or feels more competent about. These factors may appear non-essential for completing a project, but when one or more of them are not met, progress on the project might suffer. (The "completed project" in this discussion refers to what is presented at the competition, which may differ from the end-goals for the project, such as bringing a product to market or implementing a program at a school.)

I categorize students' activities in the context of IT into two "activity frames." Each activity frame is characterized by its own set of constraints and affordances. These activity

frames are associated with two types of goals: the “local,” more specific and explicit goal of completing and presenting a project of reasonably high quality and the “global,” more general and implicit goal of having a certain kind of experience with IT. Experiencing IT in a certain way may include the goal of completing a project but may also connect to various other individual and collective goals, meanings, and values associated with the competition, which may “interact” with the goal of project completion and occasionally take precedence. At the same time, the full breadth of the students’ experience in the competition is contingent on their ability to complete and present a project. Contradictions stem from the different constraints and affordances of the activity frames associated with each goal. Representing this tension in terms of activity frames makes a broader distinction than what I initially hypothesized. It focuses the analysis not on the differences between specific goals, but on the constraints and affordances which frame activities tied to these goals. In this section I present several contradictions and the related goals and strategies that may reflect ways of managing these contradictions.

### **2.a. CDP: Balancing project work with constraints**

Within the project activity system, the activity frame of project completion may be described as *object-oriented* while the activity frame of experiencing IT may be described as *rule-oriented*. Here, the *object* is the completed project which involves the actions students perform to produce tangible results such as data, documents, presentation visuals, and (if they get to it) the implementation of new composting practices at their schools. The *rules* refer to the explicit and implicit conditions and norms that constrain actions within the activity system (Engeström, 1990, p.79). A general contradiction related to the students’ *collaborative design practice* involves balancing the efforts aimed at completing the project with the constraints framing their actions.

*General contradiction: completing project of reasonably high quality (Object) vs. accommodating constraints for engagement in project work (Rules)*

## **Goals and Strategies**

Completing a project may be reframed as establishing a systematic process for engaging in collaborative design practice. This does not refer to a particular order of steps in the design process or the need to always meet in the same place at the same time (although that might work well in some cases). In the OST settings, these goals are likely to be unrealistic and may excessively limit and ultimately undermine the design process. On the other hand, the activities of project management, decision-making, communication, and collaboration require a degree of coordination of the team members' approaches to going about the project. For instance, if someone does not check their email or return phone calls, communication suffers. If someone is unreliable in performing tasks, project management is impacted. In the end, the CDP is less effective. Effective CDP refers to a process that enables/facilitates project completion under constraints. The constraints are inter-connected factors that check students' capabilities with regard to effective project work, thus problematizing project completion. A number of specific contradictions that emerged from the data analysis are detailed below, including the relevant goals, constraints, and strategies for making progress on the project.

### **2.a.1. Balancing feasibility with interest, ambitions, and skills**

An important goal for ensuring project completion involved balancing student interest, ambitions, and skills with the feasibility of the project. This goal reflects a contradiction between the *object* and the *rules* in the project activity system (Figure 15).

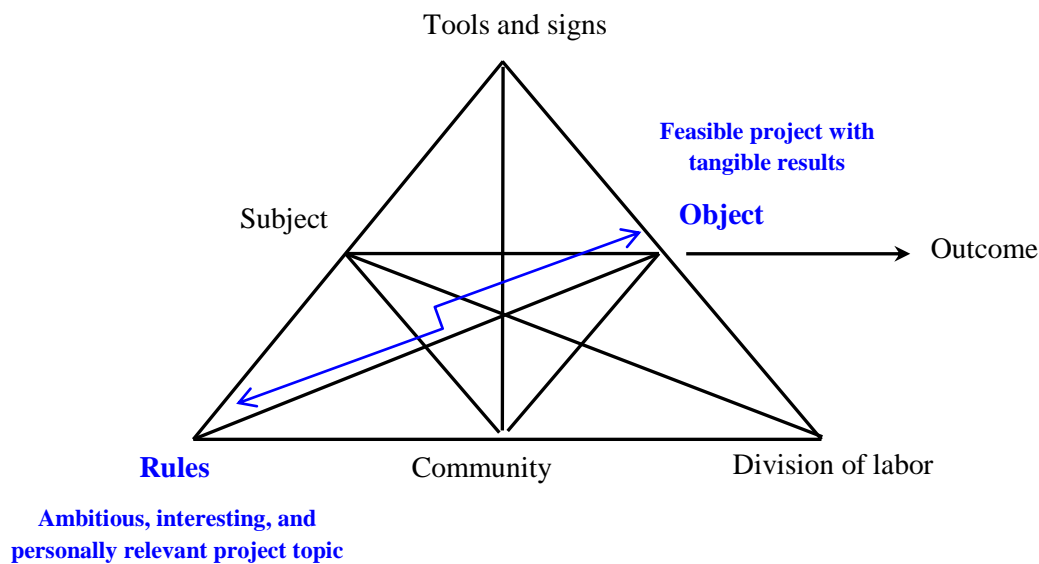


Figure 15. Contradiction 2.a.1. Feasible project with tangible results (Object) vs. ambitious, interesting, and personally relevant project topic (Rules)

Interest came up in the interviews as one of the main factors in guiding the choice of project topic. Reflecting upon the focal team’s choice of project topic, Nils summarized this as follows:

Nils: I would think it’s not just that they can’t handle this or that, because...I know that they’re bright enough to look into whatever they don’t know, so if they wanted to put something together; I think it’s more interest - they’re interested in, you know, that idea of, you know, we could do something, that impacts something here at the school, and they could see the change it produces; versus, you know, make a little widget that does something, and...YEAH, if you went through five years of patents and stuff you might get it produced, but...you know, getting a recycling and composting program incorporated -- you might see it done before you’re out of school, you know. So...could

make a more IMMEDIATE difference I think for them... (Malachite / Nils advisor interview 2)

Nils's perception of students' interest in a locally situated project resonated with Gillian's recollection of how her team latched onto the idea of looking at the recycling and composting practices at their school:

Gillian: Well, [Molly] is...I think I said this earlier, but she always wants to be environmentally friendly, like she uses...reusable water bottles, and...reusable plastic containers instead of ziploc bags and stuff, and she always recycles, and she probably would compost if she didn't live in such a residential area...and I think that she...she's like, "Well, what if we did it at school, that would be really good," and then she started to explain to [Dana] and I, because [Dana] wasn't on the team at the time, how that would work, and we thought that was a really great idea, too...it could help our school...and the environment, because then it would have less waste going out of the school... (Malachite / Gillian interview)

Similarly, on the EHS team, Kara had the following to say about her connection to their project:

Kara: For me I guess, I've been brought up to be very environmentally and economically conservative, like at church and at home when I was little, or not little I guess but younger, I would watch movies like, *Inconvenient Truth* by Al Gore, and...at church we'd do activities to clean up the outside or the inside, and so...\*our\* school, like [Seth] had said you can clearly see that we're not very good with our waste management and recycling, we don't even have much recycling I think -- I mean there are reasons to that but still -- I've always wanted to fix that, and then...so he sent out this idea of fixing the school up, and I thought 'Oh that's really cool,' cause I've really wanted to do this, and...it's really nice to be able to impact the school I guess, if this project succeeds. (Emerald group interview 1)

These comments suggest that interest in a given project idea did not arise from the idea itself, but came from the alignment between the project idea and the students' pre-existing interests, beliefs, and observations. The interview data suggest that both teams' project topics strongly aligned with the interests of all team members, and served to channel these interests.

On the other hand, interest or curiosity did not always lead teams to a feasible project. Sometimes students' early ideas were too broad and unwieldy. This resulted in a lack of focus and specificity with regard to next steps and tended to stall the transition from brainstorming to

action. Teams ran the risk of falling into a vicious cycle: lack of clarity meant not knowing what to do next, which contributed to procrastination, which in turn delayed clarification of the ideas.

This partly accounted for the dissolution of the team that Will had initially joined, prior to switching to the focal team:

AM: What's your sense of why it never really gelled together, why no one specific concrete idea crystallized over that period of time?

Will: [...] I think we were considering you know, solar panels in space and something like that, you know, while we saw that as neat and interesting, at the same time it's sort of like okay, that's nice but...do we actually have enough hard science [that] our group can actually...you know really make that a presentation... ultimately I mean, I think had we stuck to more realistic ideas and ideas that were closer to implementation, I feel we probably would've...we probably would've had something eventually. And I might've actually gone to the competition with that group, but as it was I feel that just simply sort of...our ideas were just...too outlandish. [...]and that was already compounding the fact that, you know just in retrospect, we weren't the best group in the first place: meetings were you know, 20 minutes of paging through Popular Science, and then an hour and a half playing Xbox...I mean that was literally our first meeting...we really lacked focus in any regard, and ultimately...it just collapsed. (Emerald / Will interview)

Also, when students happened to work on a project in which they were *not* particularly interested, chances were the project would be abandoned when the competition ended even if the students stayed with the competition in the following year. This happened to the MHS team in their previous year. When procrastination nearly caused the team to drop out, Nils intervened, helping students identify a realistic although not particularly interesting idea, and create a simple model of a renewable energy device using existing designs. In the current year, the team opted for a different idea, in part due to a lack of interest in the previous year's project, which had been selected primarily out of necessity.<sup>24</sup>

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<sup>24</sup> It is worth noting that neither of the teams in this study saw their projects through to implementation in the following year. Anecdotal feedback from the advisors indicates that, rather than switching to other topics, the students did not renew participation in the competition. The reasons behind these outcomes are beyond the scope of this study, but I briefly discuss them in the section on future research in the Discussion chapter.

Besides interest in making a difference in their school, another reason for choosing to develop a composting program for the MHS team was a lack of building skills and knowledge of engineering design. As Nils put it:

these girls tried last year on creating a hydroelectric downspout, they're not engineers and they are not really 'put it together' type of people; they recognize it and that's what they were saying themselves - that was difficult for them, and so they wanted to go something totally different, more people-sided...the study of people and their behavior. (Malachite / Nils advisor interview 2)

Becky corroborated this impression when she talked about a shortage of construction knowledge on the team in the context of building the compost bins for their latest project:

AM: What skills or experience do you wish you had, or were better at, that would have helped with the project?

Becky: I guess...one of the things we're looking at right now, cause we're...we actually wanna like, build these composting bins at our school, but nobody in our group really has any...construction experience at all...Or like, [...] kind of any idea how that aspect of it works...and so...that's one place where...yeah... (Malachite / Becky interview)

Finally, the chosen topics were ambitious in that the teams did not possess all of the relevant skills or knowledge from the outset. Molly and Gillian noted this when talking about the addition of Becky to the team:

Gillian: Katie, she joined this group like two months ago, only two months ago because we wanted her to be a part of our group, and she'd heard us talking about our project and was interested in it, so...she just joined our group later than...

Molly: and she was the only one who had any real background knowledge on composting...

Gillian: yeah

Molly: cause she does it at her house, so we wanted more of that, someone who's already done it and could help push the project along... (Malachite group interview 1)

More often than not, the students preferred to work on the projects during the team meetings where they could lean on one another for help with unclear or unfamiliar tasks.

In summary, the above comments suggest that interest was a key factor in the selection of the specific project topic. Moreover, the chosen topics were not only casually interesting but

personally relevant to the students on both teams. Although the dominant skills and abilities might influence the choice of the project category, students, nevertheless, opted for ambitious projects that required teamwork, learning, and some improvisation (such as adding new team members) to accomplish.

**Strategies.** To accommodate the constraints associated with how the students approached their projects, several strategies were used. I label these strategies “project-managing the interest.” The strategies are: considering the skills and knowledge needed for project work; converting ambiguous goals into specific objectives and tasks; and narrowing project scope.

Several examples of taking into account the skills and content knowledge needed to complete the project are provided above. In brief, this included the addition of Becky to the MHS team and recognition of the gap in construction skills when planning the building of the compost bin. Additional examples can be found on the EHS team. For instance, the students recognized that Seth’s communication skills helped him to effectively communicate with the judges and “put the best foot forward” in presenting the project. Although his teammates also took part in presenting to the judges, they let Seth take the lead role in these interactions. As Kara later recalled:

AM: What do you think was unique [that the team did] that others would not have been able to accomplish?

Kara: Umm...well Seth was definitely good at talking...that was good...so every judge felt flattered...not flattered but...they felt good talking to us...cause Seth kept an up tempo...positive feel, like a rhythm to our presentation; and then...Ben also had just little things he'd say, unique things that he would say to make the presentation a little more interesting; and then I guess I did the art part...the visual presentation and they liked that too, so...there're little things, what each person contributed made our presentation...it had a nice feeling to it. (Emerald / Kara interview)

Another strategy involved converting ambiguous ideas and goals into specific plans, breaking down tasks, defining objectives and milestones. The interview data suggest that the MHS team excelled at this more than the EHS team. Molly (the team leader) often talked about the planning work as a key aspect of the project and of her role in particular. Also, the students worked collaboratively at the start of project work (February) to map out and make explicit the plans and details of the project, thus clarifying and organizing the work. Here is how Gillian describes this process:

Gillian: We...went to...we went to the library and used the study room there cause there's a whiteboard and we drew out a big plan on the whiteboard, and then we have a study period time for about forty minutes on Tuesday, Wednesday and Thursday, and...Molly, Becky and I are...all in the same sixth period class, so we're all in the same study period, so we would talk about it a lot then...

AM: Ok. What was the plan, the whiteboard plan, what was it about and when did you do that?

Gillian: I think that was like our overall...big plan, everything we needed to do...we broke down each year into what we needed to do, like...we mostly broke down just what we needed to do for \*this\* year of the plan, and then we just wrote some little things on the second year, so we put like...for this year we wrote, "interview staff members" and then a list of all the people, and then..."survey students" and how we're gonna do it, and the website for our Survey Monkey...and everything and we just...we put all that up there, and then we were able to kind of see what was...what needed to be done. (Malachite / Gillian interview)

Finally, narrowing of the project scope was critical to ensuring feasibility of the design in relation to the various constraints so that the project could be completed with sufficient quality and within the allotted timeframe. The interviews suggested that this was a challenge for students, especially first-time IT participants. Nils described the experience of his students in the previous (first) year of IT as follows:

The kids threw around a lot of ideas for several science club meetings, there were students that were really interested in some wacky not very practical things, and when it came down to doing the research and yeah make a model of that, and stuff, they never did you know, they never put forth the effort; but these guys were interested in like a community type thing, and then their focus sort of changed last minute, um, like in the

last month or so...and we changed to something that they could get done. And...they procrastinated a lot, so for freshmen I think it was a big challenge, and they learned a lot in terms of what you gotta do to get the project done, and what the level is, too.

(Malachite / Nils advisor interview 1)

Nils's comment points to at least two issues mentioned earlier, which in combination create what I would call a "feasibility crisis." First, students may have a tendency to overshoot their capabilities for accomplishing particular types of activities – in particular, they may underestimate the amount of time and effort tasks require while overestimating their capacity with regard to the available time, level of persistence, and experience needed to get things done. Second, students tend to underspecify their design objectives and get stuck in brainstorming around ambiguous topics. Therefore, properly constraining the project scope, clarifying ambiguous aspects, and adjusting expectations for what may be realistically accomplished in a given timeframe are important ingredients for success.

For the projects in this study, narrowing project scope was associated with openness to extending the project beyond the timeframe of the current year's competition. Both teams faced the issue of insufficient time to implement their proposed composting programs. They resolved the "feasibility crisis" by stretching the projects over longer time horizons which narrowed the scope of what had to be achieved in the current competition year. Nils described this adjustment as follows:

Nils: They've come up with like a three-year plan on how to implement this...so this year is just the start - it's a HUGE endeavor to set up composting and water bottle recycling at a school, and they're recognizing that, and I think it's wise on their part to show the forethought of down the road, because you know they can make a big push now and fall on their face, but if they do it steady, have a LONGER term goal rather than 'we gotta make this happen by...Imagine Tomorrow or it's nothing,' I think they see that even if it doesn't work out by then, they'll at least have some progress that they can REPORT at Imagine Tomorrow and say, here's where we're PLANNING on going, and be respected for that still. (Malachite / Nils advisor interview 2)

This comment reflects the advisor’s willingness to continue participation in IT or at least to continue supporting the team’s efforts beyond the competition event. It also reflects the team’s flexibility in their understanding of the project – a quality I discussed in more detail in the analysis of Tension 1.

**2.a.2. Balancing timely progress with irregular work patterns**

Another goal for the teams involved making substantial progress on project tasks before deadline while accommodating students’ sporadic availability and productivity. Figure 16 represents the associated contradiction in the project activity system.

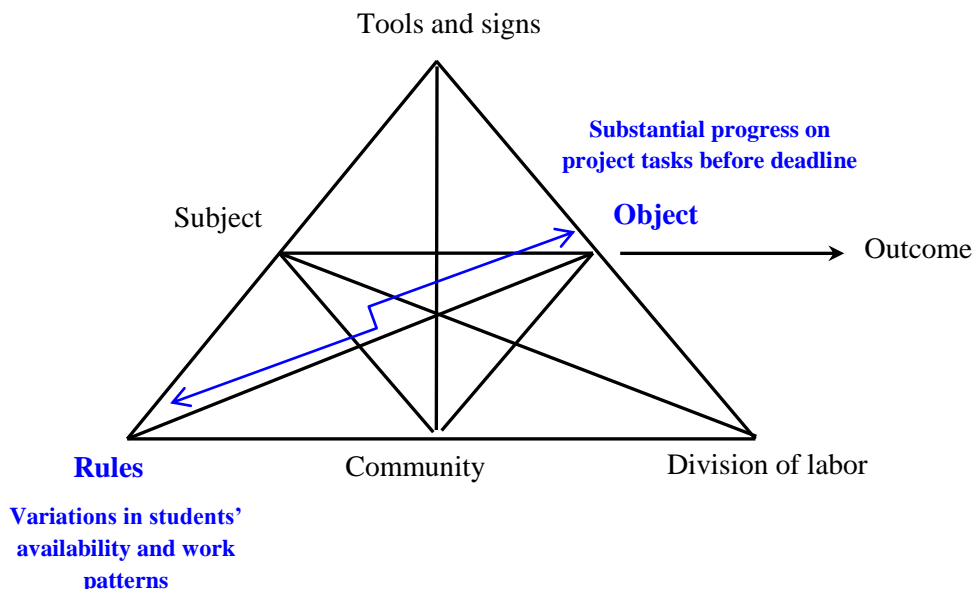


Figure 16. Contradiction 2.a.2. Substantial progress on project tasks before deadline (Object) vs. variations in students’ availability and work patterns (Rules)

Making timely progress on project tasks and being ready to present the project by the competition deadline are key factors in project success. At the same time, project work had to be

integrated into students' already busy schedules. In addition to the regular schoolwork, most members of the focal teams were involved in various other activities from school sports teams to competitive music groups and student organizations. Here is how Nils described the challenge:

AM: What do you know or believe the students may be struggling with, and the reasons for these issues?

Nils: Scheduling. Getting all members together at the same time. That's probably the hardest thing for them. Dana plays [on a sports team]. Somebody has Driver's Ed. Somebody is working. It's...you know, they're kids, they got busy lives, and they're REALLY busy lately. Several of them are in [competitive music group], so they got...during basketball season they're going to basketball games, and playing there. (Malachite / Nils advisor interview 2)

When I asked students (relatively far ahead of the deadline) where they placed project work in relation to other priorities, all of the students positioned it lower than these other commitments. Participation in IT without detriment to academic performance or involvement in other activities was an implicit *rule* of the project activity system. In other words, it was expected and assumed that project work would not directly interfere with students' other activities, and their priorities proved this assumption. When I restated the question about priorities several days before the competition, students generally indicated that project priority had escalated, although not at the expense of the other commitments. Here is how the MHS team responded:

AM: And what are one or two top things that are the top priorities this spring?

Molly: Well, grades, of course, keeping school work up, and only the play is up there too, just because I'm afraid that my [competitive music group] teacher would've tried to hurt me if I didn't show up to the play -- [Molly is smiling, and others are smiling/laughing] - cause she's kinda scary.

Becky: I think when we started this project, especially cause I didn't necessarily start with the original team, it was on the...kind of definitely the lower band, but as we've gotten...as soon as I got on the real team it definitely moved up to second, and then...I think the closer we've gotten to the competition the more...like, serious I've gotten about it.

Gillian: Yeah, um...for me, like, when we first started it, it was like kind of in the middle, cause I was excited about our project and stuff, and then for like a little while it moved down, because I...we weren't doing anything with it, and I was just like...I put it in the back of my mind, and didn't really...

AM: Other things took over?

Gillian: Yeah, I had other things to do, and...and it's been getting closer, right now it's kind of like grades and then this [gestures with her hand to indicate grades at the top and the IT project slightly lower, but her hand remains relatively high up near her forehead] because, um, it's getting closer, and we actually have stuff to do on it...

AM: All right, what about you? [referring to Dana]

Dana: For me I think it actually started pretty high because I was excited to go again, and I kind of knew that we had to get started pretty quickly on it because of what happened last year with us, starting too late, but like it kind of went down as I got into [school sport] season, because [it] is like full-time commitment, cause you can't miss practice or matches. (Malachite group interview 2)

The students' comments suggest that, on the whole, as the competition deadline approached, the contradiction between project completion and other priorities within the project activity system became more acute. For students like Dana, rigid constraints of the school-related commitments prevented participation in project work on par with peers. Other students whose schedules allowed more flexibility had to adapt to these irregularities in meeting attendance and find ways to keep their peers "plugged in" to the work.

Generally, as the competition deadline approached, project work intensified. A common indicator of this on both teams was greater amount of time spent working in meetings. Molly described her perception of time on task over the length of the project as follows:

AM: How would you estimate hours per week or per month spent on the project?

Molly: Yeah, um...in like...end of February when it started and beginning of March, there'd probably be about...half an hour per week put into the project [...] when we just had the basic ideas...but when we actually got work[ing] on the project, it turned into...usually at least an hour or two per week...

AM: Are you talking as a group or individually?

Molly: As a group...but...within the last month or so, we put in...usually...three or four hours like each individual person, and as a group together...probably about three or four...per week. (Malachite / Molly interview)

The MHS team had learned some lessons from its procrastination-related near-fiasco with the project in the previous year. As a result, their approach in the current year reflected more careful planning of project tasks to ensure it could be completed on time. Their approach also involved a

number of strategies aimed at addressing the issue of irregular work patterns (these strategies are addressed below). The success of their approach was evidenced by the fact that they had an easier time with the design of their presentation at the very end, being able to complete the work without any major last-minute push or stress.

In contrast, the EHS team did not have the benefit of a similar experience, and the students had to improve an approach that would help them complete the project as they went along. I interviewed the team in late April, at the exact moment when they were starting to feel the time pressure. Kara described this as follows:

AM: What are some doubts or challenges that you are trying to work through right now?  
Kara: Guess time management, we have less than a month to work on this...and...we're all really busy...and then like Ben said some of us don't really understand what exactly we are doing? We ha-we keep talking about ideas, 'Oh we could do this,' and we are finally starting to get more of a...what we really want to do, but we're still...we haven't really started on the project, have we. (Emerald group interview 1)

When I spoke with Kara after the conclusion of the competition, she had the following to say about their approach up to that point in April:

AM: So when was the starting point of the project?  
Kara: Hmm...beginning of May? Like actual-actual work, beginning of may, or end of April.  
AM: What led up to this actual hands-on work?  
Kara: Pretty much, I mean I did basic research on general information, but that ended up not being used; so it's just bits and pieces of research being done on my own, and then Seth talking to a number of people; Ben really hadn't been to our meetings yet, so he didn't have much of an idea of what was going on, so he didn't do anything; same thing with Will, so...once we started to really feel that time constraint we were like 'Okay we...kinda need to do this, so *let's start working.*' And that's when we really started. Oh no, we were still emailing people, that took a while...  
AM: when was this?  
Kara: end of April, I think, we were email--and yeah we had to talk to a lot of people to get to...that guy in charge of the department of maintenance and operations, and once we met with them it really kicked off, because we...at--after that meeting we really knew what we wanted to do. (Emerald / Kara interview, emphasis added)

The transition from hypothetical brainstorming to concrete action represents a pivotal occasion in the collaborative design practice. As discussed earlier, there were a number of reasons why students could get stalled at the brainstorming stage and fall into the vicious cycle of inaction. These include unrealistically defined problems as well as lack of information and direction. However, knowing what to do and actually doing it – staying on task and completing work on time – are different things. What did it take to “start working” in a way that facilitated timely progress on the project? I use this question as segue for describing the strategies the teams used toward this goal.

**Strategies.** Several factors coalesced to constrain students’ ability to engage with the projects in consistent ways and make timely progress. The data suggest a number of strategies to facilitate project work while accommodating these constraints: frequent collaboration, reliable communication, flexible roles and team structure, and sensitive leadership. These practices represent adaptive strategies for coordinating project work.

Having frequent opportunities for collaboration was at the heart of timely progress. I mentioned earlier the advisors’ contributions to facilitating team meetings. The role of different types of meetings is also covered in detail in the section on RQ3, below. In brief, frequent collaboration was achieved through regular meetings as well as quick face-to-face check-ins among the students during the school day. Such interaction was critical to progress with project work for several reasons. First, the “dedicated” project meetings allowed students to double up on unfamiliar or complicated tasks, thus motivating time on task and avoiding unnecessary frustration and delays. The following comment by Will is representative of his peers’ sentiment with regard to this particular *affordance* of the meetings:

AM: What did you meet for, in other terms what did the meeting accomplish that other ways of communication, such as Facebook or email, did not afford?

Will: Generally speaking--they allowed...I feel more organized research and they allowed for more organized work, to be honest...I mean it just felt like we got more done as a group, because we're all there, generally speaking we're focusing on one thing, and we're sort of all there at the same time, we sort of make a collective decision about it; so there was no sort of question, you know, alright, this is really well but do we really need this -- sort of like, do we need this -- yes -- no -- all right -- now let's move on...do we need -- you know...and then also sort of working together, again there is not that sort of doubt as, should I be working on this, do we need this, um, so...generally speaking, just sort of having everyone there, everyone who has a stake in the project, they're...helped tremendously. (Emerald / Will interview)

Second, both the frequent meetings and the quick check-ins helped make up for the occasional absenteeism by providing opportunities to bring “stragglers” (e.g., Dana on the MHS team) up to speed on project status and next steps. This allowed students to remain at least minimally productive rather than completely check out from the work.

The importance of regular team meetings was acknowledged by both teams in this study. The difference was that the MHS team, armed with its experience from the year before, was able to transition from brainstorming to action earlier than the EHS team did, which helped the students make better use of the meeting time from an earlier point in the process. The MHS students also appeared more intentional with regard to staying “plugged in” with the project work, creating and taking advantage of additional meeting opportunities to get up to speed. (For instance, Dana made an effort to attend the meetings on weekends although it took away from her well-deserved “downtime” from school and sports.)

Having the means to communicate reliably within the team was another strategy for ensuring more regular and stable work patterns. This strategy involved becoming aware of and adapting to each other's communication preferences. I initially assumed that high school students were relatively homogeneous in their electronic and social media use habits – that most everyone emailed, texted, and used Facebook to communicate online. The situation on the focal teams was

almost the opposite: students' patterns of electronic communication were constrained by various factors such as student habits (e.g., never checking email), family policies (e.g., no texting), and technical limitations (e.g., not having a Web-enabled cell phone or a data plan). This carried a substantial risk of limiting students' ability to communicate with their teammates in a timely and reliable manner. The resulting strategy was to develop routines to circumvent these constraints in order to get the message across. The following description of communication patterns on the EHS team is an example of how the team tried to navigate the constraints related to electronic communication:

AM: How about facebook and email, did you use these, for instance?

Ben: Um, Kara would send out like a bunch of group messages, she'd do them every couple of weeks, I guess, I don't know.

AM: She would just send out some messages through email? Did you message a lot on facebook?

Ben: Um, I was not very active in the whole messaging thing, I don't check my facebook very often, and I \*never\* check my email.

AM: you never check your email...

Ben: No. [laughs]

AM: So you are not very...into initiating [this type of] communication?

Ben: No.

AM: Ok. So just talking in class?

Ben: Yeah. Or texting. Like that worked well cause Seth would always text me whenever Kara would say we have a meeting coming up. Cause he'd get...he'd like check his Facebook or email and then he'd text me, he'd be like 'I don't know if you saw it but we have this coming up.'

AM: Yeah I noticed you have an iPhone?

Ben: Yeah.

AM: So...I was a little surprised when you said you're not into ["the whole messaging thing"]...with an iPhone. What do you do with an iPhone? It is just a fancy way to make phone calls or...?

Ben: No I...text and like...I mean I text a bunch and I do...everything else, it's just...I don't...read all my facebook that much.

AM: So was texting like a major way of coordinating or like shooting little messages back and forth?

Ben: Not really cause Kara's phone doesn't text, so we couldn't do that...and so...we'd mostly just call each other. (Emerald / Ben interview)

This comment indicates that some students (such as Ben) played a more passive role in the communication process and were mostly on the receiving end while others (like Kara, the team leader) initiated communication, and yet others (like Seth) mediated the exchange, “translating” messages across media and devices or relaying the information verbally when the students intersected at school. Being proactive in ensuring that information reached the intended individuals increased the reliability of communication within the team, thus facilitating project work. This also underscores the importance of frequent face-to-face meetings and check-ins, which helped keep the lines of communication on the team open.

In addition to frequent collaboration and reliable communication, CDP was also facilitated by flexible role arrangements and team structure. Flexible role arrangements refer to collaboration on tasks across roles even when specific individuals may have been assigned specific tasks by the team leader or volunteered to take on the tasks. Students on the MHS team had more articulated roles than students on the EHS team. Gillian described the role assignments as follows:

AM: How would you describe the role you had on the team? In what ways did \*you\* contribute?

Gillian: I was kind of more of a...just...they'd tell me to do something and I would go do it, kind of person...it's...yeah...

AM: Ok. Is that...that's it?

Gillian: Yeah...I'm trying to put it in a way different than what they say...cause we...kind of gave ourselves titles [laughs] but that's not really, like, professional...I could tell you if you want, they're not like inappropriate or anything, it's fine...like, Ok, Molly was the Dictator, because she [chuckles] she kind of was the one who kept us on track and told us what to do; Becky was the Compost Master, cause she knew everything; Dana was the Artist, cause she drew everything...

AM: wait, "compost master"...

Gillian: She knew everything about...about the compost, like...she...even though the rest of us compost, she has like a \*much larger scale\* because she actually lives on a farm, so she kind of like knew more about how much waste would be going into it, and how you would have to turn something that large, and she also got us the jars of compost; and then I was the serf, which is a...a long story...

AM: A "serf"...

Gillian: It's like a medieval thing and that goes on for a while...so...yeah...

AM: And why did you come up with these...is that something you kind of brought into the project that you kind of had before that?

AM: And why did you come up with these...

Gillian: Yeah, we had...we're always having fun with the project and we were just kind of talking about, well, who's the team leader, and Molly said, "I wanna be the Dictator!" and so then we just kind of "Okay well if Molly is the Dictator, who is...what's the rest of the titles for the group?"

AM: And then you just assigned...

Gillian: it just kind of...went on from there. (Malachite / Gillian interview)

On one hand, the role assignments added a layer of structure and *division of labor* onto the collaborative process. This was especially useful considering the "assertive personalities" on the team:

AM: How did you come to play this particular role? Is that something that you...talking among each other, "Ok, you're gonna be the "serf", or did you self-select into that, in a way?

Gillian: I kind of did select into that, like the "serf" thing, that's a really long story, goes back a long time, but...like, I really \*was\* the person who just like pretty much did what they told me, beca--like, I did come up with the ideas, but then they'd be like, "Ok, well this is what you need to do and then we'll do this," and I'll be like, "Ok, that's my job..."

AM: Are you comfortable with that?

Gillian: Yeah! I liked...I liked doing that, if I...wanted to do something else I'd be able to do it, because...but it's just...it's...like I was saying we all have kind of assertive personalities, and it is a lot easier if we just kind of like, do what we need to do instead of arguing about it...

AM: I see. So sounds like the roles maybe were like a way to organize that a little bit?

Gillian: Yeah, kind of. (Malachite / Gillian interview)

At the same time, there was significant overlap across the roles in terms of what the students actually did. As Gillian notes, working on most tasks was a team effort:

AM: Has this role changed from this initial agreement, and if so, how, or if not, tell me -- was it consistent throughout, or were there any changes, or overlapping between roles?

Gillian: I think there was probably some overlapping between roles, because Becky would sometimes decide things that needed to be done and...I think I helped Dana with her artwork, and...Molly and I...Molly would tell me, she was the dictator, she would have to tell me...or she would tell me things to do, but then she would come do them with me anyways, because that's just how our team worked, it's a lot easier to interview people when there's two of you, because then you don't miss what they are saying, sometimes, and...you don't...forget to ask them a certain question, or...yeah, when there's two people

then...it's easier... so even though we would divide up the roles, we would almost always go in groups of two or sometimes three, too...

AM: I see, OK. So suppose we had...two diagrams, two ways of representing that, and the first one, right, the differences -- the amount of overlap -- the circle is the role [draws Venn diagrams] -- would you describe the team as more...in terms of how much overlap there was, more like 1 or more like 2...

Gillian: more like the first one, definitely...[selects the diagram with larger overlap] even though we did have those titles, it was more of just...

AM: I'm just trying to get a sense of how flexible that was...

Gillian: yeah, we all worked together on everything, we didn't like...have that much of set roles, that's just kind of...it's what we said because that was like our main job, but...

AM: so the roles were more kind of a rough...label or in general...

Gillian: yeah, yeah, Dana did like, Dana did most of the art, because she is definitely more of an artist than the rest of us, but I did help her...like, I took pictures of things for her, and colored things in...

AM: Ok...collaborative roles...

Gillian: yeah, uhum. (Malachite / Gillian interview)

Flexibility in project roles may have had a stabilizing effect on the consistency and reliability of the work, by building in redundancy into students' actions, while also making the work more fun. The likely flipside was reduced efficiency of the work since making everything everybody's business may have triggered arguments that could have been avoided had the students' roles been more firmly delineated.

Sensitive Leadership. One other aspect of CDP related to flexible roles was flexible team structure which had to do with team leaders' sensitivity to the preferences of the team members in taking on particular tasks. Opportunities for team members to participate in decision-making regarding their roles and tasks created room for maximum student agency in role and task choices. This was important because students' goals for participating in IT extended beyond completing a project in the most efficient manner possible but included having fun, having a good time with their friends and peers, and learning about various aspects of the project topic. These goals may stem from the OST context of participation in IT where the norms of volunteer participation and self-selected teams may be interpreted by the students as giving them freedom

of choice with regard to the roles they take up and the level of persistence in completing certain tasks. This manifested in project work as implied norms, namely, the need to accommodate each other's preferences for doing or not doing particular tasks or taking on particular roles.

At the same time, accommodation in individual preferences carried the risk of unreliable task performance, which could delay and undermine timely progress on the project. One example comes from a group interview with the MHS team near the conclusion of project work when Gillian procrastinated with interviewing a member of the school lunchroom staff:

AM: Thinking about the team as a whole, what kinds of issues do you think are most important to resolve, or maybe since we're almost at the end, thinking back – what has come up, that you have to kind of deal with?

Gillian: the things that have mostly come up is that we'll agree that we need to do something, like...um...[pointing to Becky/Molly] they'll tell me I should go talk to the lunch staff, because I know a few people who work in it, and I...I didn't do it for like THREE WEEKS...[smiles/laughs apologetically]

Molly: [gestures by propping her head on the palm of her hand raised with elbow on the table, exclaims half-jokingly] Had to force you to do it?!

AM: Do you mind sharing why, now looking back...

Gillian: why I didn't?

AM: Is it just a time thing, or...

Gillian: just, like...I was supposed to do it before school, and every time I'd get to school, I'd just be like, I...I don't wanna go in there...and I'd end up doing something else, or I'd be like I'll go there in 5 minutes, and I'd end up talking to someone, and just don't do it...

Molly: You'd forget...

Gillian: I forget...

Molly: And you wanna do your math homework during lunch instead...

Gillian: yeah, and...um...yeah, math homework. [all are smiling] (Malachite group interview 2)

From an activity theoretical perspective, this example may be interpreted as a case of *disturbance management* (Engeström, 2008, p.35) by anticipating and preventing potential issues before they derail the project (in this case, failure to obtain buy-in from a key stakeholder in the proposed composting program). Thus, team leaders had to maintain sensitivity to both the needs of the team members and of the project itself. This was accomplished on the MHS team in

particular through Molly's regular status checks with her team and by maintaining weekly task lists through which she communicated to the team where the project was at any given time and what needed to be done next. Such tracking and planning allowed her to catch issues relatively early before they escalated into major roadblocks. This was an adaptive strategy as the norm of accommodating team members' idiosyncrasies meant that the team leader lacked any real means of enforcing task completion. In the example above, the girls ended up employing the "flexible roles" strategy and interviewing the lunchroom staff together.

Trajectories of Practice. The goals and strategies discussed in this section are associated with the tension between the activity frame of project completion and the activity frame of experiencing IT in a certain way. The outlined approaches stem from the need to balance the need to complete the project as one of the elements of the overall IT experience against various constraints that frame the participants' activities. The strategies that appear most effective for negotiating such contradictions involve adaptation and flexibility in light of these constraints rather than rigidity and entrenchment in particular ways of collaborating or designing. At the same time, these strategies reflect a concern with structure as expressed in the tendency to "project-manage" the students' interest or (loosely) demarcate team roles. Such concern is not a consequence of a top-down press on team practices but rather an attempt to reconcile the underlying tension between the patterns of goals, actions, and values that frame students' engagement with their projects. Of particular benefit in such cases may be strategies that help align project roles with students' preferences and establish clear expectations and standards for collaborative practices (e.g., reliable communication) and task completion (e.g., timely notification and proactive troubleshooting of issues by the team members).

## Research Question 2 Supplement: Adaptive and Maladaptive Strategies

In the preceding section, I reported findings from the analysis which surfaced the *adaptive* strategies which characterized project-oriented activity, i.e. strategies for completing Imagine Tomorrow projects while navigating the contradictions in the project activity systems. As defined in the Analytic Approach section, these strategies enabled project completion without apparent detriment to the participants in the project activity system. These strategies are summarized in Tables 11 and 12 below.

Table 11

*Summary of contradictions, goals, and adaptive strategies associated with Tension 1*

<b>Tension 1: Structured vs. Emergent collaborative design process</b>	
Contradictions	Goals and Adaptive Strategies
<p><i>1.a. Advisor Support: Balancing hands-on vs. hands-off involvement by advisor</i></p> <p>Completed project of reasonably high quality (Object)</p> <p>vs.</p> <p>Advisor not doing project for the students (Rules)</p>	<p><i>1.a.1. Ensuring timely progress</i></p> <ul style="list-style-type: none"> <li>- regular status checks</li> <li>- meeting facilitation</li> </ul> <p><i>1.a.2. Ensuring high standards</i></p> <ul style="list-style-type: none"> <li>- providing feedback</li> <li>- invoking quality criteria</li> </ul> <p><i>1.a.3. Catalyzing project work</i></p> <ul style="list-style-type: none"> <li>- support of team's networking with external stakeholders and SMEs</li> </ul>
<p><i>1.b. Project Context: Emergent vs. existing activity systems</i></p> <p>Completed project of reasonably high quality (Object)</p> <p>vs.</p> <p>no established structure for organizing project work (Rules)</p>	<p><i>1.b.1. Creating a project activity system</i></p> <ul style="list-style-type: none"> <li>- aligning team practices to constraints while leveraging affordances of existing activity systems (property of the individuals)</li> <li>- existing activity systems accommodating students' constraints and leveraging capabilities (property of the context)</li> </ul>

Table 12

*Summary of contradictions, goals, and adaptive strategies associated with Tension 2*

<b>Tension 2: Completing project vs. Experiencing competition</b>	
Contradictions	Goals and Adaptive Strategies
<i>2.a. CDP: Balancing project work with constraints</i>	
<p>2.a.1. Feasible project with tangible results (Object)</p> <p>vs.</p> <p>Ambitious, interesting, and personally relevant project topic (Rules)</p>	<p><i>2.a.1. Balancing feasibility with interest, ambitions, and skills</i></p> <ul style="list-style-type: none"> <li>- considering the skills and knowledge needed for project work</li> <li>- converting ambiguous goals into specific objectives and tasks</li> <li>- narrowing project scope</li> </ul>
<p>2.a.2. Substantial progress on project tasks before deadline (Object)</p> <p>vs.</p> <p>Variations in students' availability and work patterns (Rules)</p>	<p><i>2.a.2. Balancing timely progress with irregular work patterns</i></p> <ul style="list-style-type: none"> <li>- frequent collaboration</li> <li>- reliable communication</li> <li>- flexible roles and team structure                             <ul style="list-style-type: none"> <li>o team leader sensitive to team and project needs</li> </ul> </li> </ul>

### **Differences in Adaptive Strategies**

Follow-up analysis focusing specifically on strategy use confirmed that the adaptive strategies described thus far (as summarized in Tables 11 and 12) were exhibited across both focal projects. At the same time, differences emerged in the extent of the use of one strategy, “narrowing project scope” (see goals under 2.a.1 in Table 12). The Malachite team was more intentional and consistent in proactively controlling the scope of their project compared to the Emerald team. The Malachite team developed a three-year plan for their project early in the design process, revised it over the course of design work, and referred to it to manage their tasks based on the goals stated in the plan. Their plan had a dual purpose: facilitating project

management by organizing the team's activities (an operational function) as well as serving as one of the artifacts on the project presentation display. Inclusion of the plan into the presentation underscores its significance to the project. The notion of planning as part of the design process was also more prominent in the interviews with the Malachite students than in the interviews with the Emerald team. For instance, the code "student roles\_leadership\_planning team activities" appeared in 20 segments, and the code "outcomes\_plans/goals/interest in future/repeat IT participation/project extension" appeared in 35 segments in the Malachite student interviews, as compared to 6 and 12 segments in the Emerald student interviews, respectively.

Malachite team's planning had a more strategic focus, encompassing all of the team's major objectives over the three-year timespan of project implementation. Based on that plan, the team developed weekly task lists which the students reviewed in their team meetings and used to coordinate their individual and collective actions. The three-year plan enabled proactive management of the project scope, in particular, the narrowing of the scope in the present year. This is illustrated in Appendix I, which shows the draft and the final versions of the plan. Realizing that constructing the compost bins would require resources like time, supplies, money, and skills, which they did not have available at the time, the team migrated one of their goals from Year 1 (the current year) to Year 2: "Begin the process of having the kitchen staff collect the food scraps from the kitchen area to be composted" (see Appendix I). Becky described this decision as follows:

Becky: well when we were doing our year 1 plan, I think we actually...moved something to year 2...that we had...

AM: [looks up digital photo of the plan on poster board] It's hard to read..."Year 2...the process of having...our kitchen staff collect..."

Becky: I think...so it says constructing the compost bins, we kinda talked about...at least beginning to construct them, even before we went to the competition, and that was

something we had to move because...one, because of time, and two, because we didn't...yeah we didn't know [exactly how to build them]. (Malachite / Becky interview)

Thus, by working a flexible implementation timeframe into the project plan from the outset, the Malachite team was able to ensure that their goals for the current year remained feasible and appropriate to their skills and resources.

In contrast, although the Emerald team also treated their current year's project as laying the foundation for future implementation (of the student environmental council and a composting program at their school), there was no comprehensive year-by-year plan with clear objectives and steps. The team had developed some well thought-out, detailed descriptions of the main elements of their project. For example, Appendix J shows an outline view of the team's PowerPoint presentation on composting, which was part of their presentation display. However, their materials did not include a detailed plan with a clear sequence of steps and implementation timeframe. As a result, their plans appear more tentative, compared with the action plan of the Malachite team. Rather than starting with a "master plan" early in the process, narrowing of the project scope was achieved relatively late (at the end of April, less than a month before the competition). As the clarification of the project's goals and tasks was on-going, emerging alongside with the information that was being gathered, so the planning was used to address more immediate goals and coordinate day-to-day tasks and meetings. One description of this process comes from Ben's comments on Kara's role in moving the project along:

Ben: Me and SS are...like...creative and like...hard-working...but not always focused and directioned...and then when we had Kara in there, it was like...she would point us in the right direction and keep us in line, I guess...

AM: Ok. In terms of keeping the team in line, how do you feel...how was that done?

Ben: Um, email a lot. She would email us...

AM: What sort of things would she email about?

Ben: Upcoming meetings. (Emerald / Ben interview)

Overall, the scope of the project was dictated by what the Emerald team could feasibly accomplish within a relatively short timeframe (roughly a month of active project work) leading up to the competition rather than what they had intended to do from the start. As a result, planning was more near-sighted and reactive, performing mostly an operational function of coordinating the next task, thus serving a tactical rather than a strategic purpose.

### **Differences in Maladaptive Strategies**

I analyzed the interviews and the meeting observations of each project case for instances of *failure to use the adaptive strategies* as well as any other conditions that impeded project completion (see Figure 11 in Chapter 3, in the section on addressing RQ2). The *maladaptive strategies* that emerged in the analysis were decisions, patterns of behavior, or conditions which appeared to impede project completion. Six maladaptive strategies were identified (see Table 13 below). Six instances of these failures, one of each, were identified on the Emerald team, and two instances of failures were observed on the Malachite team. The strategies labeled “maladaptive” hindered project completion and had a detrimental effect on the quality of the competition experience for at least some of the students. The strategy labeled “borderline adaptive” facilitated project completion but was detrimental to the competition experience of the student involved, and thus represents an unsustainable practice of limited value. A brief overview of these strategies follows.

Table 13

*Instances of failure to use the adaptive strategies*

Failures to Use Adaptive Strategies	Project Teams		
	Emerald	Malachite	
<i>Failure to use flexible collaboration and communication routines (2.a.2)</i>			
Failure to balance priorities – dropping out from collaborative design process	Maladaptive	+*	
Failure to ensure shared understanding of project and develop common approach	Maladaptive	+	
Resistance in communication styles – listening or compromising	Maladaptive	+	+
<i>Failure to use flexible roles and team structure (2.a.2)</i>			
Resistance in tasks or roles – unreliable performance of assigned tasks or failure to support teammates in task completion	Maladaptive	+	+
Resistance in tasks or roles – individual compensating for lack of team effort	Borderline adaptive	+	

\*Indicates singular instances of failure to use adaptive strategies.

**Failure to use flexible collaboration and communication routines**

**Failure to balance priorities – dropping out from collaborative design process.** On the Emerald team, Will remained involved in team meetings through April while the team narrowed the project scope and began to tackle the tasks required to lay the foundation for the composting program and the environmental council. However, as the project deadline approached with about a week left until the competition and the work in full swing, he abruptly disengaged from all team activities, from meetings to even the most casual communication with teammates, becoming virtually unreachable for project-related purposes. Neglect of several homework assignments appeared to have been the main reason for this change, prompting Will

to refocus on academics at the expense of further participation in IT. As he recalled in a post-competition interview:

AM: Around what time would you say that you stopped showing up at the meetings?

Will: If I seem to recall correctly that was April...I somewhat slacked off in my...[classes], I was fighting to bring things back, I mean I wasn't in dire territory, but there were a few grades that I needed to raise back up to A's at that point, so I really sort of...took a...I sort of stepped back my involvement, because I...there were...other you know, more important things at that time that I sort of needed to grapple with. (Emerald / Will interview)

Will's transition off the team probably could have been smoother with enough advance notice and clarification for his team to minimize any misunderstanding. His dropping off the project without notice, however, and his complete unresponsiveness to attempts to re-contact him (including failure to confirm or disconfirm interest in attending the competition event which he ended up not attending) caused some understandable frustration among his teammates. The fortunate mitigating circumstance in this specific situation was that Will's tangible contributions to the team were relatively minor in the later stages of project work, causing little disruption to the team's progress besides the extra worries and time spent on unsuccessful attempts to re-contact him. In fact, as Kara later observed, Will's inability to attend the competition turned into an advantage for the team, preventing potentially more serious discoordination during the presentation:

AM: what are some challenges you had to overcome?

Kara: Contacting Will, that was a challenge that didn't get solved...

AM: What made it into a problem for you?

Kara: um...I wanted...I thought being a good leader would be getting participation from everyone. And if there was someone that wasn't being included, I should try to include that person...and...that didn't work out; BUT if he had come with us -- like I was trying to get him at least to come with us to WSU -- but then if he HAD come with us, since he

hadn't been working with us the whole time, he wouldn't know what to say. (Emerald / Kara interview)

**Failure to ensure shared understanding of project and develop common approach.**

The failure to achieve and sustain shared understanding of the project on the Emerald team is represented by a disconnect in Kara's and the two boys' (Ben and Seth) ideas regarding what should be included in their presentation PowerPoints. Kara wanted broader coverage of energy issues in a 'series of PowerPoints' whereas Seth and Ben were more focused on describing the proposed solution (composting) to the specific issue of food waste at their school. Kara had this to say about the misunderstanding:

AM: Suppose you were doing the same project again with the same teammates, what are some things you would do that would be important?

Kara: I would've talked to them more...so that I understood what they were thinking, I guess I was only thinking about what I had in mind, what ideas I had for the project, I mean I asked them if...I have this idea, and they...I ASSUMED that were all on the same page, and later on that kind of turned into an argument...

AM: so how...what was that disconnect in ideas?

Kara: [...] we had three parts, the...four...the survey, the council, the composting, and the PowerPoint, and I thought the composting was the smallest, they thought the composting was one of the biggest, since it was a SOLUTION to something, but I thought the COUNCIL was the biggest, and the...the purpose of the council was to raise awareness of environmental problems and solutions. So...I thought if they were to--if the council were to start off, we should have a PowerPoint or something to teach the kids, and I thought...general information should come first, then specifically what the school should do. So yeah, there I guess was miscommunication, or difference in ideas [...] *and I was a little stubborn and didn't want to change my idea* [laughs].

AM: Can you suggest how this issue could be handled better?

Kara: Um...well with the disagreement, hmmm...*my willingness to look into more ideas, I guess...and...I guess telling them my ideas more often and then asking them what their ideas were, so that we would be on the same page...it was I think my mistake to wait till that last...or one of the last days to ask them if...or to tell them how it was gonna be presented, cause then they were like 'What? That's not what we had in mind, it should look more like THIS. So...that far into the project, once I get there, I kinda don't wanna change what I was planning, but I guess...that had to be done...* (Emerald / Kara interview, emphasis added)

The apparently minor disagreement over what PowerPoint to use in the presentation could have escalated into a major design impasse or miscalculation for the team's presentation since it directly impacted what the students would highlight when describing their project to the judges. If these differences of opinion were not resolved, the students may have sent mixed messages when talking with the judges, resulting in confusion as well as lower project scores. In retrospect, Kara admitted that the boys' idea made more sense for purposes of the presentation at WSU since the time for interacting with the judges was very limited, and judges often asked to cut to the chase and talk specifics of the proposed solutions. Although describing the background for the composting program was important for the students' own understanding of the bigger picture of their project, it would have taken too long and prevented the presentation narrative from making a strong impact.

The meeting observations showed that the disagreement over the PowerPoints actually took place during the team's very last meeting, a major goal of which was to finalize the presentation display. Despite Kara's perception of lacking communication skills on her part, the fact that this disagreement surfaced and was quickly resolved in that meeting indicates that she was an effective listener, and was able to exhibit flexibility and sensitive leadership by recognizing when it made sense to yield to her teammates' stance on a key issue.

**Resistance in communication styles – listening or compromising.** The lack of Seth's communication with his team that accompanied his disengagement from the project represents an instance of resistance with regard to communication on the team. On the Malachite team, an issue with communication surfaced in students' interview comments regarding the quality of interaction during their team meetings which were not directly observed by the researcher:

AM: Could you describe project-related interaction that had the greatest effect on your own experience with the project?

Gillian: Well, Molly, Becky and I all have really assertive personalities, so there was times when we couldn't get things done because we were just...arguing over the things that...the WAY we think things need to be done... so...that was...that affected our project a lot, because maybe if we had spent less time arguing, we would've gotten more done...but we...didn't... [...] We're not actually like fighting or anything, but it's just like we all...there's a way that we want it and we...we just...we want it that way and we'll try to argue our point, but then the other two people aren't willing to listen because THEY think it should be done a certain way. And once...we all actually, like, are willing to listen to each other, then we'll come to, like, a compromise, but...it doesn't work out that way always. (Malachite / Gillian interview)

The excessive arguing due to similar communication styles and “assertive” personalities made the teams’ meetings less efficient for making progress on the project. It is noteworthy that Gillian raised these concerns when responding to a general question about project-related interactions rather than the *challenges* that the team had encountered. This suggests that the issue of excessive argumentativeness and lacking listening skills on the team had a strong influence on her overall experience on the team. Her perception was corroborated by other students in their individual interviews, such as in this comment by Dana:

AM: What are some challenges that you had to overcome as a team or individually?

Dana: Challenges would have to be...you know, talking over each other...we all kinda had what we wanted to say, and we kinda started...trying to talk over each other...and trying to say we think this is right, you know...

AM: So everybody had their sense of how it would work?

Dana: YEAH...and we had to kinda.MAKE IT all work...which was really hard...cause everyone didn't really wanna change what they were saying. (Malachite / Dana interview)

It is important to note that there was no evidence in the interviews or meeting observations signaling any animosity among the team members. On the opposite, this communication pattern appears to have been associated with overly informal social relationships among the team members, prompting them to interact more as friends and less as colleagues. There is no

evidence in the data to suggest that students had intentionally expressed disrespect or other negative attitudes toward one another; on the contrary, laughing and smiling often accompanied their recollections of arguments during meetings. At the same time, the comments do suggest that these arguments reduced meeting efficiency and partly delayed decision-making and progress.

### **Failure to use flexible roles and team structure**

**Resistance in tasks or roles – unreliable performance of assigned tasks.** On the Malachite team, only one example was observed when a student resisted completing an assigned task, thus delaying its completion and hindering progress with project work. Becky described the issue as a cause of frustration in the course of working on the project:

AM: What were some emotions that you experienced in connection with the project?

Becky: I know I definitely felt frustrated throughout the project...it was...mostly because of those time management issues...and sometimes at the other members in the group...but those were...usually like...cause Gillian was a chicken...and...we couldn't get her to go talk to people without someone going with her...but...yeah. (Malachite / Becky interview)

Gillian was well aware of being a “chicken” and acknowledged responsibility for delays with interviewing the lunchroom staff. She was the first to bring up this issue in a group interview:

AM: Thinking about the team as a whole, what kinds of issues do you think are most important to resolve -- what has come up that you have to kind of deal with?

Gillian: the things that have mostly come up is that we'll agree that we need to do something, like...um...[pointing to Becky/Molly] they'll tell me I should go talk to the lunch staff, because I know a few people who work in it, and I...I didn't do it for like THREE WEEKS...[smiles/laughs apologetically]

Molly: [gestures by propping her head on the palm of her hand raised with elbow on the table, exclaims half-jokingly] Had to force you to do it?!

AM: Looking back at it now, do you mind sharing why that happened?

Gillian: just, like...I was supposed to do it before school, and every time I'd get to school, I'd just be like, I...I don't wanna go in there...and I'd end up doing something else, or I'd be like I'll go there in five minutes, and I'd end up talking to someone, and just don't do it...

Molly: You forget...

Gillian: I forget...

Molly: And you wanna do your math homework during lunch instead.

Gillian: yeah, and...um...yeah, math homework. [everyone is smiling] (Malachite group interview 2)

In a follow-up individual interview, Gillian confirmed that this issue was a challenge for the project:

AM: What are some challenges that you had to overcome as a team, or even you personally, and how you think they could be handled better?

Gillian: For ME, I didn't really...I was really bad about doing stuff, like they'd tell me something I had to do, and then I...I would mean to go do it, but then something would come up, so I need to be better about actually going to do something instead of putting it off and putting it off... (Malachite / Gillian interview)

Interviewing the lunch staff was indeed an important aspect of securing stakeholder buy-in that was needed to ensure feasibility of the project. Gillian's failure to reliably complete the task in a timely fashion may have been due to a lack of understanding of interdependence of project tasks and, therefore, the potential implications of delays with one task for the other tasks. Molly's comment on having to "force" Gillian to do the task (in a friendly way – they ended up doing the interviews together) suggests that, as a project leader, she had a better understanding of these interdependencies and a greater sense of urgency with ensuring timely task completion. She later commented on this issue in terms of lessons learned about task assignments:

AM: If you knew then what you know now, how do you think [challenges] could be addressed?

Molly: Making sure that...we have different assignments for people, such as...not giving people who procrastinate on...stuff that they leave to do their homework at lunch, lunchtime duty, to...go and proceed to do. So...mostly just managing um...assignments, is probably. (Malachite / Molly interview)

On the EHS team, resistance in tasks or roles through unreliable performance was expressed in an instance of the lack in team members' support of the project leader in completing certain tasks – in this case, physically laying out and creating the presentation display. During the last meeting, Seth and Ben left early, leaving Kara to struggle to finish designing the presentation later that night. Her account of that situation clearly indicates that she could have used her teammates' help:

AM: If you had to do a project like this again, what are some things you think would be important to consider ahead of time?

Kara: like that last workday we had, I don't know why I felt so disappointed but...the workday where we started making the poster...they left because they were HUNGRY, which I was unhappy about [laughs] I was like 'I have snacks! What--aren't you guys feeling pressure?' They felt more RELAXED. Because I for sure thought we weren't gonna be able finish the poster in the car; the other two were thinking we'd be...wanna finish the poster in the car, worked on it during this six-seven hour ride, but...[...]once I saw the car, it definitely did not have space to work on poster, and we didn't have the supplies, NO ONE brought any supplies, even though there was the possibility of working on it, cause I had told the other two I'd work on it as much as I can, and if I don't finish they will finish it in the car, but they didn't bring anything...so if I had not finished...

AM: And you also didn't bring anything?

Kara: I didn't bring any either...I wasn't thinking...well I didn't bring any because I finished...

AM: you finished your part?

Kara: The poster, I finished the poster. (Emerald / Kara interview)

It appears that the boys had miscalculated the time and effort required to assemble the poster, opting to let Kara handle this remaining task instead of teaming up on it. Although she had counted on them for support, they proved unreliable in that particular instance.

**Resistance in tasks or roles – individual compensating for lack of team effort.** The above-mentioned example with presentation design by the Emerald team reflects one additional strategy, expressed in the willingness of an individual team member (in this case, Kara) to compensate for lack of support from the other teammates in completing a particular task. I categorized this strategy as “borderline adaptive” because it facilitates *and* problematizes project completion, thus negatively impacting the quality of the competition experience for the individual in question.

On one hand, if Kara had not finished the poster before the trip, the team would have been stuck with this task in Pullman, having to do last-minute work instead of enjoying campus and resting before the competition event. This would have likely detracted from the quality of their experience and could have jeopardized the presentation as students may have had less rest the night before the event. In this way, her proactive and responsible approach to tackling the last, though by far not the least important piece of the project single-handedly, was adaptive in that it helped ensure project completion for presentation purposes. On the other hand, her decision to assume the responsibility for this task and let her teammates “off the hook” led her on an emotional rollercoaster and negatively impacted her experience of working on the project. This is evident from Kara’s reflection on her experiences that evening:

AM: What were some emotions that you experienced in connection to the project? What were some of the most emotional moments for you?

Kara: [...] When we were making the poster [chuckles] and how the guys just weren't really...that made me panic \*a lot\* cause I thought we weren't gonna finish in time, and it was...I thought I had to finish my whole CE the next day, and I had a mentor meeting, and I had to finish the poster...and all that, so...'Oh my Gosh I'm definitely not gonna be able to...first I'm not gonna be able to finish the poster...which means our presentation is gonna be bad; my presentation to Mr. [mentor's name] my mentor would've been bad, cause he would've seen that nothing's finished, and then...I would fail my CE, so...I was...\*really upset\*, but...I met with Mr. [mentor's name] and he thought it was

fine...um, cause this project...perfection is not expected, so he was like, 'Yeah you learned that you needed to manage your time more...read people better, and all that. And then I ended--I stayed up till 3 making that poster, like at first I was really tired, but after a while it just kinda passed, and yeah, [chuckles] it was fine, then the next day was...went fine as well, cause we were the only ones finished, so yeah that's cool, we were sort of responsible, and we got to just lay back and do stuff, and then the presentation went really well so we were all really really happy, so it's...yeah it was like...panic, happy, panic, happy. (Emerald / Kara interview)

Although a team leader's (or member's) ability to pull through and pick up the pieces on behalf of the team may facilitate project completion in certain cases, this approach is not sustainable or recommended. It increases the risk of overtaxing the student and possibly leading to burnout, thus detracting from their enjoyment of the competition and causing additional frustration and stress.

One additional risk associated with this strategy is that it may be considered appropriate and become the norm for the team. This was not the case on the Emerald team where the students had for the most part collaborated and "spotted" each other on tasks as needed. However, when I asked what characteristics of the Emerald team could be considered its advantages, Ben made the following remark:

AM: What did everybody on the team bring to the project at you think was unique for this team and set it apart?

Ben: [...] she [Kara] was a good leader, and for a lot of the things that...we didn't wanna do, like she would always like make all the contacts with people and she would set up the meetings, and so she was kinda like...the head and we were some of the workers I guess, I don't know. (Emerald / Ben interview)

The above comment suggests that Ben did not see as necessarily problematic letting Kara handle tasks that did not appeal to him if that could be justified by her role as the team leader.

Equitable distribution of time and effort, which sometimes serves as a proxy for equitable *contribution*, is a common assumption and an implicit rule in group work. This assumption is

relevant to the *division of labor* component of the project activity system. However, students' volunteer participation in the competition in out-of-class settings may introduce ambiguity into this assumption because of some other assumptions that it carries. One such assumption is that students can and should proactively control the extent and quality of their contribution to the project, such that it allows them to be productive members of the team while at the same time upholding their other commitments. Ben's comment above suggests that the team leader's role could be exploited as a loophole by other team members, helping to justify offloading of undesirable tasks under the pretense that this role implies a greater commitment to the project and can bear some extra load. Within the project activity system, this may be represented as a contradiction between the system's *rules* (voluntary participation, implying control over the level of effort and tasks) and *division of labor* (based on the assumption of equal effort on the team) components. This problematizes the issue of whether Kara, as the project leader, had a greater stake or responsibility in the project. An additional complicating circumstance is associated with her use of the project for her CE graduation requirements. One way to prevent discoordinations in the distribution of workload on the team is to reduce the ambiguity introduced by the two conflicting assumptions by making the roles, responsibilities, and norms of collaboration around tasks more explicit. One way of doing this may be to ensure that team members negotiate these issues upfront and formally acknowledge the conditions of their involvement on a team.

## **Summary**

The "maladaptive" strategies discussed above represent failures to engage with the project in adaptive ways and in particular, to use the adaptive strategies that have been identified. These failures may be traced to contradiction 2.a.2, which involves balancing timely progress in project work with irregular work patterns. The work in question includes communication,

collaboration, and task performance routines, which characterized students' engagement with their peers around the projects. These failures may also be interpreted as deficiencies in certain communication, teamwork, and self-regulation skills. Although the resulting "maladaptive" and "borderline adaptive" attitudes and behaviors may be considered as distinct to make their description clearer, in practice, they tended to overlap and snowball, such that failure of one kind risked triggering a chain reaction of *discoordinations* in the functioning of the project activity system. (For instance, Will's dropping off the team was the primary cause, consequences of which may have included resistance in communicating with his peers and uncertainty with regard to his competition attendance, which could have jeopardized some of the plans for the presentation.) Regardless of the actual magnitude of discoordination associated with each of the strategies reviewed in this section, their common characteristic was that they threatened the teams' capacity to effectively navigate the contradictions within the project activity systems.

### **Research Question 3**

Research question 3 states: What role do the team meetings play in the collaborative design process? A discussion of the evidence of tensions in the project activity system would be incomplete without examining the role of team meetings. The face-to-face team meetings presented opportunities for students to come together and engage with one another in project work. The meetings were spaces where the project and non-project activity systems intersect and overlap, and where the need for coordination of project work was reconciled with other demands for students' time. Both teams' ability to make progress on the project was measured by their ability to create an emergent collaborative structure of design activity. The team meetings were important sites of such activity. In this section, I distinguish three kinds of meetings – team

meetings with the advisor, meetings with the external stakeholders, and team-only meetings – and discuss the role of each type in the context of the project activity system.

### **Advisor-team meetings**

The meetings where the advisor was present contributed to two goals: ensuring regular and timely project progress and providing a flexible structure for advisors to regulate the extent of their involvement in teamwork.

As noted in the discussion of tension #1, meetings helped to monitor team progress by allowing the advisors to conduct regular check-ins with the teams. Advisor-team meetings also allowed advisors to assist with minor tasks where students could use some help such as contacting external SMEs and stakeholders. They also allowed coordinating details such as IT logistics, including trip preparation tips and schedule of activities. Sometimes these topics were addressed concurrently with the advisor responding to students' questions and status updates, providing minor assistance and soliciting feedback regarding trip logistics. Such interaction was typical for advisor-team meetings on both teams. The following example illustrates one such episode in Nils's classroom at the start of the Malachite team's last meeting when students assembled their poster presentation. The transcript reflects interaction that took place within a four-minute segment of the meeting.

*[Catching up with students on progress on specific tasks.]*

Molly: Okay so we called [external contact name], who gave us \*this\* [shows Nils a printout]

Nils: And?

Molly: And he couldn't tell us \*much\*, but he said he emailed \*you\*...with the new information...

Nils: Okay let's see when did you call him?

Molly: Yesterday...after school.

Gillian: And I tried to email you from my phone but I don't know if you got it...it probably went into junk mail if anything weaker

Nils: Ah, I can check there...

Gillian: My phone doesn't have an email address, it probably just gave you a phone number...or something...

Molly: Yeah cuz we took some notes on questions we had, like how many are in a raw case, but apparently...we haven't ordered anything since \*October.\*

Gillian: I think he might've been talking about the DECA stuff, because...that was...he kept mentioning [school program], I was like, "we want the vending machines," and then he'd say something about the email, and I couldn't hear him very well, so...

*[Assisting students with contacting SMEs.]*

Nils: Ahh...crap...can you call him again? I know it's gonna be awkward, but...I didn't get an email from him...

Gillian: You should call him...

Nils: Okay, that works...

Gillian: I'll give you my phone...if you want it...

Nils: Yeah, I didn't bring mine today...[...] [Gillian walks over and hands Nils phone]

Nils: What's the dude's name again?

Gillian: I don't remember...

Molly: Here, I've a...[takes out a sheet of paper, pronounces the name]

*[Soliciting student feedback regarding trip logistics.]*

Nils: Ah, and we're on for the bears... [a visit to a bear enclosure at WSU]

Molly: cool! woohoo!

Nils: Saturday morning about 8:35...yeah Saturday morning, day of the competition, 8:35...

Molly: Okay, that works...awesome, bears!

Nils: Saturday morning?[self-talking]

[...]

Nils: [talks concurrently with Gillian and Dana] Friday sounds the right day that we should go to that...

Molly: Yeah, weren't we supposed to be...setting up? [posters at the competition venue]

Nils: Yeah, you'll be in the competition...Yeah, Friday...cool, now we're on...[writing email] (Malachite / Team meeting observation 3)

In addition, the advisor's classroom, which typically served as the space for the advisor-team meetings, afforded the use of facilities and resources. The classroom itself was a safe, familiar, and convenient location where a team could work with minimal constraints on time and format of interaction. For instance, here is what Gillian had to say about working at the school and public library:

AM: One thing you mentioned is that he made the classroom available for these meetings. How did that impact the project? What did it do?

Gillian: I think that if he didn't make the classroom available for us, we probably wouldn't've gotten together as much, because the library is kind of a long walk from here.

AM: the public library?

Gillian: Yeah the public library, and so...and the school library closes at, like, three every day...so that's not very...that's not a very good place to try and work on something cause you'll get kicked out right after you get anywhere.

AM: I was curious why, you know, teams don't seem to use school spaces like the library, and I guess that answers it.

Gillian: Yeah, they want us to get out of school...as fast as we can...like, people would just hang around in the hallways and the teachers will come and they'll be like, "You guys need to leave, you can't hang out here for long periods of time." (Malachite / Gillian interview).

Meeting in the advisor's classroom also meant access to equipment and supplies that could be useful, if not critical, for some tasks. For instances, Malachite students used scissors, colored paper, and the printer to print several sheets of paper for their poster boards during their last meeting, which took place in Nils's classroom.

Hosting team meeting also allowed the advisors to adjust how they engaged with the projects. Advisors varied their role in meetings over the duration of project work, typically progressing from more to less structure as the work progressed, and the risk of failure to complete projects decreased. Different roles implied different amounts of structure and capacity for agenda-setting. Examples of more proactive roles included scheduling regular meetings and actively scaffolding and facilitating meetings in order to address specific action items. Amy was more hands-on in this regard, scheduling weekly meetings and planning meeting activities as this comment from one of her interviews illustrates:

And so once I knew that [Kara] was on the right path and working with her mentor through her senior seminar I felt good to just kind of let go a little bit and just ask them questions when I saw them in class, hey how is it going, talk with so and so, um, and they seemed to be running OK; now we only have these bi-weekly meetings that I've scheduled now; I'll be able to sit and have more in-depth conversations with them, and

help them better. The first year I went with [to] IT I had one team, so I was easily able to meet with all those team members and talk. (Emerald / Amy advisor interview 2)

Less proactive advisor roles in meetings involved mere presence in the classroom for all or part of the meeting but not setting the agenda or otherwise directing the work. Merely being “around” proved a powerful tactic. First, it allowed students to come up with their own meeting agenda and work on tasks of their choosing, thus learning to exercise greater decision-making autonomy in the advisor’s presence. Second, being available to field questions also meant supporting students to the extent that they recognized a need for support and felt comfortable asking for help. Another indirect effect was produced when the advisor worked on something on a team’s behalf (e.g., making trip arrangements), while the students worked independently next to him or her. This illustrated and communicated to team the advisor’s dedication to helping them have a successful experience, thus motivating students to press on and complete the work on their end. As one example, during one of the Emerald team’s meetings in Amy’s classroom roughly a week prior to the competition, she was physically present but spent most of her time on the phone making transportation arrangements for the trip with school and district administrators. Although there was no direct evidence that her activities impacted the team’s progress, the implicit assumption in Amy’s *activity* was that the trip was going to happen, leaving few choices for the students but to press on and complete their project.

I observed another instance of students’ awareness of advisor’s work on their behalf during the Malachite team’s last pre-departure meeting, which took place in Nils’s classroom. Nils periodically rotated working in the classroom and in his office down the hall so that he could continue working on a computer while the students used the computer in his class to make last-minute changes to their presentation visuals. At one point, he called the phone in his classroom from his office and asked Gillian to close a document that was open on the classroom

machine so that he could work on it in his office. This stimulated some joking among the students on account of inadvertently locking him out of a document. As a result, the fact that he was working *on their behalf* became salient and was noted:

Gillian: [after hanging up the phone] Oh he just wants...he can't work on things in the other room because...we are logged on...on his thing. Or he had something open on here...and so...he couldn't work on it because it was open on this computer.

Molly: Oh.

Becky: He doesn't need to get any work done!

Gillian: He needs work...it's FOR US, HE IS DOING WORK FOR US!

Becky: Oh. [smiling]

Molly: Oh, well that's good! [smiling]

Becky: Nevermind then, yeah.[Molly laughing] (Malachite / Team meeting observation 1)

Such arrangement may be considered collaborative in the sense that although the advisor may have been working on separate tasks, both the advisor's and the team's work was directed toward a common purpose. It also afforded students opportunities to *help the advisor* by answering his or her questions and providing information; for instance, with regard to logistics planning, selecting what activities to do during their trip, and when to do them.

**Structure and Place.** As noted in the discussion of tension #1, the planned regular advisor-team meetings (weekly in case of Amy, bi-weekly in case of Nils) reflect movement from less to more structured process with structure imposed through consistency of scheduling, stability of the physical meeting space, and advisor presence. Project work progresses more smoothly with a certain amount of regularity in meeting frequency and team availability. The out-of-class format of participation in IT jeopardizes these components, by providing no pre-existing or prescribed participation patterns. It befalls the advisors and students to *create* such structure and an emergent project space. This, in turn, requires some improvisation.

Both advisors in this study tried to fit project meetings into the existing school structures, by allocating time for meetings in their workday and using their classrooms as meeting places. Nils accomplished this by integrating IT team meetings into the Science Club meetings, capitalizing on the existing overlap and alignment between the competition's bend toward STEM disciplines and the Science Club's mission of engaging students in fun, science-related activities. Amy's classroom was also well suited to accommodate IT teams since it was the site of instruction in chemistry where students were exposed to disciplinary content that could potentially be relevant for some of the projects. For instance, she observed in one interview:

AM: Did the project have any links to the curriculum ?

Amy: My curriculum? Chemistry? No...but kids are always intrigued when we talk about energy and chemistry, and...one of my things that I focus on is \*heat loss\*, and that 'there's always heat loss', and that seems to be like this common thread with kids, as, "Well how do we get it back? We have to be able t...to harness it!" And they don't really understand entropy all that much, so, um...but it's an intriguing thing that usually comes up in one project or another in Imagine Tomorrow, so, "We're gonna try and harness latent heat!" [chuckles] Ok, good luck! [chuckles] (Emerald / Amy advisor interview 3)

The practice of meetings with IT teams in the advisor's classroom may appear to impose some unhelpful limitations on project work, by constraining how the students could conduct themselves, and what they could do with the resources available to them in the typical classroom setting. However, no evidence of this was found in the interviews or the recordings of in-class meetings. On the contrary, it appeared to have an enabling effect. The advisor's classroom was a familiar setting for almost all IT participants where students felt comfortable to have project-related conversations. (One exception was Becky on the MHS team – I mention this in discussion of research question 4.) Having the advisor around and being limited on time also seemed to help students stay focused and get closure on some outstanding issues or tasks. Finally, the advisor could answer questions or assist with minor tasks such as tracking down contact information. Some students also took advantage of being able to make outgoing local

phone calls from the classroom using the district line. Overall, meetings with the advisors were not a one-way street of helping meet only the advisors' or the students' goals but served multiple overlapping purposes at once, to mutual benefit. Most importantly, perhaps, these meetings helped *align* the activities of the actors in the project activity system by creating affordances for and enabling the advising practice and the students' collaborative design practice.

### **Meetings with external stakeholders**

Student accounts in the interviews and data from the meeting observations indicate that the meetings with external stakeholders and SMEs may have catalyzed project activity in at least three ways: advance preparation, deeper and broader understanding of the project, and motivation. First, preparation for such meetings sometimes called for additional team meetings or conversations where students confirmed their plans and the questions they would ask. This provided the impetus to clarify the team's approach and outstanding issues, refine project goals, and discuss the way in which the individuals they are meeting with fit into or are impacted by the project. This process involved decomposition of abstract ideas into specific tasks, which helped uncover and convert gaps in students' knowledge into questions and information requests. Also, preparation required strategizing about who would be most qualified to answer specific questions, and in what order individuals should be contacted, thus giving students experience in planning and coordinating project tasks. Such preparation activities are illustrated by the following example of an exchange between students during one of the project team meetings:

*[Selecting and revising questions to ask in interviews with stakeholders among school staff]*

Gillian: I think we should just put, "Do you think it would reduce the waste..." for the lunchroom one, and then do the more specific one for the adults, because if...the students...we wouldn't really...they wouldn't really think past...significant...or they wouldn't \*know\* if it would significantly reduce the waste, 'cause they probably don't think much about it, they just like...

Molly: they also don't know what the waste output is for our school...  
Gillian: yeah, they don't know that either...  
Becky: this is something that we might wanna...  
Molly: find out and...  
Becky: if there's some...any way we can...if there's some way we can \*see\* the waste output before and after...  
Molly: Yeah...something to think of to add to our three-year plan for...data gathering... 'cause...

*[Assessing project impacts on stakeholders]*

Becky: And that might be a question that we can talk to...[head of school maintenance] about...  
Molly: yeah... 'cause...it would also probably help lighten his job, if less...  
Gillian: Well he'd probably still have to carry compost things out...of the lunchroom...  
Becky: it depends...  
Molly: Yeah...we'd just have to look...see what our system ends up being...  
Becky: yeah.

*[Clarifying wording and purpose of questions]*

Molly: so, "Do you think that a composting program would \*significantly\* lower the...amount of waste leaving the school..."  
Becky: Basically enough to make a difference...because it is gonna be...a different \*kind\* of work, and if the different kind of work is not...worth it, people aren't gonna be...interested in making a change...

*[Planning sequence of stakeholder interviews]*

Molly: yeah...OK, so...this is probably gonna be one that's just more of the general questions, and we also wanna follow-up questions towards Mr. [the principal]... 'cause he's the first person we're \*actually\* gonna like to interview... 'cause he already OK'd it for us to videotape him...[and we see so??] that last time we talked to him...  
[...]  
Molly: OK, so...more questions... 'cause we definitely need to interview...[the principal] first...  
Becky: we should really talk to the lunch ladies and [head of school maintenance] this week...  
Molly: definitely... [Gillian: yeah...] and then make the meeting...[...]

*[Deciding on approach for interviewing]*

Molly: OK, so...do we wanna inform them of our project?  
Becky: yeah...  
That might be helpful since we haven't told them anything about it... 'cause Ms. [last name] knows what [head of school maintenance] and the lunchroom staff don't know...

Gillian: [head of school maintenance] would?? wanna talk to us...

Molly: The one who said he's going home and then he stuck around the school for another hour...[chuckles] so...

Becky: So...something like, you know, "We are doing this project...for the Imagine Tomorrow competition, and we would like to...reduce the garbage...[??]"

Molly: We should probably ask them, like, how much stuff they think that they throw away that could easily be composted...

Becky: after we kinda talk about our...

Molly: Yeah, after we talk about everything...

Becky: after we introduce the project...I guess before that we should kinda like feel out whether or not they got any ideas about...composting, I'm sure some of them do, but...'cause if they don't, then we'd have to explain what can be composted before that question...

*[Interview preparation inspiring new ideas about project]*

Molly: And we're also gonna have to...compile a list of stuff that they \*can\* compost, just to make sure that way there'd be less sorting for us to do when we put in the bins...

Becky: Yeah...well I think that...the bins need to have like, what can and can't be easily...if there's ever a question, people can...

Gillian: Yeah we should put on the lids of the bins what can go in there...

Molly: And...

Gillian: And then like put signs up, maybe we can put up a paper in the kitchen or something... (Malachite / Team meeting observation 1)

Meetings with the stakeholders also helped students develop deeper and broader understanding of the project by learning valuable new information. The meetings provided an opportunity to hear different perspectives and learn about different aspects of the project which the team may not have been aware of or considered in detail. Gillian, a student on the MHS team, described this as follows:

We thought that we pretty much would be able to go to Mr. [name], who is our principal, and just say, "Hey, we wanna do composting," and then pretty much the next week just like go setup bins and start doing it, and we didn't realize what it would take to be able to do that, and all the people we would have to talk to, and I don't think we really even thought about talking to the students, to see if they would be OK with sorting their food into compost bins, because...like you can't put meat in there, so people would have to like put certain things off their plates into different bins...we didn't originally think of that so...now our project has turned into more of a behavioral project, where we're doing surveys and interviews. (Malachite group interview 1)

Gillian's comment indicates that meetings with the stakeholders raised students' awareness of opportunities as well as constraints imposed by the elements of the larger activity systems wherein projects were situated. In this case, meeting with the school principal was eye-opening with respect to the broader implications of their plans, thus transforming and making more complete their initially naïve understanding of the project. In this way, talking with the stakeholders impacted project scope. On one hand, the project scope expanded with the realization of the additional factors the teams would need to consider in order to realize their plans. On the other hand, the project scope was narrowed through the ability to better focus the team's efforts based on the new information and more clearly define the tasks that would help move the project ahead.

Finally, stakeholder meetings motivated the teams' efforts through support and encouragement of the students' ideas and intentions. As Ben, a student on the EHS team commented:

AM: Can you highlight any particular relationships that the project influenced for you, and how they came about?

Ben: Um, relationship with the district department of maintenance, the head dude there, he was super nice to us and he just helped us out as much as he could, and so...I don't know, I look forward to working with him in the future with the council and stuff...

AM: And how do you think that...do you think that had an effect on your process, how do you think it influenced it?

Ben: Um, I would say that his...enthusiasm and his being so...open to us and nice and everything definitely gave us some mojo, I guess, I and it like got us going, and some good motivation...it was encouraging. (Emerald / Ben interview)

Gaining support from the stakeholders in positions of authority provided external validation of the projects, thus inspiring the students and communicating to them that their efforts were acknowledged and valued. The willingness of district maintenance staff to explore options for instituting a composting program in a high school or the willingness of lunchroom staff to sort

the food scraps exemplify the adoption of practices to which both the adults and the students attributed value.

The notion of participating in the valued practices of the community resonates with the situative perspective on motivation (e.g., Greeno, 1998) and situated learning theory (Lave & Wenger, 1991), which view motivation as dependent on whether and how valued practices are negotiated and adopted. In sociocultural terms, by taking up (or at least, not rejecting outright) the students' ideas the stakeholders helped legitimize these ideas, thus converting students' project activities from disconnected practice into legitimate peripheral participation in a certain community. Such conversion also facilitates movement from less to more structured format of the collaborative design process (see Figure 12), by making the project activity system a part of, and thus aligning it with a larger activity system such as that of the school or the school district. Thus, meetings with the stakeholders reveal how projects might fit into larger activity systems, making students' activities meaningful and valued in the context of these systems. At the same time, this movement does not necessarily imply curtailment of student agency in the design process but rather enables their agency, by propelling the team from a position of relative ignorance and uncertainty over what to do to a position of informed capacity to execute on a feasible plan of action while leaving decision-making up to the students. While preserving their right to fail, becoming better informed through, and securing the sponsorship of, external stakeholders and SMEs earn the students a right to succeed.

### **Team-only meetings**

At the outset of my research, I thought that "team meetings" would be fairly similar and predictable in format – students meeting within their teams with all of the team members present, working for a predictable period of time, and then reconvening again at regular intervals. What I

found was that the notion of “meetings” for both focal teams turned out to be very fluid, encompassing different configurations of settings and attendees. First, the teams had “all-hands-on-deck,” team-only (no adults) meetings at pre-arranged times and locations. These locations included the school library, the school office, meeting rooms and open spaces at the local public library, and students’ homes. Such meetings typically lasted a couple of hours.

Second, there were team meetings with the advisor, characterized by various patterns of structure and supervision (as described earlier). Third, there were the meetings with external stakeholders (school/district staff), which provided opportunities for students to touch base before and after, taking advantage of being in the same place at the same time. For example, when EHS team visited a local elementary school and met with its principal, they also had a quick sync-up “meeting” in the parking lot afterwards.

Finally, students had brief opportunistic encounters around the school building during the day, such as during classes or study periods that they had in common, or during lunch. Malachite students brought up these interactions several times in the interviews when they talked about the spaces and occasions for communicating about the project:

Becky: But as far as like places, lately we’ve been...I don’t know, I have been everywhere, practically eating and sleeping it...

Molly: yeah...

Becky: I think every time you and I talk [points to Molly] Imagine tomorrow comes up...

Molly: yeah, it comes up somehow.

Becky: And I don’t interact with YOU a lot [points to Dana] but every time I talk to you it’s about this too...

Molly: So...even between classes when we see each other [refers to Becky] that’s what we talk about -- Becky: In the hallway.

Molly: We’re just walking down the hallway discussing ideas. And then we’re like “Ok bye, see you next period we have together.” (Malachite group interview 2)

On the Emerald team, Ben mentioned similar encounters when I asked about whether he interacted with teammates about the project outside of team meetings:

AM: How many informal conversations did you have, like here and there for a few minutes?

Ben: Um, fifteen? No...I bumped into [Seth], I don't know...

AM: When did you talk?

Ben: During chemistry.

AM: During class?

Ben: Yeah.

AM: Alright. Is that Ms. [team advisor]'s?

Ben: Yeah.

AM: How come?

Ben: I don't know, it's easy. [chuckles] (Emerald / Ben interview)

The students mostly used these brief chats for quick status updates and brainstorming. These occasions allowed the students to get around their different schedules and differences in electronic communication styles (e.g. not being in the habit of checking email, or not being able to text). They also prevented delays in decision-making, by facilitated quick vetting of ideas and just-in-time adjustment of approach in response to changes and each other's updates. Such meetings also allowed students who could not attend full team meetings due to scheduling conflicts to stay current on the team's activities. For example, Dana on the MHS team could not attend some of the "dedicated" team meetings due to a conflict with her school sport team's schedule. Although the students still had to give her updates during the longer meetings when she could attend those, she felt less disconnected thanks to other impromptu intersections with teammates at school. Overall, the variety of meeting configurations and spaces helped ensure continuity and regularity in project work in the out-of-class settings and helped students to maintain a certain level of engagement in their projects over time. In this sense, students' willingness to find ways to intersect with one another under different circumstances and at

different times represents an *adaptive strategy* for ensuring timely progress on and completion of the project.

In the remainder of this section I will use the term “team meetings” to denote the “dedicated,” longer meetings that the students had pre-arranged to work on their projects.

The interview and meeting observation data suggest that a large portion (and arguably the majority) of progress on the projects was made *in* the team meetings. Therefore, the team’s ability to hold more frequent or regular meetings meant making more progress with the project. The data suggest several explanations why the students were most enabled to make strides in project work during the team meetings rather than on their own time. These include norms for on-task conduct, confidence in tackling novel tasks, and most importantly, the capacity for enabling simultaneous, coordinated progress along all dimensions of CDP (project management, decision-making, communication, and collaboration).

First, the students’ busy schedules and conflicting priorities produced a scarcity of opportunity for holding “dedicated” team meetings. Examples of meetings’ interference with students’ other commitments and routines include Becky’s role in the arts program at MHS, Ben’s involvement in a community youth organization, and Dana’s weekend routine of spending time at home with her family. These contradictions were manifested in occasional absenteeism of some students at these meetings. The constraint of limited availability imposed implicit norms and expectations, namely, that meetings would be occasions for on-task behavior and close collaboration between the team members. These norms were helpful for students who did not engage in much independent work outside of the meetings to be productive and contribute to their project.

Second, working collaboratively gave students the confidence to tackle novel tasks due to the ability to share real-time feedback and verify whether they were on the right track in their approach to the task. The students made frequent use during meetings of the ability to literally co-construct artifacts. Such co-construction and negotiation – for instance, when working on common objects such as the presentation materials – supported continuous cognitive engagement with the task. In addition, members of the EHS team reported that the meetings presented fewer opportunities for distraction. The boys were less familiar with Kara, their team leader, and had no prior experience of visiting her home. The combination of these factors may have imposed additional constraints to help keep the conversations on task and disagreements to a minimum.

On the other hand, the casual, friendly relationships among the students on the MHS team were less restraining. In the post-competition individual interviews the students reported that they tended to digress and argue a lot, especially during meetings at Molly's house. It appears that the relatively more formal settings such as Nils's classroom or the public library provided more structure to their interaction and were associated with less off-task chatter and unproductive arguing. The differences between the dynamics of teamwork on the two teams suggest an "interaction effect" between within-team relationships and the project space: different teams were more or less efficient and productive in different settings.

Part of the difference was that on-task activity was *enacted* in different ways across teams. On the MHS team, the combination of friendly relationships, equally assertive personalities, and gaps in communication skills (notably, listening for understanding of each other's point of view) resulted in excessive arguing with one another, which caused inefficiency in teamwork. Nevertheless, the team managed to be productive despite much off-topic chatter. The friendly relationships gave each team member a "voice" at the table and kept everyone

involved in the decision-making process. Although, as the interview data suggest, the students tended to resent the unnecessary heated and protracted arguments, they also enjoyed the fun and easy-going atmosphere of their meetings despite all the disagreements. When I asked what she liked about the competition, Becky shared the following perspective on meetings:

AM: What did you like about participating in the competition?

Becky: Like...Pullman or the whole thing?

AM: Whatever you want to talk about.

Becky: Ok, I really liked...just...I really liked the group, and getting to spend time and...cause we did...we became, like...even kind of...a tighter-knit, yeah, closer...and so...I enjoyed spending time with them, and typically a meeting ended and we would stay for a couple more hours and just hang out...and so I enjoyed THAT part of it, I enjoyed working with my friends; and even when we were yelling at each other, it was FUN. Which is why the yelling wasn't a bad thing. (Malachite / Becky interview)

In contrast, the lack of a history of friendship between all members of the EHS team (except for Seth and Ben) and the relatively passive and non-confrontational approach by Kara in her leadership role produced a more reserved teamwork dynamic with more listening and less yelling than on the MHS team. One negative consequence that appears linked to this team dynamic was a latent misunderstanding and disagreement over which of the several PowerPoint presentations was more suitable for the competition event. However, after hearing each other's arguments, the students were able to resolve the issue and prevent any negative effects on the project presentation. The misunderstanding was resolved during the team's last meeting on the day before their departure for WSU. If the students had failed to identify this difference of opinion in that meeting, it may have escalated into a more stressful conflict during last-minute practice, and the quality of the team's presentation may have been adversely impacted.

Although both teams exhibited some gaps in collaboration skills, some of which may have impeded project completion under different circumstances, these shortcomings did not prevent project completion in these particular cases. On one hand, these issues did cause a

certain amount of resentment, thus impacting the overall quality of the competition experience for several of the participants. On the other hand, the face-to-face meetings facilitated *explication* and *resolution* of differences in ideas and opinions. By analogy, even though the ride was at times bumpy, the road – the in-person team meetings – ultimately led the teams in the right direction. The chief contribution of meetings to team success was that they helped establish *enough* intersubjectivity among the team members to complete the project.

In addition, the team meetings provided opportunities for students to work more efficiently on a variety of tasks which would have been more difficult or taken longer if done individually with communication through electronic means. An important reason for this was differences in preferred means of electronic communication, which added overhead by requiring some students to act as translators of sorts, converting messages from one medium (such as email) into another (such as a text or a Facebook post). By working face-to-face, students were able to make progress along all four dimensions of CDP. With regard to project management and decision-making, they created plans for what to do when and in what sequence, negotiated team roles, distributed and coordinated work, shared progress updates, and negotiated project goals and priorities. Planning proved to be an especially valuable part of the CDP as it enabled teams to proactively manage project scope. Planning allowed negotiating the importance of various components of the project, thus identifying which tasks must be done as soon as possible and which may be omitted or pushed back in the project timeframe or moved to a different phase of the project and competition cycle. The MHS team appeared more intentional in their approach to planning, in large part owing to Molly's tendency to thoroughly roadmap the work, track status, and make necessary adjustments.

With regard to hands-on design and artifact creation, the students brainstormed ideas, made sketches and drafted documents, co-wrote and revised documents (emails, survey questions, PowerPoint slides), analyzed, graphed, and interpreted survey data. The MHS team fused the planning and artifact-creation activities in one of their meetings by creating a timeline of the project activities. Collaboration on these activities during meetings allowed members of each team to develop shared understanding of their project’s components and their interrelations, thus achieving a level of coordination and efficiency needed to harmonize their object-oriented actions within the project activity system.

**Summary**

A summary of the three types of meetings and their respective function is provided in Table 14.

Table 14

*Three types of project team meetings*

<b>Types of Meetings</b>		
<b>With Advisor</b>	<b>With Stakeholders</b>	<b>Team-Only</b>
<i>Enabled achieving two goals:</i>	<i>Catalyzed project activity in at least three ways:</i>	<i>Two formats with complemented functions:</i>
<ul style="list-style-type: none"> <li>• ensuring regular and timely project progress</li> <li>• providing a flexible structure for advisors to regulate their hands-on involvement</li> </ul>	<ul style="list-style-type: none"> <li>• advance preparation</li> <li>• deeper and broader understanding of the project</li> <li>• motivation through support and encouragement:</li> </ul>	<ol style="list-style-type: none"> <li>1. “Dedicated” team meetings at arranged times and locations: <ul style="list-style-type: none"> <li>• extended planning, negotiation and detailed discussion of issues</li> </ul> </li> <li>2. Opportunistic encounters/ intersections at school: <ul style="list-style-type: none"> <li>• brief follow-up, status updates, and brainstorming</li> </ul> </li> </ol>

The project team meetings may be considered in terms of their two broad functions. On one hand, meetings *enabled* project completion. They organized project work by helping team members align goals, roles, plans, and activities. Meetings also enforced norms for focused, on-task behavior. In addition, they provided a safe place for tackling unfamiliar tasks such as co-constructing presentation artifacts, by enabling students to confirm task requirements (check if one is “doing it right”). On the other hand, meetings *disrupted* activity patterns, by interfering with students’ pre-existing out-of-school time routines. Successful resolution of these issues required flexible accommodation which represented an *adaptive strategy* for maintaining engagement with the projects.

#### **Research Question 4**

Research question 4(a, b) states:

4. a. What types of valued outcomes are associated with students’ participation in the Imagine Tomorrow competition?
- b. How do these outcomes intersect with the team’s ability to complete a project?

The analysis of research questions 1-3 suggests that project completion called on students to venture beyond their comfort zones in various ways, modify their established routines (e.g., schedules) and improvise, sometimes with the advisor’s help, methods for moving the project forward. These practices represent ways in which project participants engaged in the “valued enterprise” of project work and characterize the “communities of practice” around the focal projects in this study (Wenger, 1998). However, the analysis of the practices *per se* does not fully explain where the values that framed these practices originated. This issue may be addressed on the individual, interpersonal, and institutional planes. In this study, these are reconciled by considering the “valued enterprise” of project work from a systems perspective.

The preceding analysis identified and mapped practices to the tensions, contradictions, and *object*-related goals characterizing the focal project activity systems. By framing collaborative design practice in various ways, these factors have shaped and motivated strategies for project completion.

The preceding analysis suggests two general principles for organizing the project activity system in ways that facilitate project completion. The first principle involves balancing more structured with more agentic approaches to project work through supports that enable and inform but do not entirely dictate this work and through the alignment of team practices with the affordances and constraints of other existing activity systems. The affordances of the relevant activity systems include in and out of school opportunities and spaces for regular meetings and frequent check-ins with peers as well as access to relevant experts and stakeholders (decision makers, SMEs, mentors). Examples of constraints include the competition deadline and limited availability of some stakeholders. The second principle involves balancing project demands with other demands such as the students' individual and shared needs, priorities, and constraints. Student priorities that have been mentioned include working on personally relevant and interesting project topics but also ensuring feasible project scope. Recalling the theoretical framework of this study, in situative terms, these principles represent "principles of coordination in interactive systems" expressed through mutual "attunement" of individuals to social and structural "constraints and affordances," and vice versa (Greeno et. al., 1998; Hickey and Granade, 2004).

The principles of coordination in the focal project activity systems are enacted through adaptive strategies, that is, practices that enable successful project completion for presentation at the competition (the strategies are summarized in Tables 11 and 12 in the Research Question 2

Supplement section). From a situative perspective, these strategies represent attunement to the “standards and values” of the project participants and the relevant activity systems while at the same time negotiating and co-constructing these standards and values (Hickey and Granade, 2004). The preceding analysis illustrated the practices through which such attunement took place, thus enabling the attainment of the *object* component of the project activity system. However, beyond the project itself, the standards and values that framed the project activity system and the sources of these standards and values have not been described thus far in the analysis. The participants’ individual and collective goals and expectations associated with the competition as well as the actual (or perceived) outcomes achieved through participation in IT also framed students’ participation and practice trajectories. In particular, it is unclear how project completion related to other valued outcomes, i.e. the *outcomes* component in the project activity system. The valued outcomes and goals associated with participation in IT may be considered in terms of the participants’ criteria for success, such as what constitutes success for the project advisors and for the students, individually and collectively. Such account should clarify the elements of successful competition experience in a broader sense.

The standards and values salient to a project activity system encompass the expectations, goals, and priorities that are *contributed* to the activity system by its various components. These contributors or sources of standards and values may include the direct participants such as the students and advisors; the relatively more peripheral participants such as project stakeholders and SMEs; as well as other members of the community who might communicate values or otherwise influence the project. Other contributing factors include the existing norms and arrangements in the activity systems that the project activity system might be associated with, such as the competition organizers at WSU (through rules and guidelines such as the judging rubric), the

school and school district (through official policies and implicit norms), and home environments (through family practices, resources, and expectations). Finally, standards and values also surface within the project activity system in the course of project work. The analysis above suggests a number of values that have emerged through trial and error as part of the CDP, such as reliable task performance, open and timely communication, time management, advance planning, tracking the project status, flexibility in roles, subject matter knowledge, and good listening and public speaking skills.

Because the team members have been in contact with each other and their advisors before data collection began, it was difficult to ascertain whether particular goals or valued outcomes emerged through the process of meaning negotiation and coordination within the team or were adopted by the participants *a priori* based on experiences in other contexts. What is important is how these perspectives have shaped how students made sense of their project work and their competition experience in general. In the following section I focus on the standards and values of the direct participants, the students and advisors as they appear most proximal to the research questions and the preceding analyses and have the most robust grounding in the data. I provide a descriptive overview of the findings and illustrate the key points with representative quotes from the interviews. My primary goal is describing the extent to which project completion, the *object* of the project activity system was co-regulated (or not) with the standards and values (the valued outcomes) of direct participants in this system, which represent the *outcome* component in the system. These questions were most directly addressed in the student and advisor interviews whereas meeting observations appeared more illustrative of how and where the team negotiated and established priorities with regard to lower-level, project-related issues.

## Valued Outcomes: What Success Looks Like for Advisors and Students

In this section, I discuss the valued outcomes for the advisors and students in the focal project cases. The section is organized by team and participant. Students' valued outcomes are categorized into team-oriented and individual criteria for success.

**Emerald – Advisor.** The advisors' goals for the competition were mentioned in Chapter 4, "Project Case Profiles," and are also briefly elaborated here. Personal success for Amy in the context of IT was associated with exposing students to college in general and WSU in particular. As she noted, "most kids think WSU is in the middle of sticks, and that has gotta be you know, all your classrooms are in barns" (Emerald / Amy advisor interview 3). She wanted to unsettle students' preconceived notions about WSU and encourage them to consider it as a possible college choice – a goal she thought she may have already achieved:

Amy: Now I mean I've...there are lots of kids who end up going to WSU from [focal school name] High School. And maybe it's because of me, maybe it's not...

AM: Now there are more?

Amy: Oh yeah, yeah, easily I'd say...ten-fifteen percent more going to WSU in the last few years, than in years previous. Maybe because they...they hear my stories of what happened there; but also I think, um, having an opportunity to do this. (Emerald / Amy advisor interview 3)

With regard to project work, Amy's goal was to allow students to practice independent and creative thinking:

I'm getting kids to...do...think independently, think creatively about these projects; um, yeah, the perk an--the plus at the end is that we get to go to Pullman and have a great time, um, and then show people what they know. (Emerald / Amy advisor interview 3)

Amy also distinguished between the project serving as the means for exposing students to a university and for practicing thinking in these ways. She emphasized the latter where the project

served as the vehicle for pushing students' thinking, and college exposure was a secondary goal, although an important one.

When I asked Amy to speculate how the students saw success in the context of the competition, she mentioned the possibility of winning but gave more weight to the networking opportunities that the event afforded. However, her words indicate that she was the direct source of this new valued outcome, impressing it on the students in preparation for the event:

Well I think every team that goes would love to come away with a prize. But [the focal team] also had...and another team, the [team name] team I had, really appreciated and picked up on the networking piece they were allowed to do. They really...when we had our pre-presentation meeting the night before the event on that Friday night, um, I told them -- I said, you're going to be meeting people who you may see five-ten years down the road who will say 'Hey you look really familiar. How do I know you?' And you'll be able to trace back to this moment. My Gosh, you could be hired some day because of this connection you've made here and that common background. So it's always about who you know, not who you are. And so I think \*after\* the fact, when the competition was over, this [focal] team and my [team name] team \*really really got that\*. (Emerald / Amy advisor interview 3)

The valued outcome of networking, which Amy highlighted, also surfaced in student interviews after the competition event. Here is what Seth had to say:

AM: Could you highlight any particular relationships that the project influenced for you, or the connection you made?

Seth: [...] If you wanna talk about at the presentation, we had some people that gave us their contact information, not me specifically but Kara...

AM: you mean, judges and others...

Seth: There was judges and teachers that were like, you know this is a cool idea, we could do this in our school. Could you...could we email you and you'd give us the information that you've collected and things that you collected so we can try and implement this in our school. And that was one of the most rewarding parts of this project, was that the people were interested, and...um, the...the department of science head for the State of Washington was there, and she talked to us for a long time about what we were doing, and she said you know, hey, give me an ema--you know here's my

card, shoot me an email when you implement this stuff and when you implement the council idea, and I would love to come to a meeting and see how it's run, and you know, see what you guys are doing. (Emerald / Seth interview)

In her follow-up interview, Kara also pointed out the connections she made at the event:

AM: Since you returned from Pullman, have you been thinking about the project at all, or not too much? If yes, what has been on your mind?

Kara: I got an email from...a school advisor from some other school district that wanted copies of the documents that we had made, so they could start their own council or composting program...that made me happy [laughs].

AM: Is that somebody you met there?

Kara: Uhum. He was talking to--yeah I gave him my email. (Emerald / Kara interview)

The available data do not warrant causal claims about exactly what factors accounted for particular outcomes such as networking leads in the case of the Emerald team. Some of the students may have already been aware of the competition's networking potential; likewise, the networking connections which the team's presentation had generated may have happened regardless of Amy's emphasis on this element. At the same time, it appears that the Emerald students were more aware of the networking affordances of the competition event compared to their Malachite counterparts, and this corresponds with each advisor's relative emphasis on this aspect of the presentations. Based on the detailed coding of the segmented interview transcripts, in contrast to three references to networking outcomes of the competition in Amy's interview responses, Nils's interview responses contained no such references. Accordingly, whereas two of the Emerald focal team members (Seth and Kara) noted networking opportunities as one of the outcomes of the competition, only one Malachite student (Dana) did when I asked about the interactions or relationships that stood out based on their competition experience. She responded, "I think the judges also, kinda same thing, maybe a little less...they wouldn't be like, 'Oh hey you are that person,' but...they would like recognize the school" (Malachite / Dana interview).

Her answer also signaled less confidence in the efficacy of networking opportunities at the competition event compared to the Emerald students' responses. The Malachite students also reported no leads or exchanges of contact information with the judges.

The temporal order of the feedback-and-effect cycle in Amy's emphasis on networking opportunities at the competition and the consistent pattern of differences in outcomes related to networking at the competition between the two focal cases do suggest that advisors might be powerful influences on the students' value systems and how they frame their competition experience by orienting them to particular aspects of that experience. The effect of such framing (or "priming," borrowing a term from research on cognition) might be self-fulfilling prophecy: communicating or articulating (and thus validating) a valued outcome might make students more sensitive to and appreciative of that outcome, thus motivating them to (consciously or not) dedicate additional resources of time and effort toward a corresponding aspect of their performance.

**Emerald – Team.** Members of the Emerald team initially struggled to answer the question of what success looks like for the team. When I asked this question during a group interview near the competition deadline, the team was still actively working on the project. Seth's response reflected the teams' level of awareness of the big picture of their valued enterprise: "Good question. [...] I don't think we've ever really taken a step back and looked at it this way" (Emerald group interview 2). However, later the team did develop a shared sense of what constitutes success for the project. Kara described how this happened as follows:

Kara: As a team...I think just thoroughly doing the project and completing it, and then feeling good about it. And we felt good about it, because...not only did the judges like us, but we felt like we were actually making a difference.

AM: Would you say that [...] that's something that everybody shared as a goal – is it a fair description of that?

Kara: I think so, cause yeah, at the...during the presentation we were discussing how we're prob--most likely not going to win anything, but still we were doing really well, and [Seth] was like, 'Yeah, as long as we feel good about it it's fine', so. (Emerald / Kara interview)

This comment illustrates the negotiation and co-construction of certain standards and values which emerged as a result of interaction among the team members. In this particular case, another likely factor was students' interaction with the judges who instantly moved from peripheral (and almost hypothetical, behind-the-scenes) to central (and very public) positions in the project activity system. By doing so, they likely contributed their own (disciplinary, etc.) and “channeled” the competition's (through the scoring rubric) standards and values to the project activity system.

Seth corroborated Kara's view of the team's success as enjoying and feeling good about their presentation. Both he and Ben also extended the notion of team success to include project implementation at their school.

**Emerald – Individual Students.** Kara's personal goals and criteria for success included a “thoroughly done good project that was presentable, I guess I wanted that, as a product; and then since I was a leader, I wanted to be a good leader, so...yeah I guess...it was alright with that” (Emerald / Kara interview). For Seth, “Success [...] would have been winning it, to be honest with you. To be...to actually win a prize, and stand up on that...podium” (Emerald / Seth interview). Ben struggled to disassociate his personal goals from the team's, saying, “I'll feel successful when...I know...we've done the best we can, and that everything...I don't know [...] I definitely viewed it at a group level” (Emerald / Ben interview). Similarly, Will's response highlighted group practices, where “the biggest sort of indicator of success would've just...simply

been doing things, honestly, in a more timely manner...I mean, we were still doing things a little too close to the deadline...I mean we...severed a lot of our avenues based on just...how late we were doing things” (Emerald / Will interview).

Overall, there was a sense of incompleteness of the project among the students, and their reformulations of what success meant (e.g., feeling good about the project) resembled a coping strategy. This was reflected in Will’s perspective on success and underscored by Seth, who was unapologetic about his sense of where the project stood. Reflecting on the team’s accomplishments, he confessed:

The team...we had a half-finished project, it was what I felt like. We had a project that...could be a...you know, it needs more time, it needs more work, it needs more thought...and with that I think we could do really well and I think the project would be a success. Right now I feel like it's...it's almost like I was doing a school assignment and it was due...or I was doing an essay and it was due the next day, so I...rushed through it, and you know it was pretty good and it got me a...you know it got me a passing grade, but it didn't get me that A grade that I was looking for. It's almost the sense of...feeling a little disappointed, and more eager for next year...coming back with a...with something that I actually have done, and something that I feel good about, um, feel like I completed.  
(Emerald / Seth interview)

By getting an “A grade” Seth was obviously referring to winning an award. For him, success was as much, if not more, about the extrinsic motivation of formal recognition for the work, as it was about the intrinsic motivation of finishing the project for the project’s (or the school’s, or the environment’s) sake. Indeed, these objectives overlap with an award serving as a proxy for the project’s potential to make a difference. Another ostensible overlap was between Seth’s and the competition’s valued outcome since winning implies meeting specific competition standards based on the judging criteria. The missing link was having appropriate expectations for what level of performance warranted recognition.

In this case, the misalignment between Seth's orientation toward winning and the team's practices involved in completing the project became evident when it was too late:

[...] the day of, when we first walked in, we went to her [Amy] and we were like [advisor's name], what are we doing here, there's these giant projects and I don't know what they are doing over there but it's something to do with like a giant lawnmower that runs on...whatever they are running it on...[laughs]...ethanol or you know, that they created from blackberry bushes, I mean it's like, what are we doing here with our little composting idea? (Emerald / Seth interview)

This comment reveals a misalignment between the students' expectations (team standards) for what a competitive project might look like, and what they observed from looking at other projects (competition standards). After arriving at the competition the students had discovered that their perceived standards and values for project completion did not match their standards and values for participating in IT. The collision of the project activity system with that of the competition revealed a lack of attunement of the team's practices to the standards and values of the competition at large. This surfaced disconnect, or *discoordination* in activity theoretical terms, between the *object* and the *outcome* in the project activity system from the students' perspective. From Amy's standpoint, however, the discoordination may have been a moot point since the team's project and presentation met *her* criteria for success – the students likely had opportunities to think creatively and independently and had gained exposure to a college campus.

Exposure to the competition event became a rude awakening for the team, which simultaneously surfaced and became the first step in bridging the gap in standards and aligning the team's *object*-oriented activity with the valued *outcome* of the project activity system, which was contributed by the norms of the overall competition activity system and reflected in the IT judging criteria. Familiarizing the students with the judging rubric ahead of the event, sharing impressions from prior competition events, or connecting students to volunteer mentors who

serve as judges for the competition are some of the strategies that could help align the team's project work with the competition standards.

**Malachite - Advisor.** As noted in the Project Case Profiles, similar to Amy, providing college exposure for the students was an important overarching goal for participating in IT for Nils. He also appeared to adjust what he considered success in relation to specific teams. For the focal team, he prioritized gradual improvement over absolute results:

Nils: Well um, for this group, I feel they were pretty successful. Yeah they didn't win, but...to me that's a pretty small portion of it, and...they got better at a lot of stuff, and you know, I feel they were successful...they were...it's a \*sliding scale\* of course, I mean you get...degrees of success, but...it was \*worth doing,\* that's success to me. Like, it doesn't have to be \*"the best"\* for it to be worth doing still.

Speculating about what success may have meant to the students, Nils noted two factors: the possibility of winning an award and implementing the composting program. He stated:

I think that...they probably feel only partially successful, since they didn't win any money. But at the same time there were successes in getting the plan ready, I think success comes more \*here\* if the program gets implemented, like if they make the composting and recycling stuff happen, then this wasn't all just for a contest, it was like to actually \*do\* something for the school, which I think the kids care about. (Malachite / Nils advisor interview 3)

In general, the issue of winning figured more prominently in Nils's discourse compared to Amy's. In the post-competition interview when the advisors reflected on their and their students' experiences, the issue of winning came up 11 times in Nils's responses across multiple interview questions whereas Amy mentioned winning only twice. Amy did not seem overly concerned about winning, instead prioritizing the formative role of the competition in encouraging students to think creatively and independently about complex issues. As she put it, "My goal is always to see the kids finish. And that's...um, that they finish well" (Emerald / Amy

advisor interview 3). By finishing well she meant completing projects that reflected reasonable investment of time and effort but not necessarily winning. One additional reason for this could be that she already had a team win in one of the previous years, which garnered her some recognition as well as prize money to set aside as a resource for future projects.

Despite his preoccupation with the topic of winning, Nils seemed conflicted about winning as a valued outcome. On one hand, he identified with it as one of the goals an advisor should strive for:

AM: What were your goals as their advisor?

Nils: Ooh. That we...put in a better project than last year; that we have a blast at the event; um, that the kids learned science and how to work together on a problem; and of course it's a goal to try and win some money. (Malachite / Nils advisor interview 3)

On the other hand, as noted above, Nils valued the formative function of participation in IT, of allowing students to practice and develop skills and knowledge he considered important to the students. The contradiction turned out to be between Nils's interpretation of prize money as a valued *outcome*, and the competition's implicit *rules* around limited extent of advisor involvement, which enabled students to do more of the work on their own, thus reaping the competition's educational value. The following comment by Nils pinpoints the double bind of the conflicting demands that undergird this contradiction:

I don't think it's a...an advisor competition. I think it's a kid competition. And so...if we don't win because I don't put in enough effort...[laughs] that should be the way it goes! It should be riding on \*student\* achievement and \*student\* learning, and...student impressiveness, you know. Although, you see some of the projects that do well, money never hurts...and...an advisor's role I guess could be finding...funding for that kind of stuff... (Malachite / Nils advisor interview 3)

These comments suggest that although Nils considered winning a valued outcome because it provided financial resources for future projects, he lacked the leverage to promote winning (as

opposed to mere project completion). As of my last interview with Nils, this contradiction did not appear resolved. In conclusion he noted:

I hope they do this next year -- this contest -- I don't know if I am super excited about them doing the composting thing again, 'cause I'm a little worried about their chances.

AM: you mean if they kept working on the project...

Yeah, even if they kept working on it, I think that this was their year to beat out somebody else for--like they had the potential this year, next year...it might seem like too much the same hat, and not enough change. (Malachite / Nils advisor interview 3)

This position appears to partly contradict Nils's earlier statement about the valued outcome of project implementation at the school, which, in turn, carries the risk of sending mixed messages to the students. Reconciling this contradiction without trading off the benefits of project extension (implementation, etc.) would mean modifying one or both of the conflicting demands: either downgrading winning as a priority, or modifying the advising approach to support teams in ways that might increase their chances of winning by either extending a previous year's project or starting a new one.

**Malachite – Team.** Although Nils was more preoccupied with the idea of winning an award, compared to Amy, his focus on winning did not impact the students' priorities. Similar to the Emerald team, the Malachite team's perspective on success centered on project completion. When I asked what success looked like to the team in a group interview close to the conclusion of their project work, they said:

Becky: We're still here! [smiles]

Dana: I think success for the team would be like, we all understand everything and are able to get through to other people.

Gillian: yeah...

Molly: And success for the team is also ACTUALLY getting the project done?!

Becky/Gillian/Dana: yeah!

Dana: that too.

Molly: presentable...

Gillian: If we have, or if we get to a point where we're entirely presentable, or if the project is entirely presentable, then I think that's success for us.

Molly: yeah. [all nodding] (Malachite group interview 2)

The apparent lack of the transfer of Nils's preoccupation with winning to the team was that winning was more of a *personal* goal for Nils, and he succeeded in not letting it override his relatively hands-off advising approach. As he put it, "I don't treat it like, 'you GOTTA DO THIS, ah, its - yeah there's money up for grabs, but REALLY, you can't realistically think you're gonna win any of it...it's, it's...there's a lot of top notch competitors, and especially if you haven't gone before, it'd be a bonus'" (Malachite / Nils advisor interview 2). There is no evidence in the data that he communicated this stance to the students; rather, he used this statement to illustrate his own adjusted expectations about the team's chances of winning in the current year's competition, based on the quality of the winning projects he had observed in the past. Although he probably projected his concern for winning when speculating during the interview about what success meant for the students, his actual advising practices (discussed in the section on research question 1) came short of imposing this valued outcome on the team and were more attuned to the valued outcome of completing a presentable project of reasonable quality. The students apparently were on the same page.

At the same time, because their project plan spanned a three-year period, the students differentiated success for the competition's sake and success for the project's sake:

Gillian: Yeah, success for the project I think will mean that...the composting project has worked in our school, and we've been able to reduce the waste coming out of our school

and recycle more...and then the third year we're hoping to get the program into middle schools, and maybe elementary schools, and I think that would be success, too, to get our project so it works not only in our school, but...

Molly: that'd be a higher level of success, too...[Becky: yeah] that's more of a three-year, like, success each year.

Becky: and we definitely like...if we graduate, and the project is still, if the composting program is still like in place when we graduate, so that would be next year and the year after that. (Malachite group interview 2)

Thus the students were also on the same page with Nils with respect to another valued outcome that he had mentioned: project implementation in the school.

**Malachite – Individual Students.** Molly's personal criteria for success in the competition fully overlapped with the team-level priority of completing the project. In her own words, "I didn't really have any personal goals other than stuff we needed to get done, like...like little steps we needed to take to get the...overall project finished" (Malachite / Molly interview).

For Gillian, personal success also reflected team priorities:

Probably the same thing [as success for the team], I'd like our project really to...just work, and stay for a long time, because that's...that's really what would help the...that's really what would make the school green, what we're trying to accomplish is to...well more green...is, the waste reduction to continue, because if we...if it only lasts for like three or four years, then that's not really...that helpful to the environment or anything...and if it lasts for a long time, then that can be...really helpful...I think. (Malachite / Gillian interview)

Becky's notion of success for the current year's competition was associated with the expectation of continued work on the project in the following year(s). Her goal for attending the competition resonated with the effect of its attendance by the Emerald team, that is, of learning about the competition and aligning expectations:

[...] because we're gonna be taking it back again next year, and this is like our first--or it was our first year at it, I was pretty like laid back about...like, what happened, and so it

was just...it was just kind of a watch and learn year for me, I guess, just go and see what it was like, and...have a good time [...] So when I go back, I have an idea of what's happening, and...yeah, some experience. (Malachite / Becky interview)

For Dana, success corresponded with personal development in the areas of presentation skills, teamwork, time management, and subject matter expertise:

I would probably be...like...[sighs] trying to put into words...like, being there for my team, and actually...all of us working together...I think would be success for me...and, you know, know everything that you're going to say...

AM: I see...so kind of being prepared?

Dana: Being prepared, yeah...

AM: How about goals...your personal goals...did you have goals at the beginning, when you were just getting into this?

Dana: Yeah like my goals for this earlier were...not to procrastinate so much...like we did the year before, but...we didn't do that as much this year, which I am thankful for...and then also to...read some more on to the topic...because I knew a little bit about it, because my mom did the composting thing at our house but I didn't really know like, exactly how it worked, so...I looked up some of that stuff so I kinda have some background on it. (Malachite / Dana interview)

Dana's goals reflected her longitudinal trajectory of participation in IT during the previous and current years with many of the goals prompted by her team's experiences in the previous year.

Overall, the students' personal criteria for success in the competition may be described as not personal at all but rather, strongly aligned with the team's collective trajectory of refining the practices that made up project work. (This valued outcome was also aligned with Nils's goal as mentioned earlier, "That we...put in a better project than last year.") This suggests an intrinsic motivational orientation of working on the project for the project's sake and for the sake of mastering the practices associated with successful performance of related tasks and completing the project in accordance with the implementation plan. The team's standards and values for

their *object*-oriented activity appear well aligned with the competition's *implicit* standards and values since repeat participation, iterative improvement and expertise development (with specific project tasks and the competition in general – presenting, etc.) are likely to produce well thought-out, sophisticated projects and competent presentations. The students' criteria for success were at once personal, characterized by clear individual self-managed goals and “development plans,” and collective, contributing to the mutually valued enterprise of project extension and implementation. It may be argued that the trajectory of repeat participation in and of itself created (or at least facilitated) a more conducive environment for attunement of the standards and values among the various components of the project activity system.

### **Summary**

The valued outcomes for the advisors and students, organized by individual participant, are summarized in Tables 15 and 16.

Table 15

*Valued outcomes for advisors and students on focal project teams, by participant*

Valued Outcomes (goals, success indicators)	Emerald Project Team					Malachite Project Team				
	Amy (Advisor)	Kara	Ben	Seth	Will	Nils (Advisor)	Molly	Gillian	Becky	Dana
<i>Overall participation experience</i>										
- College exposure (general exposure to colleges and WSU in particular)	+					+				
- positive experience at competition: having fun, enjoying the trip						+				
- networking with judges	+	+*		+*						
<i>Learning and skill development</i>										
- independent and creative thinking	+									
- scientific knowledge and inquiry skills	+					+				+
- teamwork and collaborative problem-solving						+				+
- presentation skills										+
- performing well in given role (e.g. as team leader)		+								
- becoming familiar with how competition works (through attending and presenting)									+	
<i>Project-related outcomes</i>										
- improvement in quality compared to previous yr. project						+				
- completing project of reasonable quality for presentation; investing sufficient time and effort; presenting well	+	+	+	+	+	+	+	+	+	+
- sustainably implementing project			+	+		+	+	+	+	
- winning, recognition				+		+				

\* Likely transmitted by advisor to students

Table 16

*Valued outcomes for advisors and students, combined across teams for advisors and students*

<b>Valued Outcomes</b>	<b>Advisors</b>	<b>Students</b>
<i>Overall participation experience</i>		
College exposure (general exposure to colleges and WSU in particular)	+	
positive experience at competition: having fun, enjoying the trip	+	
networking with the judges	+	+*
<i>Learning and skill development</i>		
independent and creative thinking	+	
scientific knowledge/inquiry skills	+	+
teamwork and collaborative problem-solving	+	+
presentation skills		+
performing well in given role (e.g. as team leader)		+
becoming familiar with how competition works (through attending and presenting)		+
<i>Project-related outcomes</i>		
improvement in quality compared to previous year's project	+	
completing project of reasonable quality for presentation; investing sufficient time and effort in project work; presenting well	+	+
(sustainably) implementing project	+	+
winning, recognition	+	+

\* *Likely transmitted by advisor to students*

The analysis suggests that the valued outcomes of students and advisors who were direct participants in the focal project activity systems substantially overlapped with team-level notions of success. At the same time, differences emerged in participants' personal valued outcomes. The Emerald advisor's criteria for success privileged intangible, longer-term educational value of participation in IT while the students on the focal team, especially Seth, tended to prioritize more tangible, objective outcomes such as being recognized with an award and implementing the project. However, the students did also talk about the "soft" outcomes like getting a good presentation done, simply getting to WSU to experience the competition, and feeling like they were making a difference (which, to some extent, substituted actually doing so). Similarly, the Malachite team members' criteria for success resonated with some of their advisor's criteria such as completing and implementing the project, while diverging in other respects. One notable difference was the personal premium Nils placed on winning while his advising approach reflected an apparent double standard where mere improvement of students' practices and skills relative to their past performance (rather than the judging rubric) marked success.

The differences observed on both project cases reflect only partial alignment between the advisors' and the students' valued outcomes, exposing the project activity systems to the possibility of discoordinations in practice where attainment of the *object* (completion of a presentable project) may not yield the desired *outcomes*. Strategies for managing existing or anticipated discoordinations include clearer articulation of competition standards for project quality, as reflected in the judging rubric and represented by some (high-quality, winning) projects at the competition as well as more intentional communication and negotiation of individual goals between advisors and students.

## Chapter 6: Discussion

In this chapter I summarize the conceptual, theoretical, and methodological basis of the present research, contextualize and integrate the findings, point out the advantages and limitations, and suggest directions for future research. The next chapter addresses practical recommendations based on this study.

### Background

This study emerged from the recognition that despite substantial research on project and problem-based learning (PBL) instructional models in formal educational settings the collaborative design practice of students in project-based, out-of-class settings remains relatively understudied. This is especially evident in the context of STEM-oriented student competitions, which have proliferated in the recent decades as initiatives intended to supplement formal education with hands-on, realistic design and problem-solving experiences to provide students in the U.S. with skills for success in the 21<sup>st</sup> century global economy. A literature search on student competitions revealed no studies that closely examined out-of-class collaborative design practice, especially from sociocultural theoretical perspectives emphasizing the social and contextual aspects of design activity. The lack of such research has contributed to the reality where practice has outpaced theory with regard to models and principles for effective strategies for supporting successful student engagement in such projects. Defining success as the ability of a team to see a project from the initial idea to a presentable product, I chose to examine collaborative design practice (CDP) of high school students in the context of Imagine Tomorrow, a problem-solving and design competition in the Northwestern U.S., focusing on alternative energy and environmental sustainability. I asked the following questions:

1. What tensions characterize high school students' collaborative project work in out-of-school settings?
2. How do teams navigate these tensions in order to complete the project?
3. What role do the team meetings play in the collaborative design process?
4. a. What types of valued outcomes are associated with students' participation in the Imagine Tomorrow competition?  
b. How do these outcomes intersect with the team's ability to complete a project?

The study is grounded in an activity theory (Engeström, 1987), sociocultural (Vygotsky, 1987; Lave & Wenger, 1991) and situative (Hickey & Grenade, 2004; Greeno, 1998; Nolen, Ward & Horn, 2011) perspectives. I carried out a confirmatory, embedded case study with two cases, aimed toward theoretical generalizability through literal replication of phenomena across similar cases (Yin, 2010). The cases were two student project teams sampled from high schools near a major city in the Pacific Northwest. I gathered data about the teams' collaborative design practices through extensive semi-structured interviews with student team members and their advisors, meeting observations, and project documents, thus enabling cross-validation and triangulation of the findings. I used grounded theory (Glaser & Strauss, 1967), activity systems analysis (Yamagata-Lynch, 2010), and thematic analysis (Charmaz, 2006) to systematically examine and develop inferences from the data.

### **Putting Findings in Perspective**

As discussed in the Theoretical Framework in Chapter 2, Engeström (1987, 2001) considered the concept of motive important to an activity system, providing insights into understanding the system's hows and whys. If we consider the activity system of the IT competition at large, we can see that the *division of labor* within it prescribes certain roles and

responsibilities to the participants, thus governing their behavior toward specific *objects* without them necessarily being (or needing to be) fully aware of the *outcomes* (final objectives). Thus, it is the sponsors' responsibility to make funding available for the awards and for hosting the participants on WSU campus over the competition weekend, but they may not be aware of the participants' reasons and goals for competing. In turn, the student participants may not be fully aware of the outcome of being socialized into STEM disciplines or introduced to WSU as a potential college choice. The students may be more aware of the need to have some kind of project on alternative energy or environmental topic by a certain date and to show up on campus on that date to present it. Even though they may be aware of the overarching reasons for the competition, these are the reasons of the organizers, not the students.

At the same time, IT organizers do not dictate how specific teams should be formed, or what specific projects teams should complete, and how they should get there. The official rules and guidelines inform consideration of the possible ways for engaging with the competition. Examples of such guidelines include the project categories, the scoring rubric, and team size limits. Beyond these generic boundaries, the *competition* activity system is limited in influencing the *project* activity systems. Here the competition participants and the contexts where project work tends to be situated come into play. These factors include the project team, the advisor, the school, the school district, and the local community, among others. The *multi-voicedness* and *historicity* of the project activity system are evident in the conglomeration of these elements with each context and participant adding their own unique histories and rules to the mix.

Regarding the historical properties of and the interactions among activity systems, Engeström (2001) noted, "the division of labor in an activity creates different positions for the participants, the participants carry their own diverse histories, and the activity system itself

carries multiple layers and strands of history engraved in its artifacts, rules and conventions” (p. 136). This applies to an established activity system, but for a system that is generatively coming together, such as the IT projects, this might be reversed for some roles: the team members bring their positions into the nascent system and divide labor according to the positions and preferences which they introduce into the system from the outside (for instance, Becky established herself as the “compost expert” on the Malachite team; on the Emerald team, Ben preferred letting Kara handle email communication with external stakeholders and poster design). On the other hand, some division of labor (DOL) is built into the project activity system from the start before concrete projects begin to emerge. Such DOL stems in part from the competition rules, in particular a rule that projects should have advisors. The way DOL is enacted in each project activity system varies, however, depending on factors such as the individual’s advising style, goals, and institutional (school, etc.) structures within which the project is situated.

The project activity system exists on the boundaries of other activity systems and needs to be overlaid and coupled onto them in order to take root. This may be achieved in various ways. One approach involves repurposing existing tools and artifacts as objects of negotiation of the standards and values of the emergent project activity system in reference to other systems. I had initially anticipated that teams would orient themselves to the IT judging rubric, using it as a “boundary object” (Akkerman & Bakker, 2011; Star & Griesemer, 1989) to align project activity with the competition’s standards. The available evidence suggests that for the most part this was not the case. Although the students were generally aware of the rubric, it was not explicitly called out and systematically leveraged in project work. One hypothesis as to the possible reasons for this is that the teams had not realized the direct connection between the criteria in the

rubric and the scoring of the projects at the competition event by the judges, treating them as mere suggestions. Another explanation may be that the lack of a strong orientation toward winning among the students and the advisors rendered the rubric irrelevant to the project value systems.

To effectively engage in CDP outside of class, the teams also need to literally “push the boundaries” of existing activity systems in order to identify the relevant affordances and constraints and ferret out opportunities to repurpose structures, spaces, and practices to their ends. When students recognized this, they made progress on their projects. (Recall, for instance, the Malachite team’s ability to find workarounds such as piloting their survey questions online using Facebook, and later surveying students in person during lunchtime to get around the policy preventing surveys during class time; or Kara’s integration of the IT project work with her CE requirements at Emerald, thus gaining access to additional mentoring support.) I have referred to such practices as *adaptive strategies*, the efficacy of which for enabling project completion is indicated by their capacity for mitigating the *contradictions* arising from the systemic *tensions* in the project activity system. The tensions highlighted in this study are (a) between relatively more structured, advisor-directed design process and the less structured, emergent practices of the team; and (b) between the patterns of activity oriented toward experiencing the competition in a broad sense and the more focused orientation toward project completion. These tensions are associated with my focus on project completion – the “foreign” *object* associated with students’ decision to participate in the IT competition, in other words, involvement in the competition activity system. The contradictions, goals, and adaptive strategies associated with the relevant tensions are summarized in Tables 11 and 12 in the Supplement to Research Question 2 in Chapter 5.

The proactive “boundary-crossing practices” that team members must employ are risky, for they require flexibility and adaptability on the part of the team. As the analyses above have shown, these qualities characterize both teams in the two focal project case studies, as evidenced by the participants’ perspectives and practices. For Engeström (1987), the notion of *expansive transformation* pertains to expansion of the possibilities for practice, characterized by revision of established norms and routines. In the present study, signs of expansive transformation may be found in the students’ persistence and (predominant) flexibility in modifying their usual school and out-of-school routines to accommodate project-related activity. Rather than transforming any one existing activity system, their challenge was to stitch together a new one, while at the same time juggling many ongoing academic and extracurricular commitments. The flexibility in personal habits (e.g., Dana’s willingness to meet with Malachite teammates outside of her home on weekends, despite strong preference to the contrary) and readiness to “pivot” the project’s direction based on feedback from external stakeholders (e.g. Emerald team’s refocusing on composting and taking up the council idea) point to students’ capacity for improvisation, a trait of successful collaborative teams (e.g., Sawyer, 2008). The occasional pitfalls (e.g. Will dropping off the Emerald team at a critical time; Dana having to miss several team meetings due to a busy sports schedule), while signaling spotty time management and planning skills, at the same time underscored the resilience and commitment to success of both teams.

The practices for facilitating project completion, which I refer to as strategies, emerged within the project teams in the face of ambiguous scope, tight timeframes, novel tasks and subject matter, irregular availability and communication among team members, and spotty reliability in task completion. Although the adaptive opportunism and the nimble “pivots” in the approach may have been in part owing to desperation caused by the “hard” deadlines and other

rigid constraints (e.g. Kara's need to complete her CE in order to graduate), the data suggest that other factors played a substantial role as well.

The key to understanding *why* the teams succeeded in managing the issues they were faced with before these issues escalated into show-stopping disturbances in the activity (e.g., major delays or design impasses) may be in the situative view of motivation as contingent on social practice in context. As Nolen, Ward, and Horn (2011) observed, "although motivation has been studied developmentally, much of this research has looked at individual change with development (Eccles et al, 1993), rather than at change in individuals as part of systems" (p. 126). Such reappraisal requires consideration of the social processes accompanying motivational orientations. The loosely structured out-of-class contexts where the focal projects were situated explain nothing about the reasons for students' persistence and success in creating presentable projects in time for the competition. However, the interview and observational data allow charting the trajectories of practice, which offer some clues. One such trajectory is that the students were able to import certain identity elements such as interests, familiar resources, and competencies into the project activity systems. All of the students had at least some experience with environmentally conscious practices and were interested about making a difference in their local school contexts by helping transition the schools toward "greener" waste management practices. In term of resources, Kara incorporated the advice of her mentor; Seth leveraged his knowledge of school governance (when creating the council charter) and public speaking skills (when presenting at WSU); Becky recruited her intimate knowledge and hands-on expertise with composting on her home farm; Dana incorporated material from her mom's gardening books; and Molly negotiated a role for herself that allowed making use of her proclivity for planning and managing.

Another trajectory involved change in the meaning of project-related activity. Both teams' activities initially had the feel of independent, insulated experimentation. This may be said of the Malachite team's project in the previous year, or the Emerald team's unrealistically broad scope based on independent, unchecked brainstorming in the early stages of project work. As both teams were assisted by their respective advisors in reaching out to seek outside input, they found themselves acting alongside and with the acknowledgement of competent stakeholders – school principals, lunchroom staff, and district personnel. This outreach resulted in both teams breaking out of their molds and recognizing how their projects fit within the larger existing activity systems, thus breaking out of relative obscurity and moving toward more central, legitimate participation in their local communities and contexts. The cumulative outcome of these practices was that students had the agency (Hull and Greeno, 2006) to co-construct and identify with the goals, values, and practices of their teams.

Overall, the consideration of the social origins of motivation (e.g., Nolen, Ward, and Horn, 2011) suggests a two-pronged explanation of the focal teams' success in shepherding their projects from ambiguous ideas to focused presentations. On one hand, the focal teams were motivated to adapt their practices to the affordances and constraints of their contexts and the priorities of their communities because they were able to contribute to the “valued enterprises” (Wenger, 1998) within their teams and across their teams and their communities. On the other hand, the students were able to repurpose and adapt certain features of their contexts *to* their ends through active advocacy on their and their projects' behalf by identifying and using suitable spaces and resources. I refer to this bi-directional, dynamic adaptation as “reciprocal alignment.” This explanation of capacity for project completion entails individual as well as systemic components, implying that both the emergent project activity system and the broader, well-

established activity systems (of the school, district, etc.) wherein projects were situated possessed sufficient flexibility to accommodate the team members' improvisation and self-advocacy practices.

### **Advantages, Limitations and Directions for Future Research**

**Advantages.** This study has several advantages which pertain to the relevance of the findings. First, the majority of the new participants, and many of the repeat participants in IT engage in project work in out-of-class settings, not as part of formal curriculum. The same may be the case with other K-16 student competitions whose organizers, advisors, and student participants may find the insights from this research applicable to their local contexts. The recommendations for practitioners based on this study are covered in greater detail in Chapter 7.

Also, IT is no different from most student competitions in that the number of teams recognized with awards is relatively small compared to the total number of participating teams. Defining success as project completion rather than winning focuses the analysis on issues of relevance to the majority of participants, including advisors who have seen their students sign up for IT only to drop out later, leaving promising projects unfinished. The focus on strategies associated with effective project work implies a process orientation, emphasizing sustainable individual and team practices where the end does not necessarily justify the means, and students' impressions about the competition are not determined in a large measure by whether their team wins or not.

An additional, methodological advantage of the study comes from the similarity between the school contexts where the focal cases were embedded and between the teams' project topics, achieved through purposeful sampling. This reduced the uncertainty of the analytic interpretation and inference building, thus increasing the theoretical generalizability of the findings. This was

augmented by the ability to confirm meaning and triangulate the findings across multiple in-depth interviews with all of the focal participants, *in situ* observations of collaborative activity during the team meetings, and access to some of the teams' design and presentation documents and artifacts.

**Limitations.** A number of methodological limitations of the present study are worth noting. The emphasis on theoretical generalization implies a trade-off with the generalizability of the findings to specific contexts or populations. The confirmatory multiple-case study approach retains the possibility that the focal competition, community, and school settings were unique and constrained the range of phenomena that may be observed in different settings. The same applies to the unique individual characteristics of the study participants and the dynamics of their interaction. Finally, the relatively short project timeframes compressed the duration of research activity, limiting opportunities for tracking the developmental trajectories in collaborative design practice as well as the changes in students' perceptions regarding their projects and the competition.

**Future research.** Student competitions and other similar outreach programs represent a fascinating and fruitful platform for further research in education and other social scientific disciplines. Further research is required to address numerous remaining questions about the role of competitions in students' collaborative endeavors, disciplinary socialization, and formal and informal learning. Researchers may consider using different methods, for instance, fine-grained quantitative and qualitative analyses of interaction patterns on the teams or between the teams and advisors or external stakeholders. Attention might be given to the role of particular goal orientations, especially when the students or the advisor are highly oriented toward winning. The role of individual difference factors such as gender, identity characteristics, and communication

and collaboration styles framing teamwork dynamics in project-based, loosely structured settings are also worth exploring. Indeed, the situative perspective encourages deeper, more comprehensive accounts of activity *in situ* over the trajectories of participation in project work. Longitudinal studies of the stable and dynamic characteristics of collaborative design practice over multiple years and competition cycles may be especially productive in this regard. Such research should be more robust for addressing questions about the potential role of the competition in shaping student identities, interests, attitudes and academic or even career trajectories.

Overall, I believe that studying how and why students act in out-of-class settings provides insights about the upper limits of students' collaborative and design skills and competence that are informative for the design of collaborative learning environments and instructional models in formal academic settings (e.g., PBL). Knowing the signs of optimal student collaborative practice and having at one's disposal a number of evidence-based practices for supporting teams in their design and problem-solving pursuits can go a long way toward helping students successfully negotiate the murky waters of unfamiliar new experiences and activity systems, and navigate the raging rapids of agency over what and how to design, if given a chance.

Finally, in the present study, I focus on how projects develop from an idea to a presentable project within a given competition year rather than what mediates their full implementation or completion in an ideal sense (what exactly this means varies depending on the nature of the project and the available resources). Follow-up inquiries to the IT advisors who participated in this study revealed that neither of the teams ended up competing in the following year. I was unable to re-contact the students during that time, and the exact reasons behind these decisions remain unknown. Rather than speculate, I gave the teachers who were their IT advisors

an opportunity to comment on these teams' participation as well as the general status of participation in IT at their schools. I have secured permission to quote their responses, so they can speak for themselves. Here is what Amy wrote:

[Emerald] took teams the last [number of] years, but not this year - and that's my decision as I'm too busy with my [professional certification program], but I will definitely go next year!

Last years' team was a group of 5 girls who were very passionate about the garbage collecting company in our city and how antiquated their services are. These girls worked hard to research the costs associated with acquiring an all-in-one recycling sorter and tried to convince the local refuse collection company to purchase one. They even crunched the numbers to figure out how much our garbage bills would change to accommodate the large purchase.

[The boys from the focal team] never returned to IT as [Seth] and [Will] graduated that year. [Ben]'s interests took him to other projects his senior year.

There is still no composting program at our school but I know there is an interest in getting one started - but no outlet/reason to organize one outside of IT. (personal email correspondence, March 2014)

In turn, Nils replied as follows:

The team from [the year the study was conducted] never did get the ball rolling enough to introduce the concept to incoming Freshmen. There was likely some sort of roadblock that they couldn't or didn't feel motivated to work through. So...we have no composting as of yet at [Malachite].

I had no participants step up in [the year following the year the study was conducted], including [students on the focal team] so we didn't send a team to IT. All of them graduated in [year], and [Molly] earned a scholarship from IT to the tune of \$1000 which was exciting for me. She is playing in the [competitive music program] @ WSU this year and loving it.

In [year], I had teams boys, all freshmen. They seem keen to participate again, but since it is an outside school effort many lack the drive and organizational skills. I was able to support my teams significantly more last year however by having them come in during our "study time" period at the end of the day at least once a week to work in my room on their IT project. This helped greatly and I was able to push and prod and question effectively to get them to produce a project that was worth of taking to IT. Even with this, there is always a last minute push and doubt as to participation for teams.

"Roadblocks"--AKA excuses. Call it like it is. For some it is that prom is often on the same weekend. For others they are overextended with sports, course load, or work or

videogames. I am hoping to play a mentor role but not attend this year. I'm working on my [professional certification program] this year. The long distance is a bit of a barrier for us. To fully get the experience we need to be there for the whole of Friday, but doing that means leaving CRAZY early or Thrs night. We have left Thrs night with great success, but that puts more time away from my family unpaid. If our district helped teachers make this happen by supporting it better more teachers would be up for it I think. Overall, I think I will likely return to IT next year, and make a big push to get upperclassmen. (personal email correspondence, March 2014)

The above discussion and the advisors' comments suggest several questions. One question is why students abandon (rather than re-engage and extend) projects when they repeatedly participate in the competition. A related question is why students discontinue participation altogether. Yet another question is how best to support the *teachers* who spearhead participation in student competitions such as Imagine Tomorrow at their schools in their efforts to sustainably provide opportunities for their students to participate in these competitions. These questions are beyond the scope of the present study but would be worth exploring as part of a systematic program of research in the context of this and other student competitions.

### **Chapter 7: Recommendations for Practitioners: Strategies for Success**

By the estimates of the organizers of the Imagine Tomorrow competition, roughly one-third of the teams that initially register fail to show up on the day of the competition. This chapter focuses on suggestions for effective advising of student teams for the competition. As in the rest of this dissertation, I focus on teams that work on their projects in out-of-class settings characterized by limited formal structure and oversight although the recommendations may also be relevant for classroom settings. If there is only one chapter in this dissertation that practitioners who are already involved or consider becoming involved in student competitions have time to read, this is it. The primary audience for this chapter is educators such as high or middle school teachers who are directly involved in advising or mentoring students in the

competition. It may also be of interest to other practitioners such as volunteer mentors and SMEs in the community, whose impact on students' success in the competition should not be underestimated. Last but not least, the Imagine Tomorrow competition organizers as well as the organizers of other student competitions of similar format may find this information useful if they are interested in understanding the issues that students and advisors sometimes encounter in preparation for the competition, and what avenues for supporting the participants might be available to ensure a productive and positive competition experience for all.

In this chapter, I draw upon my research, including observations not included in the formal analysis, to share recommendations for advising practice that can be implemented right away. My goal is to promote reflection and, if needed, adjustments in advising strategies in order to help students have a successful competition experience. These recommendations cover the general strategic decisions regarding the advising approach as well as some nuts-and-bolts of guiding the teams.

The narrative is organized into three parts. First, I discuss two key challenges students face and related advising strategies. Next, I review several types of advisor support, in other words the project-related activities that advisors could facilitate. Finally, I cover a number of additional points for consideration, to supplement these recommendations.

### **Student Challenges**

Students face a variety of challenges in their out-of-class project work, especially if it is their first time participating in IT. (I discuss the benefits of repeat participation in the competition later in this chapter.) It is important for first-time as well as repeat participants to realize that not everything will necessarily go smoothly. Sometimes teams drop out of the competition in the early stages of project work because they experience difficulties working as a

team or are unable to identify a viable project topic. At other times, students may wait too long to begin work and realize shortly before the deadline that they don't have a project. In the latter case, the team has only two options: drop out and fail to attend the competition or salvage the situation with a last-minute attempt to complete a project of nominal complexity and sub-par quality. Both options are associated with lower overall benefit from the competition experience compared to a longer period of systematic project work.

The students themselves may not feel too disappointed about either of the two scenarios due to relatively low investment of time and effort on their part. From this perspective, the competition represents a relatively low-stakes context for messing up, and there is value in learning from mistakes. However, the advisors, especially if they are first-time participants, tend to incur significant costs from such outcomes, expressed in the (unpaid) time and effort spent researching the competition rules, handling paperwork, registering teams, and making travel arrangements. Both IT advisors in this study have had such experiences with their teams, and both have mentioned that they felt their efforts were at least partially wasted as a result. I believe it is possible to learn equally valuable lessons (about mistakes to avoid) from more successful competition experiences by building awareness of and preparing to anticipate and prevent or effectively resolve some predictable challenges before they escalate into major delays, high-stress situations, and show-stopping impasses. Therefore, although this chapter focuses on strategies for success in supporting students' project work, I believe it would be useful to present these strategies against a backdrop of some key challenges that students face.

Figure 17 shows the key areas where students tend to struggle. They include two major causes of inability to complete a quality project: time management and the scope or complexity of the project, which I also refer to as feasibility. The result of these two challenges is that teams

procrastinate until it is too late. Sometimes they drop out altogether or go into panic mode attempting to salvage the project. The students may neglect consulting the judging criteria, practicing, or thinking through all aspects of their presentation, which can raise the team’s doubt or anxiety regarding the merit of their project relative to other teams’ projects. This may cause stress, frustration, disappointment, and other negative emotions, resulting in a less positive overall competition experience. Indeed, such experience could become a valuable lesson for the team, especially if the students have an opportunity to learn from their mistakes and “iterate” on the competition, modifying their approach the following year. But it is fair to say that, as a rule, such outcome is less desirable and best avoided, if possible. In the sections that follow I offer a more detailed account of these challenges as well as strategies for mitigating their effects on collaborative project work. A summary of these strategies is also provided in Table 17.

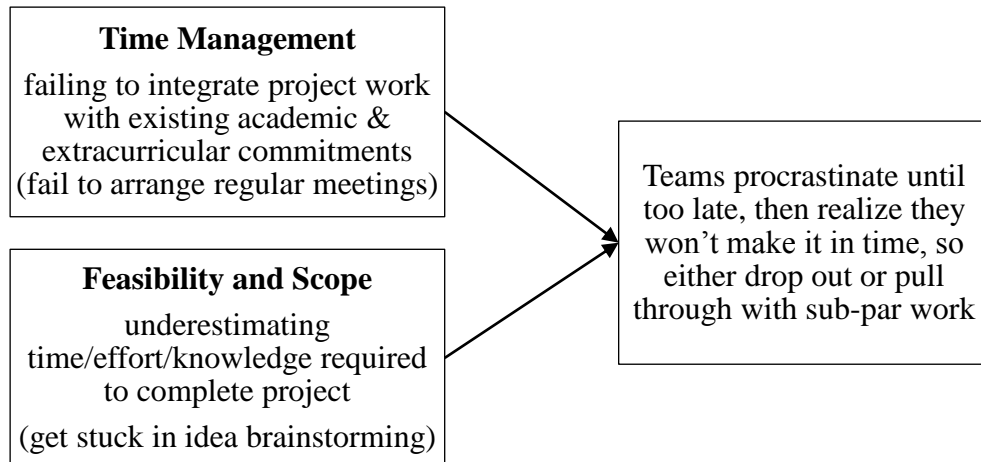


Figure 17. Some challenges students face in the Imagine Tomorrow competition.

Table 17

*Mitigation strategies for Imagine Tomorrow challenges*

<b>Time management</b>	<b>Feasibility and Scope</b>
<p><u>Mitigation Strategies:</u></p> <ul style="list-style-type: none"> <li>▶ Regular status checks with team leaders</li> <li>▶ Providing opportunities to meet (time/place)</li> <li>▶ Helping to identify and connect with external contacts (stakeholders, SMEs)</li> <li>▶ Setting expectations for time commitment by all team members (but stay flexible)</li> </ul>	<p><u>Mitigation Strategies:</u></p> <ul style="list-style-type: none"> <li>▶ Consult with stakeholders about structural or resource constraints, dependencies, etc. (budget, expertise, timeframe)</li> <li>▶ Consider a phased approach for project development/implementation (high quality on small scale better than the opposite; plan backwards from goals/deadlines)</li> </ul>

**Time Management**

Time management problems arise for a variety of reasons, but the major difficulty is inability to integrate project work with other commitments and priorities. Failing to meet as a team on a regular basis to work on the project tends to compound this problem. Some of the students in this study did their best work and were most motivated and able to stay on task when they worked together with their teammates. Thus, meetings may be used as one yardstick of progress. If students are not meeting on a regular basis – either among themselves or with any combination of other stakeholders, mentors, or whoever that has to do with the project – chances are they are not making progress or not being as productive as they could be.

**Mitigation Strategies.** There are various ways for helping students manage their time spent on project tasks. I would like to highlight four such strategies. First, teams are likely to have a student who will act as team lead, keeping track of project tasks and scheduling who does what, when, and in what order. That student is likely to be best informed about team activities and can be a good resource for the advisor to check in periodically and stay up to date.

Second, students who work on the project out of class might struggle to find a time and place for everyone to meet. Offering to use the advisor's classroom at specified day and time (weekly or bi-weekly) helps reduce the scheduling difficulties. The advisor may play a more active role in such meetings by suggesting particular agenda items and thus adding structure to the team's process, or a more passive role by merely being available to field students' questions. The advisor's presence also helps keep the students accountable for showing progress, by communicating to them that their teacher is making arrangements for them to get work done.

Third, the advisor might also assist with identifying external contacts that students might wish to reach out to as part of their information-gathering and research. Students may be inexperienced in navigating bureaucratic structures where they have to send formal-looking emails to adults. They might also get sent around some departments, for example, in the school district, which can be confusing for them as well. So finding the right individual can sometimes save them unnecessary frustration and avoid delays. This does not mean that the advisor should do all the legwork for the students – learning to communicate in a professional manner and navigate organizational structures is important. But some initial guidance to get them started should not hurt the learning process.

Finally, as the teams are being formed, it may be helpful to encourage students to discuss their availability over the coming weeks and months with their teammates, to set expectations for how much time each person would have available, and when they might be unavailable. Some students' schedules are more intense than others' with sports, clubs, and other extracurricular activities filling most of their out-of-school time. The students should be clear about each other's limitations with regard to independent project work as well as meeting attendance.

## Feasibility and Scope

Another major challenge is underestimating the time, effort, or skills required to complete the project. Students tend to err on the side opposite to caution when setting boundaries for what they would like to accomplish, and how soon they expect to do that. One early sign that students may be unable to properly constrain the scope of their project topic is if the team lingers too long in the idea brainstorming stage at the start of the design process. Students typically seem to overshoot their capabilities and, at least initially, set goals that are ambitious to the point of becoming unfeasible and lacking a clear roadmap to a solution. This ends up stifling progress. Some measures can be taken to make these expectations more realistic.

**Mitigation Strategies.** One strategy is to encourage students early on in the design process, i.e. as soon as they have settled on their project idea, to identify individuals who might be either impacted by their project or might have knowledge that could add value to the project. These could be other teachers or staff in the school or the school district, stakeholders in the local community, or university or industry professionals who are SMEs in the project topic. Consulting with such individuals can help students understand various constraints and process dependencies that exist in the real world, including issues related to costs, intellectual property, or timeframes of various activities. Such knowledge may prove essential to the team as students often have little idea about the factors involved in realizing their ambitious project plans.

Another strategy is to encourage students to think beyond the competition deadline and consider a longer time horizon for their project. What would they ideally want to accomplish? What would constitute definitive success of their projects? Once they have that as a point of reference, they can estimate some milestones for partial or phased implementation of their ideas. For instance, one phase of the design process might involve research and conceptual design of a

product or process; another phase might involve prototype development and testing; then after that, pilot implementation, and only then full roll-out to the intended users or consumers. There have been competitive projects at the IT competition representing any one of these phases of completion. Realizing this can help overcome getting stuck in the “all or nothing” mentality, and trade scope for quality.

### **Types of Advisor Support**

In this section I summarize several ways advisors might support their teams. The section also includes a number of “factors to consider,” which reflect additional lessons learned and best practices that have emerged from this study.

**Rules and Logistics.** First, advisors provide support with trip logistics, handling all the paperwork and consent. It is a good idea to check early to ensure parents of participating students are well aware of the trip component of the competition, so there are no surprises later on. It is also important to make sure students are aware of all the key facts of the competition, such as that there are monetary prizes; that there is a rubric for scoring their projects; all the key deadlines; the length of the drive to Pullman; and what kinds of activities are available during their stay on WSU campus. Having a clear understanding of the format of the competition event, the standards of the competition with regard to project quality, and judges’ expectations based on the scoring rubric are important elements of successful participation in IT. Often the students do not bother to carefully study the IT website, which contains a variety of helpful information. Students should be encouraged to visit the site multiple times and explore all links and pages. This is especially relevant for first-time participants.

**Initial Brainstorming.** Advisors also tend to play an important role in setting a direction for the team by participating in or facilitating early brainstorming of project ideas. This can take

different forms such as doing online research collaboratively with the students in the library or sharing examples of projects (the slideshows and videos available on IT website allow to catch a glimpse of some projects). At the same time, it is important to allow students to exercise independent thinking and decision-making to allow them to iterate on their ideas through feedback and revision with external experts and stakeholders.

**Networking.** Another type of advisor support is assistance with networking with the project stakeholders and SMEs in the community. In some cases I have called this “sponsorship.” For example, if the students do not feel comfortable contacting someone (like their school principal or district staff that may seem unapproachable) the advisor might help arrange or accompany the team to the first meeting. Finding a contact’s email address or calling the principal on students’ behalf to setup a meeting time can go a long way in catalyzing student work on the project.

**Enabling Team Meetings.** This type of support elaborates what I mentioned earlier, in terms of providing a meeting place or perhaps even scheduling and facilitating team meetings in the advisor’s classroom. The meetings with the advisor should not necessarily be the only times when the students get together to work on their projects. Rather, such meetings should complement students’ out-of-class project work. Meetings where the advisor is present achieve several goals at once. First, they help the team come together at the same time and place to check in with one another. Second, they make the advisor available to answer students’ questions. Also, they provide an additional opportunity for status-checking with the team leader and the whole team.

**Progress Monitoring.** Monitoring the team’s progress is a simple yet powerful practice. It acts as a motivational press on the team and the team leader in particular to make tangible

progress with the project tasks, thus adding a degree of accountability. It also helps the advisor stay up-to-date of any changes in the team or the project, such as project category, title, or if someone drops out or is added to the team. Such changes might impact team registrations with the competition organizers. I have mentioned status-checking or progress monitoring in the context of advisor-team meetings. If such meetings do not happen frequently enough, it can also happen on other occasions during the school day, such as before or after a class that some of the team members might have with the teacher who is also their IT advisor.

**Planning for Practice.** As the saying goes practice makes perfect, and presentations are no exception. Skipping this step might seem harmless, but it can undermine the team's presentation to (at least) the first judge and result in scores that are lower than what the project might actually deserve. Mock presentation can take many forms. Relatively more formal arrangements might involve some other teachers, district staff, or outside experts coming in to judge the projects using the IT scoring rubric. An example of a less formal arrangement might be the students setting up their projects in front of the cafeteria and chatting about them with other students. Although all judges use the same rubric, they differ in what aspects of the project they emphasize in the conversation or consider most indicative of the project's merit. Practicing not only helps to work on team coordination and individual public speaking skills, but can also reveal gaps in the design and provide insights on how to improve the project.

**Making the Most of the Trip.** I have found that exposing students to a college campus was among the advisors' top goals for participating in the competition, sometimes trumping that of winning an award. The competition event offers students a unique opportunity to see and learn about the interesting work that others have done. It allows them to directly compare their and other teams' presentations on similar topics, and thus develop a better understanding of the

presentation's strengths, as well as areas for improvement. The competition also may present opportunities for students to interact with other teams. Students who have a history of successful project completion (as well as winning) may be eager to share their IT expertise with the newcomers. Such interaction is likely to be a win-win, allowing the new teams to learn from the competition "veterans" while allowing the experienced participants to step into mentoring roles and share their own lessons learned and strategies for success. (If a school has a history of IT participation, such transfer of expertise may also be arranged in-house, preferably early in the competition cycle. This would help ensure that the accumulated experience with the competition is recycled rather than lost when students graduate or otherwise drop off the advisor's radar.)

Beyond the competition itself, time spent on campus may be utilized for activities to help students gain a deeper exposure to college. Whether it is a tour of the university library or a research lab or a meeting with a faculty member from one of the departments – such experiences may be firsts for some students, giving them a better idea about the college lifestyle or a particular academic discipline.

### **Factors to Consider**

**Participant Demographics.** The ways advisors recruit students for the competition impact what kinds of students end up participating. One common strategy is to promote the competition in the classes the advisors teach, which typically represent STEM subjects and science in particular. Since the classes one teaches are related to grade levels, this has implications for what kinds of students end up on the teams. On the other hand, diversifying the teams based on grade level helps build-in continuity into the participation patterns so that the collective experience and knowledge related to IT participation are not lost when students graduate. To expand the pool of potential participants, advisors might collaborate with other

teachers in (or outside) their department to promote the competition. (One note of caution is that students on mixed-grade-level teams may find fewer opportunities to intersect during the school day for quick informal check-ins outside of the all-hands-on-deck team meetings. Students on such teams may find themselves having to depend more heavily on electronic communication. To be effective, such communication requires students to be reliable and flexible users of different technologies and forms of online communication – texting, email, etc.)

A related consideration involves the kinds of students who may end up *not* participating as a result of this strategy – for instance, a particular demographic that tends to be underrepresented in a given class or subject area. The same limitation applies to other contexts (e.g., the Science Club in one of the schools in this study). One approach may be to advertise the competition widely at the school through morning announcements or the school paper. Still, some students may feel awkward about jumping into an unfamiliar context with an unfamiliar teacher. The situation resembles the proverbial “catch 22” – students are more likely to participate in IT if they know the advisor (e.g. have taken or are currently taking his or her class), but their best (or only) chance to get to know the advisor may be by joining an IT team. In these cases, social connections and friendships among students may be the deciding factor. Students tend to team up with students they know. Thus, attracting certain kinds of students may involve focusing on one or two such students who are most likely to join, and their friends will follow suit.

**Number of Teams.** Student awareness of the competition at any given school tends to spread with time as more teams experience the competition over the years. After the first year or two of participating in IT, new participants are likely to be attracted to the competition by hearing positive feedback about it from their peers. The desire to participate seems to be

associated with whether those who have gone before had a positive overall experience at WSU. Whether those who had gone before won any awards appears less important. Advisors who went out of their way to ensure their students enjoyed their trip to WSU campus may see an upsurge in initial student interest the following year (the competition caps attendance at eight teams per school). This may create mixed emotions as advisors weigh the demands of time associated with coordinating more teams and tracking progress on more projects. It may be easier for one or two teams to slip under the advisor's radar and procrastinate or not get the support and feedback they need to produce a quality project. Determining the optimal number of teams an advisor might take on can change from one year to the next and involve balancing concerns over equity in student participation with other personal and professional commitments as well as the estimated time demands required by providing quality advising support to all teams.

**Effective Teams.** Several factors seem to make a difference in how well a team works together *to complete a project*. Friendship alone is not enough. Students may have a great time simply hanging out together and brainstorming wild ideas for a project. Using meeting time productively to make progress and complete a project on time is a different matter. The most effective teams seem to be those where the students (a) know one another or are friends; (b) bring complementary skills and knowledge to the project; (c) approach their roles flexibly, i.e. do not mind pairing up on tasks or adjusting their communication styles to meet the team's needs; and (d) have some overlap in schedules, providing opportunities to intersect and "check in" with one another during the day at school. With regard to complementary skills, an important consideration for teams is having one or two members with good leadership skills, capable of driving the collective effort through planning and organization of the team activities. As one of the advisors in this study noted when I asked what affects how well a team works together,

“Organization skills. I think enthusiasm can only take you so far.” To ensure a good mix of skills, advisors may elect to have students apply for spots on project teams, filling out paper questionnaires or interviewing with one another. Such strategy may work best when students participate in IT as part of a class and are therefore more constrained in terms of who they get to team up with for a given project. In out-of-class settings, advisors typically let students self-select into teams though they may facilitate this process by arranging initial brainstorming and idea-sharing meetings in their classrooms for all prospective participants.

**Advisor’s Support Network.** Participation in IT is a multifaceted undertaking, requiring efforts on multiple fronts. The responsibilities may seem daunting, especially for first-time advisors: coordinating paperwork, team registrations, and trip logistics; recruiting participants; providing opportunities and space for team meetings; finally, supporting the design process by providing feedback, helping students network around their projects, and arranging opportunities for practice with presentations. To accomplish these tasks, it may be beneficial (indeed, necessary) for advisors to create and sustain their own support network. Such network may consist of individuals in a variety of settings and positions. For instance, advisors may need to secure support from the school’s Principal to obtain financial assistance with transportation for the trip to WSU as well as potential data gathering by some of the teams at the school (e.g., surveying the student body, interviewing staff). The Principal might also be interested in helping raise awareness about the competition by recognizing the participating students at the end of the school year. In addition to school administration, the advisor might also reach out to colleagues such as teachers in his or her department, to assist with promoting the competition, acting as SMEs for the teams, judges at mock presentations, or chaperones for the trip. Outside of school, advisors might use their contacts in the local community to connect students with working

professionals who are SMEs in the fields related to students' projects and may be willing to serve as volunteer mentors. Following the competition, to ensure on-going support in the future, students might wish to write Thank You cards for all adults who have directly or indirectly contributed their time and expertise to their competition experience.

### **Benefits to the Students**

In conclusion of this chapter, I would like to point out what students stand to gain from participating in a competition like Imagine Tomorrow, and, accordingly, what they stand to lose if they drop out for reasons that could have been anticipated and possibly avoided. This discussion foreshadows my final recommendation on the advantages of supporting students' repeat participation in the competition. Although no two student competitions are exactly the same, and no two participants' experiences in such competitions are exactly alike, there may be some common elements in terms of benefits to the students. Below I mention several factors that have surfaced in my research and first-hand experience as a competition judge and mentor with regard to what students get out of participating in IT and probably other similar, university-sponsored student competitions as well.

**College Exposure.** In my study, college exposure emerged as one of the chief objectives that advisors have for doing Imagine Tomorrow in the first place. Many students have not had the benefit of exposure to the college environment. They might have simplistic or biased notions of what life is like on a college campus, and – this is important – how they might fit into such an environment. They might not know what opportunities are available at different universities. From this perspective, attending the competition event on WSU campus in Pullman represents a low-stakes opportunity for students to “try on” a college lifestyle. For some, it serves as a point of reference, against which they can gauge their experiences on other campuses (assuming they

will have such opportunities). Or it might give them a target – a “prototypical” campus experience to work towards academically. WSU provides this opportunity at virtually zero cost to the students, a feature quite unique for a STEM competition, and quite commendable. The corporate sponsors share the credit for this as well.

**Skills and Knowledge.** The second category of benefits is all the experiences students get to have while actually working on their projects, prior to the competition event. One clear benefit is energy literacy – the capacity to think critically and constructively about environmental concerns at different scales, to reflect on their personal everyday practices, and the environmental impact of their and their peers' behaviors. Beyond that, there is a long list of skills: teamwork, personal responsibility, managing multiple competing priorities and demands on their time; communication skills as they interact with one another, their advisor, and whatever other adults they might interface with (SMEs out in the industry or the community, school administrators, etc.); project management skills, including leadership (because someone on the team has to be in that sort of role); skills with various technologies, or practices, depending on the technical or procedural nature of the project (whether design tools or scientific measurement techniques); and so on.

### **Advantages of Repeat Participation**

This section addresses the advantage of a long-term outlook on the competition experience where participation extends beyond a single competition year and instead develops into a pattern of repeat participation. There are several reasons why this appears important. One is that as far as I could tell from conversations with advisors and students who had gone before, students that get the most out of their competition experience are those who participate more than once. There are practical advantages to repeat participation, such as opportunities for

iterative revision and refinement of the projects. Of course, iteration and revision based on feedback is a key part of effective design process. One example is software development, where the first version of an application is rarely the best. In scientific research, the first tests are rarely the last, as well. Feedback-and-revision cycles are critical for learning how to be successful engineers, scientists, technology professionals, writers, and artists.

**Toward Deeper Learning.** Not all students might be able to participate repeatedly (some might be graduating, etc.). Teams might also decide not to continue with a project from the year before but to do something different. In any case, some continuity in the participants, or ideas, or skills that they gained will be carried through and will form the “knowledge capital” that will give them a running start in the future. Long-term participation should also have a greater impact on student learning, providing plenty of opportunities for students to make mistakes, adjust their thinking, increase the depth and breadth of their knowledge of particular topics, and so on. This translates into developing real expertise in a particular area, whether it is teamwork, communication skills, project management, knowledge of subject matter, or knowledge of research or design methodology (e.g., the importance of a data-driven, empirically grounded inquiry process). All this before even graduating from High School! Finally, repeat participation can prove rewarding for the students as it increases their chances to (1) have their hard work recognized with an award; (2) be in position to share their competition expertise with peers by taking on mentoring or leadership roles in the following years with students participating for the first time.

**Toward a Better Project.** If repeat participation is not feasible for some reason, it may still be possible to build-in elements of such iteration and revision within a single competition cycle. One way is by offering student an opportunity to give mock presentations at their school

and receive feedback from adults such as other teachers, district staff, or outside mentors. Such experiences offer opportunities to refine presentation skills, identify and fill in gaps in the projects, and to become better acquainted with the judging criteria (the importance of which tends to be underestimated by the advisors and the students alike). All of this suggests that it is important to adjust expectations – to ensure that students understand that however much progress they made *this year*, there is always room for growth. Thus, it is important to maintain such long-term perspective and work not with an eye toward the May deadline *per se* but toward a higher-quality, more sophisticated project. Of course, the deadline must not be ignored, but neither should it be the final frontier for a project or a team.

**Winning.** Although my research does not focus on winning as a measure of success, there is nothing wrong with an orientation on winning if it helps a team produce a solid project. Recognition and money can be motivating for some students and advisors who tend to be naturally competitive and for whom the worth of the time invested in a project is measured in part by the probability of receiving an award. But winning typically requires a fairly high level of performance, which, as I mentioned, is more likely for teams that have reaped the value of repeat participation by gaining the knowledge of how the competition works and what to expect as well as the experience of collaborating on complex, ambiguous projects in distributed (in and out-of-class) settings.

## **Summary**

In this dissertation, I have used a broader definition of success than might be expected in a study of a student competition where substantial monetary prizes are awarded for top projects. The definition I have used is applicable to not just the winners but to the majority of teams that compete in Imagine Tomorrow. It involves getting to the competition with a reasonably high-

quality project. Whether a project wins or not is not critical here because the students are still going to learn (recall the notion of “productive failure”) and gain transferable skills. From this perspective, whether or not they walk away with a monetary prize is not necessarily an indicator of learning or of the overall quality of their competition experience. On the other hand, quite a few teams end up dropping out and don’t make it to the competition event. My interest in this particular study was not in why teams fail, but why and how they succeed in terms of carrying a project from an idea to a ready-to-present product. In this chapter, I have discussed some of the challenges students face as they work on Imagine Tomorrow projects in out-of-class settings, and the strategies that should help advisors support their students in completing their projects. I hope advisors will consider these recommendations as they strategize and plan a trajectory of their and their schools’ involvement in Imagine Tomorrow as well as any other student competition.

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## Appendix A. Bibliography of Peer-Reviewed Research On Student Competitions

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## Appendix B. Criteria for Judging Projects in the Imagine Tomorrow Competition

**Total points possible: 25**

### Objective

**5 points:** The objective was clearly stated and is relevant to the competition challenge in which it was entered. The proposed solution is workable and would be acceptable to the typical user.

**4 points:** The objective was clearly stated and is relevant to the competition challenge in which it was entered. The proposed solution is workable but may not be acceptable to the typical user.

**3 points:** The objective was clearly stated and is relevant to the competition challenge in which it was entered. The proposed solution may not be workable.

**2 points:** The objective was clearly stated and is relevant to the competition challenge in which it was entered. The proposed solution is definitely not workable.

**1 point:** The objective was clearly stated, but it is not clear why this project was entered in this particular challenge of the competition.

**0 points:** The objective was unclear. I don't know what this project is trying to accomplish.

### Creativity

**5 points:** The project shows original thought and incorporates a novel approach to the problem. Techniques and/or ideas are used in ways that I have not seen done or suggested before.

**4 points:** The project shows original thought and incorporates a novel approach to the problem. It builds on existing techniques that are being discussed as potentially useful for solving the problem.

**3 points:** The project shows original thought, but attacks the problem from a standpoint that other researchers have already begun investigating. The idea has potential however.

**2 points:** The project shows original thought, but requires approaches and/or technologies that are simply not practical at this point. The idea has long-term potential however.

**1 point:** The project simply builds on ideas that others have already advanced. It could make a contribution toward solution of the problem, but a minor one.

**0 points:** The project is a simple replication of work being done by others. No original thought seems to have gone into the work.

### Inquiry

**5 points:** The project offered a clear and testable question. The procedures were well thought out. The methods for evaluating the question were appropriate. The team recognizes the limitations of their study, and presents ideas for follow-up research.

**4 points:** The project offered a clear and testable question. The procedures were well thought out. The methods for evaluating the question were appropriate. The team recognizes the limitations of their study, but does not seem to have ideas for follow-up research.

**3 points:** The project offered a clear and testable question. The procedures were well thought out. The methods for evaluating the question were appropriate. The team does not note any limitations of their study, nor do they seem to have ideas for follow-up research.

**2 points:** The project offered a clear and testable question. The procedures were well thought out. The methods for evaluating the question can be improved. The team does not note any limitations of their study, nor do they seem to have ideas for follow-up research.

**1 point:** The project offered a clear and testable question. The procedures were not well thought out. The methods for evaluating the question can be improved. The team does not note any limitations of their study, nor do they seem to have ideas for follow-up research.

**0 points:** The question driving this project is either unclear or not truly testable.

### Thoroughness

**5 points:** The team demonstrates an understanding of the scientific literature that is appropriate for high school students. They are familiar with different theories that are germane to the problem. The approach they have adopted is broad enough to address all major aspects of the research question. Key references have been cited.

**4 points:** The team demonstrates an understanding of the scientific literature that is appropriate for high school students. They are familiar with different theories that are germane to the problem. The approach they have adopted is broad enough to address all major aspects of the research question. No references to key studies are provided.

**3 points:** The team demonstrates an understanding of the scientific literature that is appropriate for high school students. They are familiar with different theories that are germane to the problem. The approach they have adopted is useful for some, but not all, major aspects of the research question. No references to key studies are provided.

**2 points:** The team demonstrates an understanding of the scientific literature that is appropriate for high school students. They are familiar with different theories that are germane to the problem. The approach they have adopted is insufficient for fully evaluating the research question. No references to key studies are provided.

**1 point:** The team demonstrates an understanding of the scientific literature that is appropriate for high school students. They do not seem to be familiar with different theories that are germane to the problem. The approach they have adopted is insufficient for fully evaluating the research question. No references to key studies are provided.

**0 points:** The team does not understand the scientific literature at a level that one would expect from high school students.

### **Presentation**

A 5-point presentation will contain all of these features:

- The project display completely covers all aspects of the work.
- The nature of the problem is clearly explained.
- The idea and actual work are clearly explained.
- The students explained their work and answered questions to my satisfaction.
- Students clearly worked as a team in that they could all answer questions about any part of the project.
- The visual presentation was appropriate, pleasing to look at, and uncluttered.

One point will be deducted for each feature that, in the judge's judgment, does not meet these standards.

### Appendix B.1. Emerald Team's Project Scores

Criteria	Judge ID*	Score (0-5 pts.)	Comments
Objective	A	5	very workable solution and I believe would be acceptable to most users, especially with the right combination of stakeholder identification and involvement as this team has done! :)
	B	4	This is a great project that can grow.
	C	4	
	D	4	Both designing the "system" and changing behavior - and thinking ahead to other possibilities
	E	5	Excellent title
	F	5	Very clear idea - The novel important aspect of this project is organizational --> bringing together multiple schools & groups within schools.
<i>Objective Avg. Score</i>		4.5	
Creativity	A	4	Builds on existing programs to expand to new "customers"
	B	3	The idea is not new but the addition of a "council" approach is different.
	C	3	
	D	3	Creating a Green Council for students, starting w/ composting but looking @ other opportunities - have seen idea before but showed a diff. way of thinking about it
	E	5	Very simple but effective with a great impact.
	F	4	The notion of composting in schools is hardly novel, but the idea of a council and organizing multiple schools & school orgs has great merit & timing
<i>Creativity Avg. Score</i>		3.7	
Inquiry	A	5	Great plan for follow up research - has identified and addressed limitations, understand barriers to implementation
	B	3	the team didn't focus on their question's limitations
	C	3	
	D	4	Seemed to have ideas for possible future topics, clear and testable - looked a little difficult but had thought of when they could best implement
	E	4	Include more tangible impacts or measures of impacts to grab people's attention. Keep up the good job!
	F	3	The testable question wasn't really providing critical knowledge, nor were the conclusions very illuminating

<i>Inquiry Avg. Score</i>		<i>3.7</i>	
Thoroughness	A	4	No key references cited - suggestions to include next time: survey creation, case studies of other schools or communities adopting composting
	B	3	Much more research on marketing is needed.
	C	3	
	D	3	Could have covered a bit more on the ways to change behavior and what other players in the system need to know/do
	E	5	
	F	3	I didn't see much inquiry or research.
<i>Thoroughness Avg. Score</i>		<i>3.5</i>	
Presentation	A	5	Great enthusiasm, very professional - the team's passion really comes through! We've got some great leaders here! Good work!
	B	5	Well articulated; powerpoint; nicely done.
	C	4	
	D	3	Weren't quite sure who should answer what, a little challenged in responding to questions
	E	5	Great participation by all 3 participants
	F	4	Covered all the bases, but wasn't fully organized to ensure complete coverage of all issues.
<i>Presentation Avg. Score</i>		<i>4.3</i>	
<b><i>Total Avg. Score (0-25 pts.)</i></b>		<b><i>19.7</i></b>	
Specialty Awards	A	Community Impact	See above! The entire school district is engaged and the program itself is sustainable to continue addressing sustainability issues in their schools! And has impact on personal behavior. Will be interesting to see their survey results next year.
	B	Community Impact	
	C		
	D	Community Impact	
	E	Community Impact, Most Inspirational	
	F	Community Impact	

\* The letter ID's are nominal indicators assigned for purposes of this summary. The six individuals who scored each project self-selected from a much larger pool of volunteer judges. The projects could be scored by the same or different individuals. Judges' IDs were not tracked by the scoring data entry system.

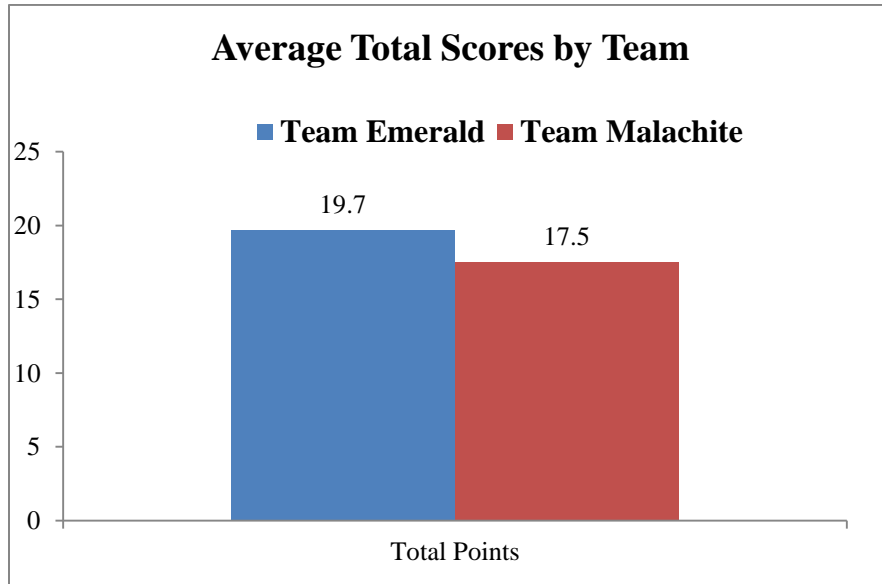
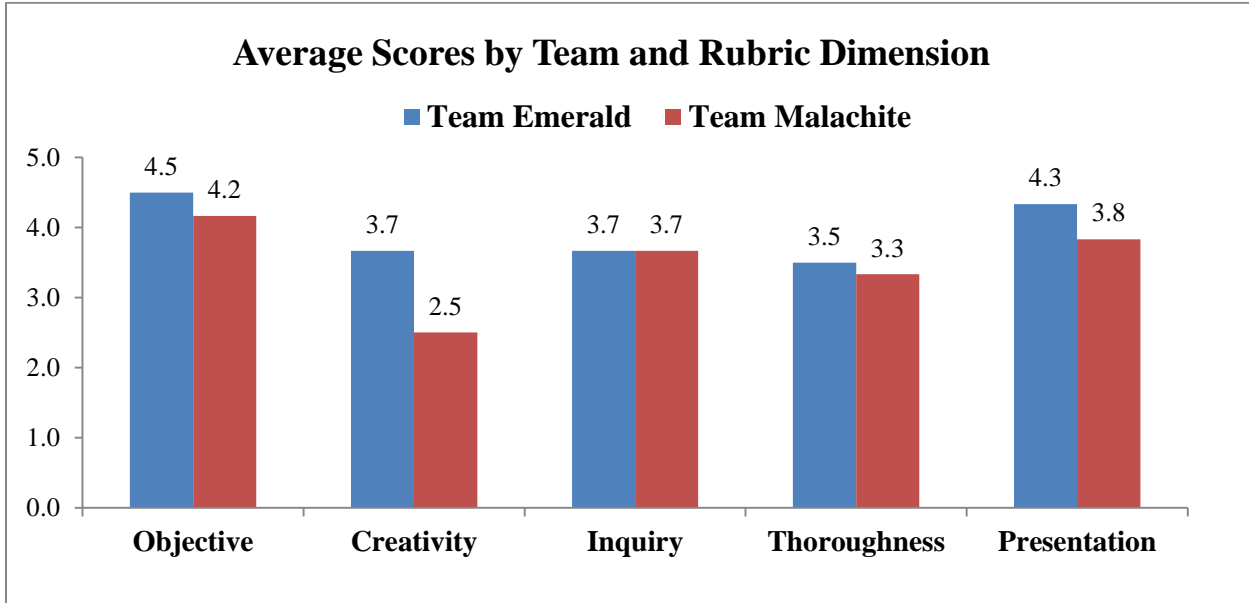
### Appendix B.2. Malachite Team's Project Scores

Criteria	Judge ID*	Score (0-5 pts.)	Comments
Objective	A	3	Concerns about how much waste is produced for backyard style system
	B	5	Good achievable objective. Project is in early stages and has great potential. I'm glad to see the research and background work being done 1st, rather than just putting in a compost bin. Project will be sustainable in future years.
	C	4	Hope to see it come back as working model! Good use of cooperative approach with multiple stakeholders to compost waste.
	D	4	A worthy, but somewhat common goal
	E	5	
	F	4	
<i>Objective Avg. Score</i>		4.2	
Creativity	A	1	The idea was something that has been done before & might not impact a large part of the problem
	B	3	Composting isn't a new idea but these students are working to implement a successful long term program. Well done!
	C	3	Introducing a proven methodology to a new audience - effecting potentially community change.?
	D	2	Would have liked to more creative plan to promote the composting concept (community? ) (Middle-school?)
	E	3	
	F	3	
<i>Creativity Avg. Score</i>		2.5	
Inquiry	A	3	Had a 3 yr plan but hadn't looked as broadly to talk about why they chose the system they did & what other opportunities there could be
	B	4	
	C	2	Need permission - did not only know change? Small set, used "survey monkey" technology; What percentage of student body queries returned 10 percent??..
	D	3	Research of composting was current. Not sure if there are other aspects which were not presented.
	E	5	
	F	5	

<i>Inquiry Avg. Score</i>		<i>3.7</i>	
Thoroughness	A	3	Had missed some of the key Q's
	B	5	Good job with understanding the logistics of implementing a program like this.
	C	2	Used native knowledge from family source; could use more research, by in from school staff, teachers. Responses from student body; did not talk to county official about possible solid waste programs -- suggest this approach also.
	D	3	Covered the obvious aspects of composting.
	E	3	
	F	4	
<i>Thoroughness Avg. Score</i>		<i>3.3</i>	
Presentation	A	3	Good display, explained problem, team lead by 1/2 of kids
	B	4	Great job!
	C	3	Visual good - compost stages excellent.
	D	4	Good display - stages of composting/team were sharing presentation responsibilities / 5 major survey questions with circle charts (understandable).
	E	4	
	F	5	
<i>Presentation Avg. Score</i>		<i>3.8</i>	
<b><i>Total Average Score (0-25 pts.)</i></b>		<b><i>17.5</i></b>	
Specialty Awards	A		<i>Not recommended for specialty awards.</i>
	B		
	C		
	D		
	E		
	F		

\* The letter ID's are nominal indicators assigned for purposes of this summary. The six individuals who scored each project self-selected from a much larger pool of volunteer judges. The projects could be scored by the same or different individuals. Judges' IDs were not tracked by the scoring data entry system.

### Appendix B.3. Focal Teams' Average Project Scores



## Appendix C. Student Interview Questions

### Student Group Interview 1

STUDENT PARTICIPATION	1. How did you end up participating in the competition? (go around the table, ss take turns responding)
STUDENT PARTICIPATION	2. What's the driving motive, or top reasons for participating [in IT] , assuming it will require effort, what makes it worth it?
TEAM PROCESS	3. How did your TEAM choose to do this particular project?
STUDENT PARTICIPATION	3a. Did you feel that you have a personal connection to this particular project -- I am interested in how you see yourself relative to the project, or to the group? So is it a matter of participating because of who else is participating in the group; because of what the competition in general is about; or..?
STUDENT PARTICIPATION	3b. Is this your first time participating in this kind of competition, or have you done anything similar, where you work with a team, then show what you've done over a period of time?
TEAM PROCESS	4. What is the project as you see it now? Could you briefly describe how you see and understand it? And is it different from what it was at the beginning?
TEAM PROCESS	4a. What are some doubts, some challenges that you are having to work through right now about this?
PROJECT CONTEXT	4b. Imagine you are at WSU right now, in an elevator with somebody who judges or organizes the competition, and have 2 minutes to answer their question: "What's YOUR team doing?" First, who wants to be in the elevator? (someone should volunteer)
TEAM PROCESS	4c. To role-play a judge: "Wait a minute, you are going to bring something to Pullman in 3 weeks, and you are talking about (xyz). What am I going to <u>see</u> from your team in 3 weeks?" (press for specifics about what team will complete)
STUDENT PARTICIPATION	5. Each of you probably has a somewhat different angle on the project, an area that interests you. So to break that down a little, to get your perspectives, what is interesting about the project for you specifically? (prompt for every student to answer)
TEAM PROCESS	5a. Describe what kinds of things are on your mind, what worries or concerns do you have? What kinds of issues have you been focusing on, what tasks have been occupying your time?
TEAM PROCESS	5b. Is there a to-do list, like a rolling list of tasks to do before the competition -- a laundry list of things that have to be in place in order to complete the project? (students may not be ready yet to answer, so may brainstorm)

## Student Group Interview 2

TEAM PROCESS	What has happened on the project since the first interview until today?
TEAM PROCESS	What project results or product do you plan to present at the competition?
PROJECT CONTEXT	What kind of feedback have you heard from those who were not directly involved in the competition, if any?
TEAM PROCESS	How has your understanding of the project changed between our meeting a couple weeks ago, and now?
TEAM PROCESS	What do you consider to be helpful resources, tools, or sources of feedback that you have taken advantage of?
STUDENT PARTICIPATION	What's success for the team, and for the project?
TEAM PROCESS	Thinking about the team as a whole, what kinds of issues do you think are most important to resolve, and do you still have things that need to be resolved? [OR] <u>Thinking back</u> – what has come up, that you have to kind of deal with?
TEAM PROCESS	What other activities and formal commitments are you juggling in your life as a student that take your time parallel with IT?
TEAM PROCESS	Suppose there are three “bands” of priorities in your life: “low” -- things at the bottom, “middle” – things of medium importance, and stuff at the top. Over the time your involvement in the project, where has it been for you?
STUDENT PARTICIPATION	Why did you decide to participate in the competition this year?
TEAM PROCESS	If I were interested in learning specifically about how students worked on the project, where would I need to be present, and what would I need to pay attention to really get a sense of how that actually happens?
TEAM PROCESS	Are there other things you've done (besides talking to people) as far as looking for information, or learning about the topic of the project (online research, etc.)?
TEAM PROCESS	If you had a chance to start over, would you follow about the same schedule of working on the project, or would you have changed anything in terms of timing?
TEAM PROCESS	Suppose you have more capacity and more time, would you have spent more on it or about the same?
PROJECT CONTEXT	Besides personal constraints such as time, were there other constraints that were limiting your ability to do the work?
PROJECT CONTEXT	What are the boundaries of the project -- how far down the line of the process are you thinking in terms of what happens when the project is implemented?

### Student Individual Interview (Post-Competition)

Interview Theme	Question
STUDENT PARTICIPATION	1. In terms of your experience with presenting the project in Pullman, what has stuck with you most?
TEAM PROCESS	1a. Did that experience change how you see your project -- if so, in what ways?
PROJECT CONTEXT	1b. Did you notice any things that other projects did better?
PROJECT CONTEXT	1c. How about things that you saw others did not have that you thought were your advantage?
STUDENT PARTICIPATION	1d. What impressions did they have from looking at other projects? What lessons did they take home, if any?
TEAM PROCESS	2. Since you returned from Pullman, have you been thinking about the project at all, or not too much? If yes, what has been on your mind?
PROJECT CONTEXT	3. Now that the competition is over, how do you see or understand the “project” your team did?
TEAM PROCESS	3a. How would you describe what the team had accomplished?
STUDENT PARTICIPATION	3b. What is “success” for the team in the context of this competition? -- What were the team's goals?
STUDENT PARTICIPATION	3c. What is “success” for you personally? What were your goals?
TEAM PROCESS	4. What other information/things do you wish you had known in advance of the event?
TEAM PROCESS	5. Do you feel that you (and/or team) could use some assistance, mentoring, and other help that was not provided but could be helpful in achieving their goals? (including a better project presentation or project itself)
TEAM PROCESS	6. Looking back on the work your team had done on the project, can you briefly describe how your team approached this project? (Alt phrasing: What kinds of steps you followed, or if there were strategies and things you and others did that really shaped the project?)
TEAM PROCESS	7. What did you meet for? What did a meeting accomplish that other ways of communication or settings did not afford? What purposes did a team meeting serve as opposed to these other forms of interaction? What was accomplished in such meetings that could not be accomplished elsewhere?
TEAM PROCESS	8. If you had to do a project like this again, what are some things you think would be important to consider ahead of time?
TEAM PROCESS	8a. What are some challenges you had to overcome? How do you think they could be handled?

TEAM PROCESS	9. Assuming that you had to work with others a fair amount, could you describe interactions that had the greatest effect on your own experience with the project?
TEAM PROCESS	9a. Could you highlight any particular relationships that the project influenced for you? If so, tell me a little about how that happened...
TEAM PROCESS	9b. How do you think it shaped the project, if at all?
ADVISOR	9c. [ALT: Looking specifically at the role of your team advisor...]
ADVISOR	9d. What did your advisor do that you think had an impact on the project? Can you give any specific examples of what she said or did that made a difference for you?
TEAM PROCESS	10. What did this particular team have that you think was unique, that others would not have been able to contribute?
STUDENT PARTICIPATION	11. How would you describe the role you had on the team? How did you contribute?
STUDENT PARTICIPATION	11a. How did you come to play this particular role or have these responsibilities?
STUDENT PARTICIPATION	11b. Has your role changed from what you initially thought, and if so, how did it change?
STUDENT PARTICIPATION	12. Looking back at the project and your role on it, what previous experiences in your life or skills do you think were helpful?
STUDENT PARTICIPATION	12a. What skills or experiences do you wish you had or were better at?
STUDENT PARTICIPATION	13. What did you like about the competition when you decided to participate?
STUDENT PARTICIPATION	What did you like or most enjoy as you were working on the project? What was your favorite part?
STUDENT PARTICIPATION	13a. What did you not like...? (etc etc.)
STUDENT PARTICIPATION	14. And what do you like about the competition now that you can look back on your experience?
STUDENT PARTICIPATION	14a. What did it [the competition experience] give you?

STUDENT PARTICIPATION	15. What about this project seems most useful or worthwhile to you, and why?
STUDENT PARTICIPATION	15a. What if any impact do you think this experience might have for you moving forward?
STUDENT PARTICIPATION	15b. Has the competition affected your future plans in any way? School-related? Beyond school? Personal interests?
TEAM PROCESS	16. Suppose someone asked you to write a one paragraph essay to answer the question: How did you "engage" with the project? Your answer begins with: "I engaged with the project by..." How would you continue this sentence?
TEAM PROCESS	16a. Now suppose the question was changed to say "The project got me engaged in..." How would you continue this sentence?
TEAM PROCESS	17. What are some of the activities you did that may be interpreted as a sign of your "engagement" with the project? Alt phrasing: If there was a test of your engagement, what do you think you should be graded on?
TEAM PROCESS	18. What are some things you thought about, or some "intellectual work" that you did, that may be said to indicate your mental engagement with the project?
STUDENT PARTICIPATION	19. What are some emotions that you experienced in connection to the project? What were some of the most emotional moments for you?
TEAM PROCESS	20. When was the start point of the project work? How would you estimate hours per week spent on project? Week by week, or pick your unit of analysis?
TEAM PROCESS	20a. Ask to estimate # of meetings with others, or # of informal conversations, or time spent online interfacing with them (facebook, email).
ADVISOR	21. What kinds of things did advisor help with? What information has he/she volunteered? What kinds of questions did you have for the advisor?
TEAM PROCESS	21a. Ask how many times met with advisor, if not then why not; how communicated with advisor, why interacted a lot or not too much with advisor.
TEAM PROCESS	22. What were the sources through which you learned about the competition?
TEAM PROCESS	22a. Did you use the competition judging rubric in any way?
TEAM PROCESS	22b. Did you use the competition website?
ADVISOR	22c. What do you remember from what the advisor said?
STUDENT PARTICIPATION	23. Is there anything else you'd like to add about the team, the project, or the competition in general?

## Appendix D. Advisor Interview Questions

### Advisor Interview 1

ADVISOR	1. Could tell a little about yourself, like how long you have been teaching, how long have you been at this school, and what is your subject?
ADVISOR	2. Can you talk a little about how you became involved in the competition?
PROJECT CONTEXT	2a. Could you briefly outline the project idea?
TEAM PROCESS	2b. How did this idea come about?
STUDENT PARTICIPATION	3. How was the student team formed?
STUDENT PARTICIPATION	3a. If there were any changes to the team with respect to students leaving or joining, do you have a sense of the reasons for that?
ADVISOR	4. How would you describe your role on the team?
ADVISOR	4a. What were your goals as an advisor?
ADVISOR	4b. What project activities were you involved in?
ADVISOR	5. In hindsight, would you have done anything differently, and why?
TEAM PROCESS	6. Describe to me how the team went about their work on the project? Maybe talk about the “average day,” if there was one?
TEAM PROCESS	6a. If I were interested in learning specifically about how students worked on the project, where would I need to be present, and what would I need to pay attention to really get a sense of how that actually happens?
TEAM PROCESS	7. Can you give an example of a challenge that came up and how it was sorted out?
STUDENT PARTICIPATION	8. What do you think draws students to the competition?
STUDENT PARTICIPATION	9. What do you think the students got out from participating in the competition?
STUDENT PARTICIPATION	9a. What kind of feedback have you heard from students about their competition experience?
STUDENT PARTICIPATION	9b. What experiences do you think had the biggest long-term impact?
STUDENT PARTICIPATION	9c. Was there anything not beneficial to the students or that negatively affected the quality of their experiences?
TEAM PROCESS	9d. Do you wish the students had done anything differently, and why?
PROJECT CONTEXT	10. Did the project have any links to the curriculum or specific class?

PROJECT CONTEXT 11. What did the competition mean to the school? (How big of a deal was it?)

PROJECT CONTEXT 12. What kind of feedback have you heard from those who were not directly involved in the competition, if any?

PROJECT CONTEXT 13. What kinds of constraints affected the process and outcome?

PROJECT CONTEXT 13a. In your opinion, what made a difference in how the project turned out?

## Advisor Interview 2

STUDENT PARTICIPATION	2. Let's talk about how the team came together. How did it form?
STUDENT PARTICIPATION	2. Let's talk about how the team came together. How did it form?
TEAM PROCESS	1. To the best of your knowledge, how did the project idea come about?
TEAM PROCESS	1. To the best of your knowledge, how did the project idea come about?
ADVISOR	7. How would you describe your role on the team for this year's competition?
ADVISOR	7a. What are your goals as an advisor?
ADVISOR	7b. What activities do you involve yourself in?
ADVISOR	8. How do you position yourself relative to the team with regard to the competition, and what do you see as your responsibility this year?
ADVISOR	9. How specific is the advice you give when you talk to the team?
ADVISOR	9a. How hands-on are you?
ADVISOR	10. Do the students ask you specific questions, or do you prod them to see what's going on (with the project)?
ADVISOR	10. Do the students ask you specific questions, or do you prod them to see what's going on (with the project)?
ADVISOR	10. Do the students ask you specific questions, or do you prod them to see what's going on (with the project)?
TEAM PROCESS	6. What is your sense of what the project is right now?
TEAM PROCESS	6. What is your sense of what the project is right now?
TEAM PROCESS	6. What is your sense of what the project is right now?
TEAM PROCESS	6a. If the project has changed (from initial idea), how so?
TEAM PROCESS	6a. If the project has changed (from initial idea), how so?
TEAM PROCESS	6a. If the project has changed (from initial idea), how so?
TEAM PROCESS	4. Can you share some general observations about what has been going on this project?
TEAM PROCESS	5. What do you know or believe the students may be struggling with, and why?
STUDENT PARTICIPATION	3. What do you think was the major reason (at least the key person of) the team decided to do it?
STUDENT PARTICIPATION	3. What do you think was the major reason (at least the key person of) the team decided to do it?
ADVISOR	11. Have you made suggestions that you feel were pivotal to the project – such as a change of direction, a major push, or that allowed them to overcome a critical issue?
ADVISOR	12. Did you use or point students to the judging rubric?

### Advisor Interview 3

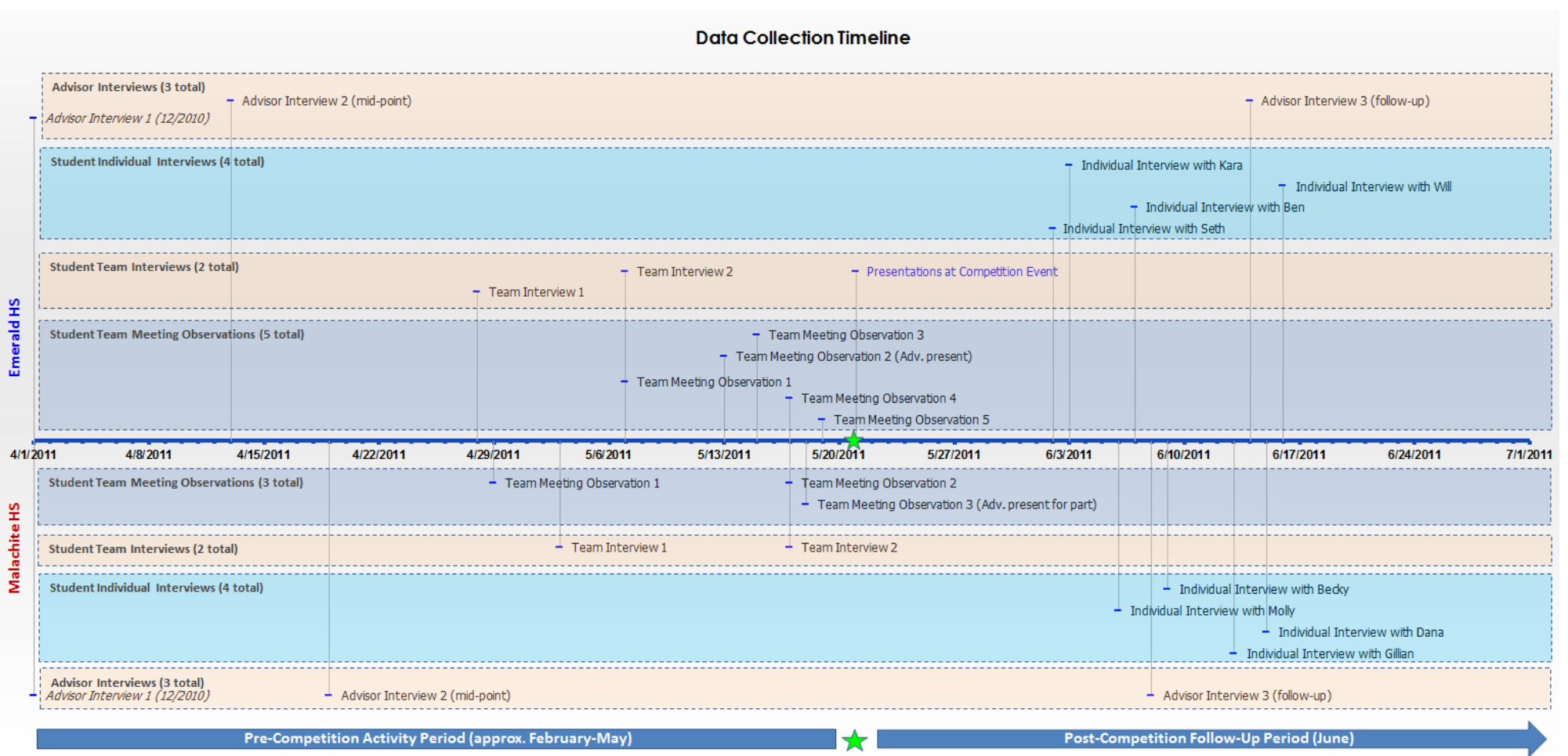
STUDENT PARTICIPATION	1. What do you think the students got out of participating in the competition?
STUDENT PARTICIPATION	1a. What kind of feedback have you heard from students about their competition experience?
STUDENT PARTICIPATION	1b. What experiences do you think had the biggest long-term impact?
TEAM PROCESS	1c. Do you wish the students had done anything differently, and why?
PROJECT CONTEXT	Could you briefly outline the project idea?
TEAM PROCESS	How did this idea come about?
STUDENT PARTICIPATION	How was the student team formed?
STUDENT PARTICIPATION	If there were any changes to the team with respect to students leaving or joining, do you have a sense of the reasons for that?
ADVISOR	How would you describe your role on the team?
ADVISOR	What were your goals as an advisor?
ADVISOR	What project activities were you involved in?
PROJECT CONTEXT	What did the competition mean to the school? (How big of a deal was it?)
PROJECT CONTEXT	4a. Did the project have any links to the curriculum?
STUDENT PARTICIPATION	4b. Thinking about the results of the competition judging, how important was that for <u>the team</u> ?
PROJECT CONTEXT	5. What kind of feedback have you heard from those who were not directly involved in the competition, if any?
TEAM PROCESS	How would you describe what they actually accomplished with their project?
STUDENT PARTICIPATION	And what do you think is "success" as a notion for the team in the context of the competition? In terms of the goals that <u>they</u> had for it, what would have meant getting there, succeeding?
STUDENT PARTICIPATION	What is success for you personally, in relation to this group?
ADVISOR	What did you do that you think had an impact on the project? What practices/strategies did you use that you feel made a difference?
ADVISOR	What kinds of things did you help with? What information have you volunteered to them? What kinds of questions did they have for you?
ADVISOR	2. In hindsight, would you have done anything differently in terms of your advising, and why?
TEAM PROCESS	3. Can you give an example of a challenge that came up and how it was sorted out?

PROJECT CONTEXT	6. Stepping back and looking at the bigger picture, are there any overarching factors that you think made a difference in how the project turned out?
PROJECT CONTEXT	6a. What kinds of constraints affected the process and outcome?
TEAM PROCESS	Suppose someone asked you to write a one-paragraph essay to answer the question, "How did the team engage with the project?" And your answer begins with, "The team engaged with the project by..". Would you continue the sentence?
TEAM PROCESS	Now suppose the question was changed to say, "The project got them engaged in.." and answer that..
TEAM PROCESS	What are some activities that they did, that may be interpreted as a sign of their engagement? If there was a test on their engagement, what do you think they should be graded on?
TEAM PROCESS	What did you observe in terms of their intellectual work, that may indicate their mental, cognitive engagement with the project?
TEAM PROCESS	What did the meetings with students accomplish?
TEAM PROCESS	What do you think was accomplished in such meetings with you, that could not be accomplished elsewhere or through other means?
ADVISOR	Did you use the competition website?
ADVISOR	Did you use or point students to the judging rubric?

**TABLE 1.1 Relationship of Skill Areas to the Phases of the Design Process**

Steps in the engineering design process	Skills and tools for the process			
	Decision making	Project management	Communication	Collaboration
<i>Phase one: Defining the problem</i>	<ul style="list-style-type: none"> <li>• Research and data gathering</li> </ul>	<ul style="list-style-type: none"> <li>• Discussing and defining project expectations</li> </ul>	<ul style="list-style-type: none"> <li>• Active listening and probing skills</li> </ul>	<ul style="list-style-type: none"> <li>• Group formation and development</li> </ul>
1. Forming the problem statement	<ul style="list-style-type: none"> <li>• Eliminating biases and overcoming assumptions</li> </ul>	<ul style="list-style-type: none"> <li>• Coordinating schedules and planning meetings</li> </ul>	<ul style="list-style-type: none"> <li>• Laboratory record book</li> <li>• Composition skills</li> </ul>	
2. Identifying functional requirements	<ul style="list-style-type: none"> <li>• Analyzing key phrases</li> </ul>	<ul style="list-style-type: none"> <li>• Establishing working agreements</li> </ul>		
3. Recognizing constraints and limitations	<ul style="list-style-type: none"> <li>• Using objective trees</li> <li>• Using sketches</li> <li>• Clarifying the problem over time</li> </ul>	<ul style="list-style-type: none"> <li>• Adhering to your working agreement</li> </ul>		
4. Defining a schedule and forming a team				
<i>Phase two: Formulating solutions</i>	<ul style="list-style-type: none"> <li>• Innovation versus origination</li> </ul>	<ul style="list-style-type: none"> <li>• Preparing and using Gantt charts</li> </ul>	<ul style="list-style-type: none"> <li>• Sharing the data gathered</li> </ul>	<ul style="list-style-type: none"> <li>• Ensuring open participation</li> </ul>
1. Defining design parameters	<ul style="list-style-type: none"> <li>• Considering external factors</li> </ul>	<ul style="list-style-type: none"> <li>• PERT/CMP techniques</li> </ul>	<ul style="list-style-type: none"> <li>• Writing proposals</li> </ul>	<ul style="list-style-type: none"> <li>• Reaching consensus and building commitment</li> </ul>
2. Identifying alternatives	<ul style="list-style-type: none"> <li>• Brainstorming</li> </ul>	<ul style="list-style-type: none"> <li>• Establishing and maintaining records</li> </ul>	<ul style="list-style-type: none"> <li>• Preparing bibliographies</li> </ul>	<ul style="list-style-type: none"> <li>• Managing conflict</li> </ul>
3. Evaluating and analyzing alternatives	<ul style="list-style-type: none"> <li>• Nominal group and delphi techniques</li> <li>• Lateral thinking</li> <li>• Systematic decision grids</li> </ul>			<ul style="list-style-type: none"> <li>• Avoiding groupthink</li> </ul>
4. Selecting a solution	<ul style="list-style-type: none"> <li>• Force field analyses</li> <li>• Making estimates</li> </ul>			

## Appendix F. Data Collection Timeline



## Appendix G. Analytic Theme Matrix

	<b>Analytic Themes by Research Question*</b>			
<b>Interview Themes</b>	<b>(RQ1) Tensions in Project Activity System</b>	<b>(RQ2) Strategies for Completing Project</b>	<b>(RQ3) Role of Team Meetings</b>	<b>(RQ4) Outcomes &amp; Participation</b>
<b>General Theoretical Framing</b>	<p>*Evidence of implied tensions in the project activity system. * tensions may be manifested in contradictions/discoordinations/mis-alignments/competing pressures in organization and processes of the activity system</p> <p>Dimensions: (2x2 square) * CONTEXT/FORMAT OF DESIGN PROCESS: structure-emergence tension * GOALS/MOTIVES: object/outcome tension (use value vs. exchange value)</p>	<p>* Evidence of effective/ineffective approaches to moving project toward completion. * Effective/adaptive strategies indicate expansive learning/innovation/transformation in CDP; * Ineffective/maladaptive strategies indicate maintenance of status quo w. regard to pre-competition routines/activities/roles</p> <p>General types of strategies: inward-aimed (within-team); outward-aimed (team-context), interfacing with stakeholders</p> <p>*navigating the project-school-community boundaries ("project space") * mediated/scaffolded (by advisor, parent, etc.)</p> <p><i>Dimensions: (2x2 square)</i> * PROJECT COMPLETION: successful / unsuccessful * QUALITY OF INDIV/GROUP EXPERIENCE: high/low</p>	<p>* Assumption that meetings are essential elements of project activity system where substantive project work happens, and therefore a site of interaction that may offer insights into CDP on detailed level.</p> <p>Analyze for: * evidence of tensions (RQ1); * evidence of the effectiveness of strategies used in project work (RQ2);</p>	<p>* Relationship between goals/reasons for participation and capacity for completing project</p> <p>*Relationship between attainment of the "object" of the activity system (i.e. the finished project/presentation) and the associated "outcomes" of individual and collaborative activity (i.e. visiting WSU campus, winning, making a difference in school/community, etc.);</p> <p>* how understanding of "success" with regard to project completion and other outcomes shapes perceived quality of competition experience;</p>
<b>PROJECT CONTEXT</b>	<p>* structural constraints / affordances: * school/curriculum integration * project topic/scope boundaries</p>	<p>Responses may be relevant in terms of: *points of contact/intersections between project activities and students' typical in/out-of-school activities, roles and responsibilities. * possible adaptive strategies: - reaching out to/involving/consulting with advisor or community members (to "think outside the box"); - using school/community resources to "join" project to other activity systems (thus creating opportunities for "expansive transformation" or innovation of activity)</p>	<p>Responses may be relevant in terms of: * how meetings are integrated/squeezed into students' regular activities and schedules; also in how meetings with "external" stakeholders impact project completion.</p>	<p>* structural constraints / affordances: * school/curriculum integration * project topic/scope boundaries * external feedback/input</p> <p>* factors/constraints/circumstances that impacted students' ability to participate in project activities</p> <p>* perspective on project beyond competition timeframe/criteria</p>

<b>ADVISOR SUPPORT</b>	<p>re: structure-emergence</p> <p>role/impact/approach/activities related to project (mediation/scaffolding of project work)</p>	<p>re: structure-emergence</p> <p>* strategies that indirectly focus/guide project work (evaluation criteria, IT guidelines/info)</p> <p>* strategies that mediate/scaffold student activity (sponsorship/facilitation)</p>	<p>Responses may be relevant in terms of:</p> <p>* advisor's role in team meetings (indirect facilitation/scheduling, and/or direct participation/contributions)</p>	<p>re: structure-emergence</p> <p>* how advisor's background/prior experience with I.T. may have shaped the pathways/trajectories of student participation (affiliation through class/after-school activities)</p>
<b>COLLABORATIVE DESIGN PRACTICE</b>	<p>re: structure-emergence, object-outcome challenges/contradictions/discoordinations in CDP (decision-making, project management, communication, collaboration)* roles/tasks* tools/resources* changes in CDP associated with time constraints and other priorities</p>	<p>re: adaptive/maladaptive may be mapped to elements of CDP (DM, PM, COMM, COLLAB)* roles/tasks; * tools/resources* possible effective/adaptive strategies:- changes (re-appraisal/revision) of norms/objects/motives of activity; - integration of project tasks with established routines/rebalancing of priorities;- flexibility in approach; moves to compromise w. peers/adults* possible ineffective/maladaptive strategies: - avoidance of problems or responsibility; - resistance to change/adherence to established norms/routines; - inability to integrate project work into other activities and re-balance priorities; - defensiveness/stubbornness/passivity; non-receptivity to feedback</p>	<p>re: tensions (RQ1), strategies (RQ2)May help understand the mechanics of how... * tensions in the overall activity system (structure-emergence; object/outcome) are instantiated in contradictions/discoordinations;* strategies, tools, and resources aimed at completing the project are identified/developed/leveraged (disagreements/misunderstandings resolved, plans and decisions made, tasks/roles coordinated, etc.);* objects of collective activity clarified; goals negotiated and aligned; engagement/persistence in working on project fostered.</p>	<p>re: adaptive/maladaptive* project topic selection (how contributed, what inspired; related interests/goals)* perceived project progress/results/outcomes; how clarified/negotiated through collective project activities* intersection of students' participation trajectories w. project topic/idea</p>
<b>STUDENT PARTICIPATION</b>	<p>re: object/outcome</p> <p>* goals/reasons for participation (negotiation/alignment of)</p> <p>* social context of participation (affiliations/belonging/relating to/identity)</p> <p>* how perception of success relates to quality of competition experience</p>	<p>Responses may be relevant in terms of:</p> <p>* the role of certain strategies (inward/outward-aimed) in facilitating or sustaining interest/motivation/engagement in project activities:</p> <p>* possible adaptive strategies:</p> <p>- capacity building through recruitment or replacement of additional team members;</p>	<p>Responses may be relevant in terms of:</p> <p>* the role of meetings in motivating engagement/persistence in project activities over the duration of project timeframe;</p>	<p>re: structure-emergence, object-outcome</p> <p>* how become involved with competition; how select/organize into teams; reasons for changes in team membership;</p> <p>* motivation/goals/expectations/plans related to project and overall competition experience;</p> <p>* balancing competing roles/priorities, and their impact on ability to participate/complete project</p>

\* Green-highlighted cells indicate initially hypothesized intersections between interview and RQ themes. Yellow-highlighted cells indicate additional intersections that emerged during data analysis

## Appendix H. Interview Analysis Code List\*

Code ID	Codes / Categories**	Definition
1	#ADV. ACT_ADMIN/LOGISTICS	advisor activities/issues associated with making arrangements for ss to participate in IT (Imagine Tomorrow) and attend the IT event (paperwork, logistics planning, collecting necessary info from ss, informing ss about IT regulations/procedures) - also planning any additional itinerary/events for ss to do while at WSU
1a	#adv. act_admin/logistics_burden of paperwork	forms/paperwork associated with participation in IT (registering, attending), including forms from IT organizers as well as schools/districts.
1b	#adv. act_admin/logistics_collecting sign-up info from ss in advance	collecting paperwork (signed forms from ss and parents) in advance to avoid it becoming a last-minute scramble before the competition.
1c	#adv. act_admin/logistics_familiar with process/logistics of IT participation	being familiar with the admin tasks/rules due to repeat advising/participation experience.
1d	#adv. act_admin/logistics_pre-packaging info about IT for ss	preparing/distributing information about IT to help ss learn about and decide whether to participate.
1e	#adv. act_admin/logistics_matching projects to categories	talking about competition categories that projects fit into (IT rules specify that projects must fit into one of four categories: technology, design, behavior, and multidisciplinary).
1f	#adv. act_admin/logistics_strategic about pre/registration for IT	having certain principles/being strategic about the registration process.

2	#ADV. ACT1_RECRUITMENT	activities/issues associated with recruiting student participants for IT.
2a	#adv. act1_recruitment_advertising/raising awareness about IT	advertising/raising awareness of IT at the school through various means, such as announcements and posters, and trying to generate student interest in participating.
2b	#adv. act1_recruitment_supporting repeat participation	supporting ss interested in IT based on their past participation experiences. (for ss deciding to participate based on their own or others' past participation in IT, use code <a href="#">#pathways_friendship/social relationships/repeat participation</a> )
2c	#adv. act1_recruitment_targeting certain student groups	targeting/trying to target specific student groups when recruiting for IT.
2d	#adv. act1_recruitment_selection criteria for teams/projects	having/not having criteria for selecting or allowing teams to participate in IT.
3	#ADV. ACT2_INITIAL IDEAS	activities/issues associated with brainstorming/suggesting initial project ideas
3a	#adv. act2_initial ideas_brainstorming initial project ideas	assisting with/facilitating brainstorming initial project ideas.
3b	#adv. act2_initial ideas_suggestions for researching project ideas	providing suggestions/guiding ss' selection of project ideas.
4	#ADV. ACT3_FORMING TEAMS	activities/issues associated with forming teams from students interested in participating in IT (assigning ss to teams, helping ss find teammates, etc.)
5	#ADV. ACT4_TEAM MEETINGS	activities/issues associated with arranging/providing opportunities for ss team meetings; also adv. meeting with ss.
5a	#adv. act4_team meetings_considering ss needs	considering ss' needs when arranging/facilitating project team meetings.
5b	#adv. act4_team meetings_providing opportunities to meet	providing opportunities for ss to meet to work on their projects: includes facilities such as classroom space, equipment, arranging time after class (or as part of existing structured activity, such as science club)

6	#ADV. ACT5_NETWORKING	Referring ss to/facilitating networking with contacts.
7	#ADV. ACT6_DESIGN PROCESS	activities/issues associated with advisor's role/involvement in the project work/design process.
7a	#adv. act6_design process_communication w. teams_flexibility	being flexible/using different ways/adapting/tailoring the mode/style of communication with ss in attempt to make it work, be effective; also includes making changes/taking steps to improve communication with teams.
7aa	#adv. act6_design process_asking questions/promoting critical thinking	advisor asking open-ended questions to promote independent/critical thinking and decision-making in students
7b	#adv. act6_design process_adjusting scope/feasibility to focus/complete project	<p>specific suggestions or changes proposed or implemented by advisor to help ss bring the project to completion; includes pursuing a more feasible, doable project idea (e.g. by reusing existing technology, or creating a tangible apparatus/device that performs a specific function).</p> <p>comments or concerns related to the scope or feasibility of project ideas; includes specific suggestions or changes proposed or implemented by advisor to help ss bring the project to completion; suggestions focused on a more feasible, doable project idea (e.g. by reusing existing technology, or creating a tangible apparatus/device that performs a specific function).</p> <p>project is compatible to/matches ss' abilities; adjustment of ss expectations.</p>
7c	#adv. act6_design process_engaging other school teachers/staff/leadership	involving other teachers or staff at school to assist with ss' project work.
7d	#adv. act6_design process_hands-on involvement	advisor having more (or LESS) direct hands-on involvement/providing assistance with project work. <i>(use #other_LACK OF for mention of less hands-on involvement).</i>
7e	#adv. act6_design process_practicing presentation skills	providing opportunities for ss to practice presentation skills before the main competition event (e.g. through mock presentations)

7f	#adv. act6_design process_proposing extension of another project	proposing extensions of a project based on something that was done in the past by this or other teams.
7g	#adv. act6_design process_scientific/data-driven approach to project	advocating a scientific/data-driven approach to project ( <i>mostly applies to Emerald interviews</i> )
7i	#adv. act6_design process_use of IT website/rubric	using or making ss aware of the IT website and/or other IT materials/resources related to project work, including the project judging rubric and criteria (advisers referring ss to website/rubric to help prepare for competition; aligning project to competition requirements).
7j	#adv. act6_design process_time management	advisor employing strategies for interacting with teams or participating in design activities aimed at effectively managing his time in advising teams.
8	#ADV. APPROACH	descriptions of advising approach, changes in approach, or practices as part of general approach.
8a	#adv. approach_changes	changes in the advising approach.
8b	#adv. approach_changes_scientific practices	changes in the advising approach specifically in relation to emphasizing scientific method/practices in project work.
9	#ADV. GOALS	description of advisor goals related to IT participation, projects, or students. - Statements are expected to be more <b>outcome-focused</b> (e.g.: "My goal is always to see the kids finish. And that's..um, that they finish well.") - There may be categories of goals: project completion, winning, skill building (teamwork, scientific method, etc.), attitudes toward college.
9a	#adv. goals_college exposure/orientation	goals related to exposing ss to college, becoming familiar with what a college campus is like and what opportunities it affords.
9b	#adv. goals_confidence/esteem/accomplishment	developing ss' confidence, esteem, sense of accomplishment and similar attitudes ( <i>code is similar to OUTCOMES, but discussed as a goal, rather than what was actually achieved</i> )

10	#ADV. IDENTITY/POSITIONING	how advisor might position him/herself in conversation in terms of elements of who they are that are relevant to their involvement in IT (examples: being the only teacher involved in IT; having a connection to WSU as alum, etc.)
11	#ADV. ROLE	<p>descriptions of advisor's role on ss teams in relation to advising or IT participation.</p> <ul style="list-style-type: none"> <li>- Statements expected to be more <b>process-focused</b> compared to goals</li> <li>- Roles may be thought of as more general descriptions of advising activities, e.g.: providing encouragement, nudging/motivating, structuring, providing opportunities to meet, providing constructive feedback on specific activities, etc.</li> <li>- May refer to different kinds of activity: project work, WSU trip experience, overall participation in IT, future plans, etc.</li> </ul>
11a	#adv. role_monitoring progress	<p>advisor checking in, following up with teams to monitor progress on project during project work; includes:</p> <ul style="list-style-type: none"> <li>- asking ss for status on project tasks, milestones, or challenges;</li> <li>- ensuring ss are aware of deadlines;</li> <li>- making oneself available for student questions/offering help;</li> </ul>
12	#CHALLENGES	<p>circumstances due to certain individual or collective activities.</p> <ul style="list-style-type: none"> <li>- includes challenges with team process: procrastination, structure, leadership (some overlap with "LACK OF" code - consider collapsing later)</li> <li>- e.g. ss not having the #content/background knowledge to do certain kinds of projects (e.g. one team not doing an energy device due to lack of knowledge etc.)</li> </ul>
12a	#challenges_ADV_managing multiple teams/losing team members	challenges with managing multiple teams, including logistics, communication with students, staying informed on progress, providing feedback.

12b	#challenges_ss being unable to attend IT	challenges associated with students being unable to attend the competition for reasons beyond advisor's control.
12c	#challenges_SS_procrastination	challenges related to students' procrastination and apparent failure to invest the time necessary to complete a project, or a project of sufficient quality.
13	#CONSTRAINTS	conditions associated with context-related/structural limitations that frame project work.
13a	#constraints_access to/availability of school staff	constraints associated with involving other teachers or staff at school to assist with any aspect of ss' competition experience.
13b	#constraints_communication	advisor difficulties communicating with ss for various reasons, including delays in responding, poor use of certain communication media (e.g. email)
13c	#constraints_family impacts	family involvement that limits ss' ability to participate in project work or presentation (attending the competition).
13d	#constraints_IT rules	IT rules which create/impose limits on participation in IT (such as capping number of teams per school, or requiring ss to work in teams)
13e	#constraints_liability	advisor/school/IT liability concerns that might directly impact project work.
13f	#constraints_money	money/funding as a limiting factor in project planning or implementation, including scheduling or feasibility.
13g	#constraints_other impacts on ss	awareness of other unspecified constraints that might affect project work or student experience.
13h	#constraints_time	limited time, scheduling difficulties, or having to manage multiple priorities which directly impact time available for project work.

14	#DESIGN PROCESS (SS)	elements/issues involved in the design process used <b>by the team</b> - includes scope/feasibility of project; timeframe; time/effort spent on project; other characteristics that are part of or shape the design process, including both the individual and collaborative aspects.
14a	#design process_brainstorming project ideas	brainstorming of the project ideas by ss.
14b	#design process_hands-on	the hands-on, practical experience associated with project work; may be mentioned in contrast to just theoretical/textbook-based.
14c	#design process_info gathering_online research	performing online research when gathering information for the project.
14d	#design process_info gathering_SMEs/resources	consulting with subject matter experts (OK to double-code as <a href="#">#feedback_SMEs</a> ) or using other resources (parents, books, knowledge of similar projects).
14e	#design process_making changes	making (or resisting) changes to: design process, project categories, project topic, etc.
14f	#design process_allocating/scheduling/spending time	allocating/scheduling/spending time on tasks specifically related to project design activity/making progress on project work.
14g	#design process_school-centered	project ideas being related to the school the students go to, or to other schools in their community.
14h	#design process_starting late/scrambling	procrastinating, starting late, and scrambling to complete a project late in the competition timeframe.
15	#FEEDBACK	feedback about the design process from the advisor, SMEs/stakeholders in school/community, IT judges, etc. - does NOT include ss' feedback about their competition experience. (see OUTCOMES)
15a	#feedback_adv	feedback from advisor to ss in relation to project work.
15b	#feedback_judges	feedback which the advisor and/or ss receive from the judges.
15c	#feedback_SMEs	feedback which the advisor and/or ss receive from subject matter experts (SMEs) in relation to project work. <i>Code feedback from SMEs who are judges at competition event as <a href="#">#feedback_judges</a>.</i>

16	#LEADERSHIP (ss)	indicators of student leadership in managing the project or project team: in the process of working on, implementing, or presenting the project; also includes self-perceptions about one's role/impact on project. <i>May be combined with code #other_LACK OF to indicate insufficient/lacking leadership qualities or skills.</i>
16a	#leadership_planning team activities	leadership expressed in planning team activities, such as meetings (proposing date, location, duration, or agenda), assigning/managing roles, distributing tasks, setting priorities and deadlines.
16b	#leadership_representing/advocating for team	leadership expressed in representing, speaking, or advocating on behalf of the team.
17	#LINKS TO CURRIC/TEACHING	Connections, including alignment or lack thereof, between the school curriculum and ss' IT participation and project work.
17a	#links to curric/teaching_alignment_advising and teaching	alignment between the advising and teaching roles, responsibilities, or practices.
17b	#links to curric/teaching_alignment_course or curric. and IT (theme/topic/skills)	alignment between IT participation and curriculum content or practices (e.g. understanding scientific concepts, or applying scientific methods or design principles); also alignment with teacher's priorities or perceptions of skills and abilities the ss acquire through participation in IT which might compliment school curriculum.
18	#MEETINGS	discussion related to planning and coordination of student team meetings as part of project work; the role of meetings in the collaborative design process; the way particular meeting arrangements or spaces might impact the process of project work; also includes meetings with advisor.
18a	#meetings_adv./classroom norms	classroom norms that might shape meeting dynamics.
18b	#meetings_in-school/in-classroom	meetings in classroom or lab spaces in schools

18c	#meetings_in-school/out-of-classroom	meetings in school spaces other than classroom (offices, school library, cafeteria)
18d	#meetings_out-of-school	meetings outside of school (public library, ss' homes, other sites)
18e	#meetings_tools/resources/spaces	tools, resources, or features of meeting spaces that are utilized in team meetings as part of project work.
18f	#meetings_with adv.	meetings of individual students, teams, or groups of ss interested in participating in IT with the advisor, where the advisor typically participates in a way that (directly or indirectly) informs or shapes project work.
19	#OUTCOMES	outcomes associated with project work or general participation in the competition, including: - becoming interested in topic if talked about as outcome; - making a difference/seeing impact of the project in school/community (e.g. ss may see results of a composting program at their school) - achieving specific project goals, reaching, milestones, completing activities.
19a	#outcomes_confidence/esteem/accomplishment	ss' sense of confidence, self-esteem, accomplishment through completing and presenting a project.
19b	#outcomes_content despite not winning an award	ss feeling OK, not too discouraged about not winning; may be related to statements about expectations.
19c	#outcomes_exposure to other projects	ss being exposed to other projects through opportunity to attend competition.
19d	#outcomes_fun/enjoyment	fun or enjoyment as outcomes of competition experience.

19e	#outcomes_plans/goals/interest in future/repeat IT participation	goals, plans, or interest related to future participation in IT; includes experience of previous or repeat participation in IT as a factor in ss' knowledge or decisions about participation or project work; includes wanting to re-live the experience, re-engage with the competition; may be related to desire to improve project.
19f	#outcomes_learning	learning various things as an outcome of participation in IT.
19g	#outcomes_teamwork experience	sense of cohesion as a team, successful collaboration, team spirit, a shared experience.
19h	#outcomes_winning/not about	ss either being or not being motivated by the notion of winning, receiving a prize/cash award.
19i	#outcomes_winning_consequences (negative)	negative consequences of receiving an award/recognition for 'placing' in IT in a given year.
19j	#outcomes_winning_consequences (positive)	positive consequences of 'placing' in IT in a given year.
20	#PARTICIPANT CHARACTERISTICS/IDENTITY	ss' characteristics/traits/ways of being, including labels/stereotypes/generalizations, as described by advisor or ss themselves.
20a	#participant characteristics_general abilities/traits	describing ss in term of general abilities, such as being bright/creative; <i>for specific disciplinary traits, code as #participant characteristics_disciplinary orientation/skills/abilities</i>
20b	#participant characteristics_college-bound ss	describing ss as planning or being oriented toward going to college
20c	#participant characteristics_prior IT/similar experience	describing ss in terms of having/not having prior IT or similar competition/complex/real-world project work experiences.
20d	#participant characteristics_disciplinary orientation/skills/abilities	describing ss in reference to specific disciplinary/professional traits, such as engineering design, or technology use, or art.

21	#PATHWAYS	The pathways and trajectories of participation in IT, including team formation, selection of project topic, and engagement in project activities.
21a	#pathways_common schedules/other experiences/grade level	school schedules or other in-school or out-of-school activities/experiences as a factor in ss' participation in IT (e.g. science club); includes grade level as a related factor (but not necessarily success - for that use more specific code: <a href="#">#success factors_grade level</a> )
21b	#pathways_friendship/social relationships/repeat participation	friendship/social connections/relationships between ss as a factor in participation in IT activities; includes ss' awareness/interest in IT resulting from their own or other ss' participation in IT in previous year(s).
22	#SC	mention of the Science Club (SC) as context that is directly or indirectly associated with ss' participation in IT. - SC codes <i>only apply to Malachite interviews, since there was no science club in the context of this study at Emerald.</i>
22a	#SC_framing for recruiting ss	SC as a context or place (SC meetings) for recruiting students for IT.
22b	#SC_goal alignment with IT	alignment of SC activities/goals with IT: includes involvement of minorities/low-socio-economic status students, girls, ss with different interests/skills, doing hands-on science, etc.
22c	#SC_grade level of ss	grade level of ss in SC.
22d	#SC_leadership	leadership in SC - who is in charge of what, etc.
22e	#SC_meeting frequency	frequency of SC meetings.
22f	#SC_number of students	number of ss in SC.
22g	#SC_role in team formation	role of SC in how student project teams were formed for IT.
22h	#SC_typical/familiar activities	typical activities in SC.

23	#SUCCESS FACTORS	factor in team/project success or quality of IT participation experience.
23a	#success factors_grade level	ss' grade level as factor in team/project success/quality of IT experience.
24	#TIMEFRAME	description of the timeframe or scheduling of events or steps in the process around project work or participation in IT in general, focusing on the "when" of decisions, activities, changes, or milestones.
24a	#timeframe_initial project ideas	timeframe for initial discussion/brainstorming of project ideas.
24b	#timeframe_mock presentations	timeframe for mock/practice presentations prior to the competition event.
24c	#timeframe_pre/registering for IT	timeframe for pre-registration or final registration for IT.
24d	#timeframe_project changes	timeframe for making project changes, such as switching from one IT project category to another, changing project topic, changes in team members, or other project-related activities; includes general comments about 'changes.'
24e	#timeframe_use of IT criteria/rubric	timeframe for using the IT judging rubric (if/when it was used) as part of the project work.
24f	#timeframe_when advertised IT	timeframe for the advisor's advertising of the IT competition in order to raise awareness and recruit student participants.
25	#OTHER	do not use as a code - when coding, use specific codes in this category.
26	#other_AGENCY	ss having capacity or opportunities to make and/or act on decisions regarding the project work or how/when to participate in the competition, with little or no guidance or structure from the advisor or others; may involve any project activities, such as brainstorming, planning, and implementing ideas; choosing teams or teammates; presenting at WSU.

27	#other_COMPLETING PROJECT (in/ability)	ss' ability or inability to complete the project, take it from ideas to final presentation or implementation; includes ss having unrealistic expectations about their ability to complete project.
28	#other_IDENTITY (ss)	ss' characteristics/traits/ways of being, including labels/stereotypes/generalizations, as described by advisor or ss themselves.
29	#other_LACK OF	ADD-ON code, indicating a lack of some property or phenomena coded with another code. <i>(used to distinguish codes of somethat that is present from when it is missing)</i>
30	#other_MOTIVATION (ss)	n/a (do not code - will be coded based on keyword search later)
31	#other_STRUCTURE	structure, regulations or rules in the organization, planning, and process of project work;
32	#other_adv./teacher knowledge	knowledge of subject matter or processes (scientific methodology or design) that is of relevance to project work.
33a	#other_affect/emotions_adv.	advisor's emotional/affective states or responses mentioned in relation to advising or project work.
33b	#other_affect/emotions_ss	ss' emotional/affective states or responses mentioned in relation to project work.
34a	#other_effort/time/quality_adv.	advisor commitment of effort, time, or focus on quality in relation to project work or the competition.
34b	#other_effort/time/quality_ss	issues around applying effort, spending time, or paying attention to quality in ss' project work, such as in an effort to improve project or meet expectations.
35	#other_experience at/of IT	non-specific comments about ss' experiences related to attending or presenting at the IT competition event, or the significance/impact of that experience.

36	#other_interest_alignment	alignment of IT/project work with ss' interests, including discussion of how IT compliments ss' interests or what excites them/what they enjoy doing in their life outside of school or in certain courses in school.
40	#other_project topic	mention or description related to project topic - the kind of project that was done, what it was about.
41	#other_repeat participation_value of	specific benefits/results of previous or repeat participation in IT, either for ss or advisor.
42	#other_school/community demographics	description of the demographic characteristics of a given community or area, for example the area where the school is located, or if demographics are used as an input in project-related decisions.
43a	#other_visibility_at school	visibility/awareness about the individual students, teams, projects, or advisor at school associated with participation in IT.
43b	#other_visibility_outside school (community etc.)	visibility/awareness about the individual students, teams, projects, or advisor in the community (beyond the school) associated with participation in IT.

*\* representative quotes for each code were also used for reference in the coding process (omitted for brevity)*

*\*\* The abbreviation “adv” stands for advisor, and “ss” stands for students*

## Appendix I. Malachite Team's Draft and Final Project Plan

### Three Year Plan (Rough Draft)

#### Year One (2010-2011):

- Implement our behavioral project into our school through interviews and surveys
- Lay the ground work for our school wide composting program
  - figure out logistics (Planning placement, talk with horticulture teacher and the kitchen staff)
- **Begin the process by having the kitchen staff collect the food scraps from the kitchen area to be composted**

#### Year Two (2011-2012)

- Educate the student body and staff about the importance of recycling and composting
- Begin the use of compost bins school wide
- Have follow up interviews with previous interviewees

#### Year Three (2012-2013)

- Educate the students of local elementary and middle schools
- Introduce our Waste Reduction plan into our school district's middle and elementary schools

### Three Year Plan

#### Year One (2010-2011):

- Implement our behavioral project at our school through interviews and surveys
- Lay the ground work for our school wide composting program
  - figure out logistics (Planning placement, talk with horticulture teacher, the kitchen staff, and the head of the janitorial staff)

#### Year Two (2011-2012)

- **Construct more compost bins**
- **Year Two (Begin the process of having the kitchen staff collect the food scraps from the kitchen area to be composted)**
- Educate the student body and staff about the importance of recycling and composting
- Begin the use of compost bins school wide
- Have follow up interviews with people who were previously interviewed

#### Year Three (2012-2013)

- Continue to educate students of [...] High School and continue the composting/ recycling program already in place
- Educate the students of local elementary and middle schools
- Introduce our Waste Reduction plan into our school district's middle and elementary schools
- Towards the end of the year pass down the leadership for the program down to new students for its continuation



## Appendix J. Emerald Team's PowerPoint Presentation on Composting (Outline)

### Cafeteria Waste Disposal

*“What can you do to help?”*

#### What is wrong?

Here at [school name], we throw all of our waste into one type of garbage can at lunch. Much of the materials currently being thrown away and shipped off to landfills are recyclable material.

Did you know? The majority of waste produced by schools is food waste. Next comes paper.

#### How can this problem be fixed?

The solution is very simple and convenient. To fix our waste issues, all we have to do is *participate* and *cooperate* in implementing the new *COMPOSTING SYSTEM*.

#### What exactly is this?

By teaming up with [...] composting company, [school name] will keep paper and food scraps out of landfills. New collection bins will be placed in the cafeteria for us to sort our waste by:

Liquids

Compostables

Garbage

#### How do you know it will work?

The same composting system was successfully implemented at [school name] Elementary (start date: January, 2011). In 3 months, [elementary school name] composted over 2000 lbs of waste! [high school name] has nearly three times the number of students. We have the potential to compost 6000 lbs in 3 months, and 24,000 lbs in a year!

#### What goes where?

- ❖ LIQUIDS: There will be five gallon buckets with a screen over the top for you to pour any liquids into.
- ❖ COMPOST BINS: These are the large green bins, place all your compostable materials into them.
- ❖ GARBAGE: The big black bins that are the same as last year, this is where everything else goes.