

IS MOTIVATION AND ENGAGEMENT INCREASED FOR TEACHERS AS
STUDENTS CONDUCT PROJECT-BASED SCIENCE INQUIRY?

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2015

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DEDICATION

This paper is dedicated with much love to Teikyo, Marion and Hope, my amazing children. Too many times you had to talk to my back while I worked or manage without me but always you supported me, and encouraged me even when I whined or complained. I love you all.

ACKNOWLEDGEMENT

I wish to acknowledge Dr. John Graves for being the most supportive and encouraging adviser one could ever ask for. Dr. Graves singlehandedly made my experience with the MSSE program the most fruitful and enriching of my educational life to date. His nonjudgmental cheerleading and unconditional support led me back from the edge of the cliff on many occasions and whose advice, inspiration and solid mentorship made the creation of this paper possible.

I must also thank Diana Paterson for being with me each step of the way.

Thank you!

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ABSTRACT

This study investigated the outcome of graduate students as they progressed through self-selected inquiry projects. Data was collected on prior knowledge and understanding of inquiry as well as comfort levels in choosing their own topics. The results showed that student motivation and engagement increased as project autonomy increased. Findings also revealed that metacognition increased when students were allowed greater control over project outcomes leading to conceptual changes in understanding.

INTRODUCTION AND BACKGROUND

The Masters of Science in Science Education (MSSE) offered by Montana State University is an “exemplary student centered science and applied science education” (About Us). According to the program website the goal of this online Master’s program for teachers is to create science educators who can actively participate in the “systemic reform of science education” (About Us) at all academic levels. This is accomplished by guiding and instructing science educators through enhanced awareness of pedagogy and content, reflective practices, instructional skills, strategies and research based science and engineering practices which emphasize Next Generation Science and National Science Education Standards. Students enrolled in this program come from all over the country and international locations.

I am currently an MSSE student and have taught high school level science in Connecticut for six years. The student-centered approach as taught by the MSSE program has been eye opening to me as my previous educational experience and practice was almost exclusively by direct instruction. During most of my teaching career I taught the way I had been educated through traditional teacher-centered methods of lecture, guided notes and scripted activities. My students were given limited opportunities to select their own research topics. As I read and was exposed to different teaching theories I tried to incorporate more activities during which students were given more autonomy over the topics they chose to research and the methods and artifacts they chose to collect. I noticed that many students appeared more invested when they were given a measure of control, and also seemed more satisfied with the outcome when they were allowed to select their

own methods of process and delivery. An additional bonus during this type of problem-based learning was that many students remained more engaged and were able to sustain that engagement when they had more control of the development and outcome. However while some students met open-ended challenges head-on other students struggled when not provided explicit directions. Given the opportunity to engage in inquiry sometimes resulted in too many questions and not enough answers, a situation that created frustration and loss of engagement. As an undergraduate and graduate student I had sometimes struggled between wanting to be given exact directions and the desire to focus on topics that were more relevant to me. It seemed that high school students and college students were not very different in this respect.

Inquiry Through Science and Engineering Practices is an MSSE course. The objective is to help teachers in the process of becoming project-based instructors. The MSSE students are all educators and as such accustomed to being teachers but not necessarily inquirers. As part of this course students are required to conduct an inquiry based project of their own choosing turning the tables on educators and putting them into the position of being problem-based learners. In the course of my own studies I had been exposed to many new ideas, which had resulted in changes in my thinking as I worked through different problems. I wondered if other graduate students who were allowed to self-select their own research topics and consistently encouraged would be more motivated and engaged than the same students who were given teacher-selected topics and methods. Would other student's metacognition increase and result in conceptual change if they were more engaged in the entire process? This led to the creation of my

primary focus question, *What are the effects on MSSE student's engagement in project-based inquiry explorations?* and secondary question, *To what degree does inquiry practice undergo conceptual changes as a result of engagement in project-based inquiry explorations?*

CONCEPTUAL FRAMEWORK

Much research supports the creation of greater student engagement and deeper understanding when students are allowed to make their own decisions and learn by hands-on and authentic learning (Blumenfeld, 1991; Bowman, 2011; Bradford, 2005; Duval, 1991; Johnson, 2013; Markham, 2011; Simmons, 2010). Students will retain more knowledge and learn more deeply when they attach meaning to their learning, generate their own learning opportunities, and are allowed to create their own investigations (Bradford, 2005). The more engaged students are in the learning process, the more successful and invested they are in their learning (Duval, 1991).

In project-based learning, students do not learn isolated facts out of context as delivered by their teacher. Instead teacher-centered delivery is shifted to a more student-centered approach as students investigate, learn and apply information to real-world contexts while conducting on-going student-directed research. The methods they use to conduct their research utilize real-world problem solving skills in finding viable solutions. The knowledge and skills gained during their inquiry address relevant issues and help to develop real-world skills (Bradford, 2005; Technology & Learning, 2004). Learning opportunities are created as students collaborate and choose the inquiries they will investigate, as well as decide on the artifacts and end products they will produce.

Teachers act as facilitators during problem-based learning rather than as deliverers of static and predetermined information. Metacognition is the process by which learners think more about the process of learning as they actively endeavor to solve authentic problems. The more metacognition taking place the more students take ownership of their learning. Engagement can be sustained over a longer period and deeper and more long lasting understanding is possible (Abell & Brown, 2007).

Educators are given the task to impart designated knowledge and skill sets to our students as determined by the district curriculum, state and local standards. Many new teachers fantasize about a classroom full of students who are anxious and eager to learn, are prepared to think deeply, and arrive motivated to do whatever it takes to succeed. The reality is that not every student comes equipped with a strong work ethic, and even those who do are not solely motivated to succeed by the promise of a brain crammed full of knowledge. Students will often lose interest and motivation when there is no apparent connection between what they are learning and what they feel the need to know. Static curriculum that lacks relevance or real-life connections for the learners, does not offer opportunity for authentic learning. Students will be bored and disengaged by what they perceive to be meaningless (Allen, 2013). Unmotivated students are not actively engaged in the learning process (Duval, 1991). Teachers are expected to determine what will motivate students to do their best and achieve the standards.

Accomplishing tasks does not guarantee motivation or engagement. The secret to what motivates our students to learn has long been debated. Many generations of students will be familiar with the linear and algorithmic method of teaching, where a set of tasks is

given to accomplish, with a predetermined product or conclusion. These prescribed assignments allow students to accomplish tasks and go through the motions of physically doing without mentally engaging (Bowman, 2011). Many writers on the theme of motivation acknowledge that while teachers may not always be able to motivate their students, they can discourage them by taking away student autonomy instead of allowing students to seek out their own learning and determine their own paths (Lindblom, 2010).

Self-determination theory suggests that humans are motivated by what will best serve them, making intrinsic motivation the highest level of self-determination (Deci, Vallerand, Pelletier & Ryan, 1991). Many variations on the theme of self-determination and intrinsic motivation include extrinsic factors used in an attempt to activate intrinsic motivation. These are proverbial carrots on a stick like the promise of good grades or more tangible rewards like candy or homework passes for correct answers. Positive Behavioral Intervention Strategies (PBIS) offer rewards of pizza parties and movie-days for compliant students. Extrinsic motivators have been shown to work in the short term but cannot sustain long-term enthusiasm necessary for deeper learning (Pink, 2009).

An environment that provides basic human needs of autonomy, purpose, and mastery will allow students to feel control over and pride in their accomplishments (Bowman, 2011). Basic freedom of choice allows students to feel autonomy over their futures. Purpose provides students a direction and reason for their learning. Mastery is the end result that will allow students to feel a sense of pride and accompanying self worth. In allowing students choices, they control the path of their learning while also feeling more autonomous (Lam, Cheng, Ma, 2009).

Project-based learning allows students to experience autonomy, purpose and accomplishment. In writing about what motivates workers to do their best, Bowman (2011) wrote that “pride in the work itself is the most powerful agent of change” (p. 266). It is what motivates all humans regardless of their occupation, to do their best (Katzenbach, 2003). Teachers therefore must function not as motivators so much as pride builders (Bowman, 2011). Self-efficacy and pride are both results of problem-based learning. Csikzentmihalyi (1980) defined this winning combination as flow, or the perfect union of intrinsic motivation and pride.

Bowman (1982) wrote about flow in describing the similarities between successful classrooms and video gaming systems. Some expected similarities include: high probabilities for success, freedom from ridicule and a clear outline of responsibilities and roles. Other characteristics less common in the classroom but characteristic of flow include the ability to choose ones problem-solving strategies, a “progressive hierarchy of challenges to sustain interest, and nearly infinite opportunities for self-improvement” (Bowman, 1982, p. 62). In both cases when students feel active control in choosing their learning opportunities, they experience greater flow (Nowicki, 2013). When students feel powerless to control their own outcomes, they may choose to disengage or make inappropriate choices (Simmons & Page, 2 010). Environments that promote democracy and a high degree of self-direction and pride in one’s own work also allow a higher degree of flow for students. The traditional teacher-centered classroom does not promote this type of democracy or flow.

Research on learning and video games brought recognition to the similarities between ways players find satisfaction while playing video games and students' satisfaction in their classrooms (Bowman, 1982). In comparing the exhilaration experienced during gaming and success in the classroom Bowman (1982) acknowledged that the rewards for students were both intrinsic and extrinsic, but the flow experienced by students in both contexts acted as strong motivators. The "prizes" earned while playing create a high degree of motivation for persevering through failures. An infinite variety of sounds and visual excitement provide continual and ongoing feedback and encouragement to strive for the next level. Students involved in collaborative efforts like those experienced during problem-based learning are allowed opportunities for frequent and immediate feedback from their collaborators and teachers and are more able to manage workflow and overcome setbacks (Christine Chin, 2010).

One of the perks of problem-based learning comes from the opportunity to collaborate within small groups. While some students may perceive this as an opportunity for socialization, in reality it helps teach collaborative skills (Johnson & Delawsky, 2013). Students more accustomed to the linear model of prescribed and scripted problems may be unprepared for the unaccustomed events and lack of structure a project-based problem may present (Markham, 2011). When things don't work as expected, the ability to brainstorm and rely on the strengths of the group, instead of acting in or out of frustration will help students persevere (Hallerman, 2013).

Teachers can assist in keeping students on track or in mediating conflicts of differences of opinions that may occur (Chin & Chia, 2010). Students may need guidance

and assistance with time management, the efficient use of resources, implementation and use of technology, formulating inquiries and using problem-solving strategies effectively (Blumenfeld, 1991). The role of teachers as facilitators and providers of feedback can help students realize the opportunities that failure presents for real growth and expansion of ideas (Chin & Chia, 2010). The prospect to inquire, strive, fail and problem-solve allows measurable growth for real world life skills (Markham, 2011).

Problem-based learning is a more student-centered philosophy. The traditional teacher-centered curriculum has been the norm since the archaic days of the one-room schoolhouse. The timing and calendar of this standard were based on the needs of a largely agrarian society, which followed the growing seasons. Students completed school by late spring in order to be released to help on their family farms. The only major changes, which have occurred to that model, occurred after the Industrial Revolution, when our society shifted from an agrarian culture to an urban and industrial-based culture. There was great need to man the factories with an educated mass that prized uniformity, conformity and compliance to the rules. To a lesser degree there was need for a managerial elite whose skills would be needed to husband the compliant masses. Fifty-five minute classes and school bells trained future factory workers. The old curriculum itself was borrowed from the monastery schools of old Europe and the Middle Ages and favored math, science, the arts and language (Trilling & Fadel, 2009). This curriculum and its reliance on rote memorization has remained largely unchanged despite major changes in our society's demographics and economic needs.

Today's global economy requires less focus on the skills required for manual labor and repetitious work and more focus on what Trilling and Fadel (2009) refer to as *knowledge work*. Knowledge Taxonomy is structured similarly to Bloom's Taxonomy, where *Knowledge* is the base to a pyramid of learning. Knowledge Taxonomy builds with *awareness* followed by *comprehension*, *application*, *analysis*, and *synthesis*. The culminating highest level of knowledge comprehension is Evaluation (Daggett, 2014). Knowledge work requires critical thinking and the ability to utilize technology and resources to process large amounts of information quickly. Knowledge work promotes 21st century thinking instead of turn of the century thinking. There is less need for memorization of large facts since the body of knowledge is multiplying faster than humans can assimilate. Up-to-date facts and figures can be accessed by anyone with Internet access. Curriculums that focus on critical thinking and problem solving will better prepare our students for the current job market and jobs of the future (Trilling & Fadel, 2009).

Problem-based learning allows opportunities to develop 21st Century skills like critical thinking, reflective reasoning and practical hands-on learning (Lam et al., 2009). By collaborating with small groups, students practice and develop critical social skills. Project-based learning also allows students to make interdisciplinary connections as they gain deeper understanding of key principles and apply these methods to broader ideas and concepts. Active engagement can be sustained over a period of time as students work through the often chaotic or unscripted route their inquiry leads them, mirroring real-life situations as they find real world solutions (Blumenfeld et al., 1991).

The sustained engagement and deeper understanding which may occur during problem-based investigations can result in many benefits including conceptual changes to thinking (Johnson, 2013). The acquisition of new knowledge can challenge or fill gaps in understanding but the self-reflection and metacognition that accompanies problem-based learning may also correct unperceived prior misconceptions. Challenges to misconceptions can result in categorical shifts in thinking, or conceptual changes to thinking (Chi, 2008).

METHODOLOGY

This case study followed the effects of project-based learning on motivation, engagement and conceptual changes of graduate students as they worked through a project-based inquiry-model project. Students/teachers enrolled in the MSSE course *Inquiry Through Science and Engineering Practices* were asked to participate in this case study and informed that participation would not affect their grade or class standing. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Prior to introduction of the inquiry project a Pre-Inquiry Survey was administered to participants (Appendix B). The four-option Likert-type survey asked participants to choose *Strongly agree, Agree, Disagree* or *Strongly disagree* to compare motivation and engagement working on teacher-imposed projects and self-selected projects. The Pre-Inquiry Survey provided quantitative baseline data to help answer the focus question, *What are the effects on MSSE student's engagement in project-based inquiry*

explorations? A second survey Post-Inquiry Survey was given post-project in order to compare responses and determine the amount of conceptual change if any (Appendix C). Responses to the Pre-Inquiry and Post-Inquiry Surveys were separated into categories that identified changes to student feelings of motivation and engagement before starting their inquiry projects and after completion. The data collected was categorized by the percentage of answers for each response and used as a baseline to which all future responses were compared. The comparisons between the Pre-Inquiry Survey and Post-Inquiry Surveys helped show changes and transformations in thinking to answer the secondary question, *To what degree does inquiry practice undergo conceptual change as a result of engagement in project-based inquiry explorations?*

Additional information gained from the Pre-Post Inquiry Surveys included numerically rated questions about participant's level of understanding of science inquiry and science and engineering practices, where level 1 was *nonexistent* and level 10 was *comfortable enough to present at an NSTA conference*. To analyze the data responses were divided into categories which supported the focus question as well as the sub question, and then further divided by those that supported increased motivation and autonomy on problem based projects and responses that did not. The percentage of responses in each category was compared and evaluated for changes. The surveys also included four open-ended questions which asked participants to define inquiry and comment on their level of understanding and confidence in the inquiry process for additional evidence of conceptual changes in understanding.

Weekly online discussions as required for the course were periodically reviewed for discussion threads which discussed inquiry, uncovering misconceptions and conceptual changes to thinking. Threads in which students shared and compared inquiry strategies learned during the weekly assignment to practices in their own classrooms as well as discussions on their final inquiry projects that week were evaluated. These qualitative comments were separated into those which showed increased motivation for self-selected projects and those that did not, those indicating a high degree of comfort with science inquiry and science and engineering practices and those that showed conceptual changes to thinking. These comments were used as qualitative evidence supporting the focus questions.

Requirements for the inquiry project as outlined by the instructor included incorporation of the essential 5 E Learning Cycle components of Engage, Explain, Explore, Extend and Evaluate, a project reflection, Nature of Science (NOS) and other course components. In order to determine the degree to which participants had gone through the scientific inquiry process or experienced a conceptual change in thinking while conducting their projects a Final Inquiry Rubric was used (Appendix D). Projects were evaluated on a scale from 0–4 with four being the most complete and providing the most evidence. Direct evidence of prior knowledge leading to the question or problem statement and creation of the investigation was evaluated and compared to inferences made during the investigation. Direct evidence or strong inferences which identified and lead to the creation of new questions and had resulted in conceptual changes to thinking to the original inquiry were evaluated and received a maximum score of 4.

After final inquiry projects were submitted randomly selected participants were interviewed by phone and asked questions from the Post Inquiry Interview Questions (Appendix E). The interview was conducted in order to gain further insight into participants' feelings about conducting their own investigations and changes in their conceptual understanding of science inquiry and science and engineering practices. The Interview questions were very similar to Pre-Post-Inquiry Survey questions and gave participants the opportunity to reflect on their previous answers, their motivations during the inquiry project and their feelings about the entire process. The responses were grouped by common themes and divided by responses supporting increased motivation and those that did not, and changes in conceptual understanding. Interview and weekly discussion responses were triangulated to qualitatively support the focus questions along with the quantitatively evaluated survey responses (Table 1).

Table 1
Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
1. What are the effects on MSSE student's engagement in project based learning inquiry explorations?	Pre-Post-Inquiry Survey	Weekly Discussion	Post-Inquiry Questions Final Inquiry Rubric
2. To what degree does inquiry practice undergo conceptual change as a result of engagement in project-based inquiry explorations?	Pre-Post-Inquiry Survey	Weekly Discussion	Post-Inquiry Questions Final Inquiry Rubric

DATA AND ANALYSIS

Results from the Pre-Inquiry Survey specified that 55% of the participants had *Limited* experience with researching their own inquiry topics, 30% had experience with any kind of inquiry and 15% considered themselves to have *Much* experience before the final inquiry projects were initiated ($N=21$) (Figure 1). One student replied, “I haven’t researched much on inquiry topics. I don’t really even know what that means. What are inquiry topics?” Another student remarked, “I read Llewellyn’s book *Inquiry Within* as I prepared to begin teaching a new course.” Before the final inquiry project 24% of the participants implied that inquiry was a method “they would expect their own students to use to find answers,” when asked to apply scientific practices. As one student stated “Inquiry allows students to find the answer themselves without being given the answer. It can help students have an application of using the scientific method.”

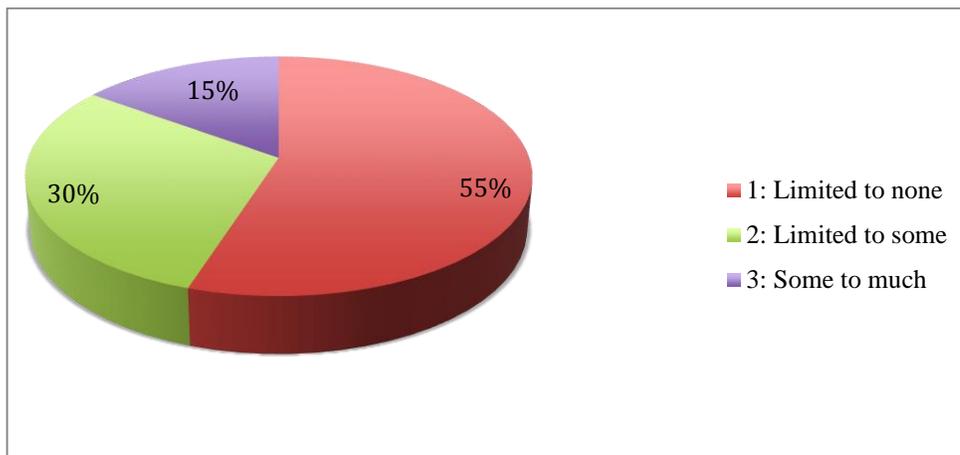


Figure 1. Pre-Inquiry Survey: “What has been your experience in the past with researching your own inquiry topics?”, ($N=21$).

Fourteen percent mentioned the use of exploration when asked for the definition of inquiry in Pre-Inquiry surveys, this number increased to 100% in Post-Inquiry results.

Many also cited the need for patience and more open-ended questioning as in the response, “A method by which to seek answers. It takes time to build confidence and to construct a framework of knowledge for further discovery.”

The Pre-Inquiry Survey asked students to rate their understanding of inquiry before the final inquiry project, a total of 53% of the participants rated themselves 6-7 on the 10-point scale, with 20% of responses below 5 and 15% above 7 on the 1-10 scale, where 10 was complete understanding of inquiry. On the Post-Inquiry Survey the number of students rating themselves above 6 increased 50.0% (Figure 2). After completion of the final inquiry project one student said “I definitely think I can impliment more inquiry and allow my students to experience it more because I finally get it!”

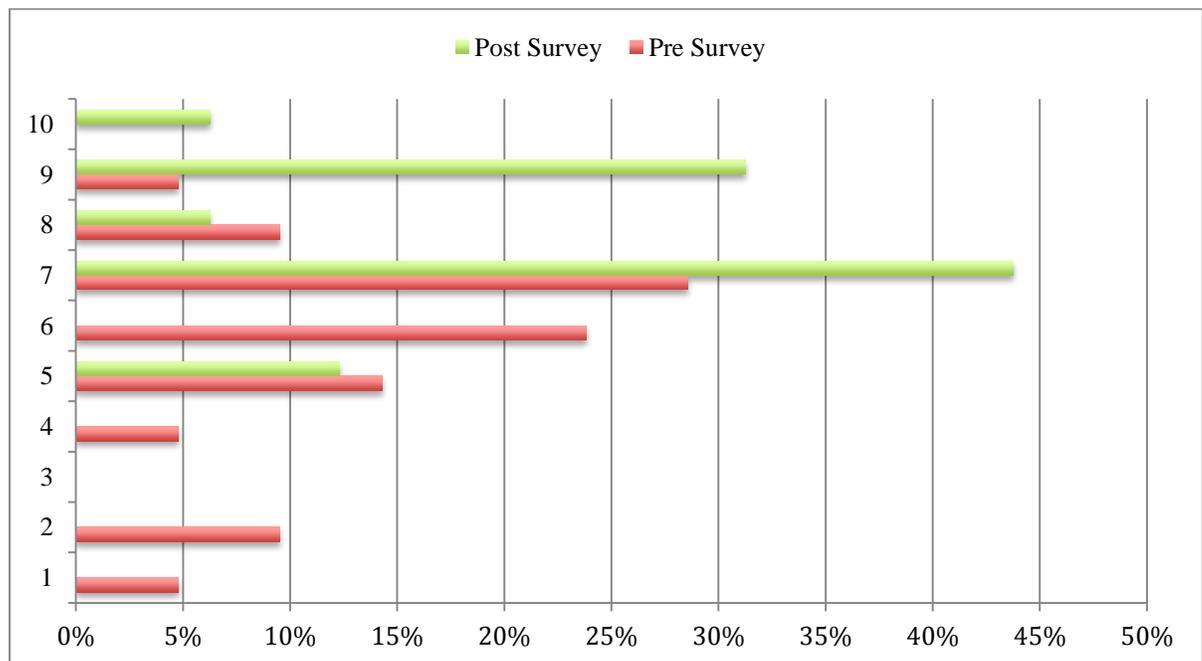


Figure 2. Pre and Post-Inquiry Survey: “On a scale of 1-10 my understanding of inquiry is...”. 1 = non-existent and 10 = “I can present at the next NSTA conference on my topic my understanding level of science inquiry is”, (N=21), (N=16).

On Pre-Inquiry Surveys 76% of the participants chose *agree* with the statement *I like to choose my own problems and solve it myself*. This increased 17.75% to 94% in the Post Survey, with 43.75% of those selecting *strongly agree*. One student put it this way “I wouldn’t have said this before but in choosing my own it was more fun when it was for me.” Forth-three percent of the participants chose *agree* to *I am motivated to continue working when I am told exactly what to do*, but this decreased to 31% on the Post Survey. “I am more comfortable now than I was before, since my project. Choosing my own, I was more motivated to find out. Finding my own answers are more interesting instead of finding someone else’s answers,” said one student.

In Pre-Inquiry Surveys 29% of the participants agreed with a statement *I need to follow the steps I first thought of and ignore separate questions that arise*, however in the Post-Inquiry Survey 81% now chose *disagree*. A student remarked, “Its no longer about finding the right answer but is about investigating and exploring where it will go.” Another student said, “I used to correct my students when they would try to change their hypothesis or alter their experiments, now I see how I kept them from really investing in their learning.”

Topics for the final inquiry project were diverse and included beer making, avian biodiversity, Hershel’s light, making shaving cream, identifying clouds, yogurt making, the effects of coffee on running, triops, quilting, skate skiing, isopods, a stream study, aquaponics, aquatic invertebrates, creating a hay infusion, and singing by sight. Eighty-six percent of the projects provided a clear testable or researchable problem or question, outlined by prior knowledge. Ninety-three percent outlined clear methodology for how the

problem would be addressed or researched. However less than half, 43% of projects demonstrated new questions being developed or investigated as result of inferences made. Forty-three percent provided evidence of metacognition during the project but less than 30% indicated changes to conceptual thinking as measured by the Final Inquiry Rubric (Figure 3).

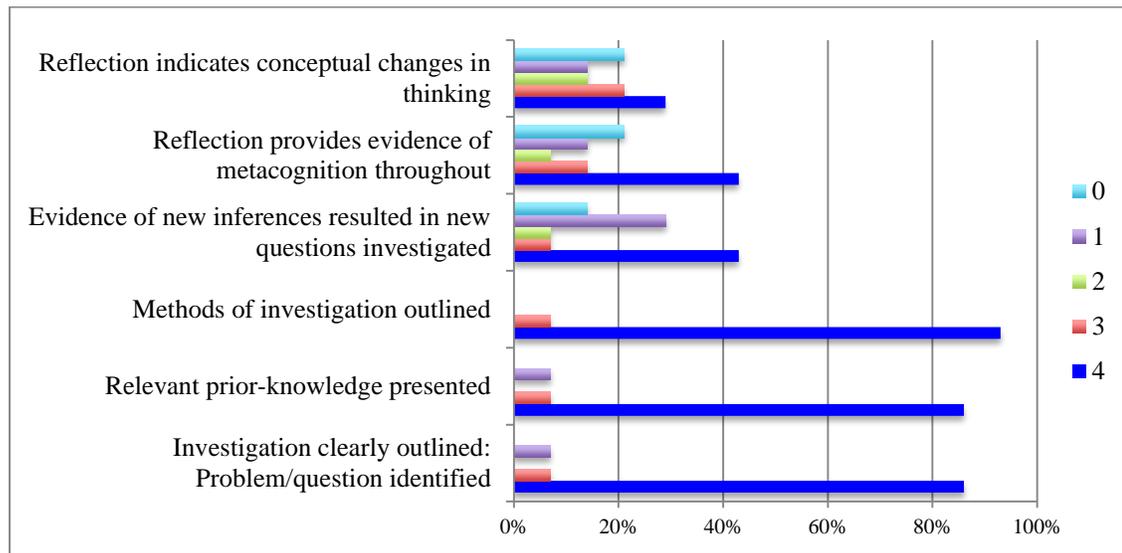


Figure 3. Final Inquiry Rubric results, where 1 = least supportive evidence provided and 4 = most supportive evidence provided, (N=14).

INTERPRETATION AND CONCLUSION

To answer the primary question, *What are the effects on MSSE student's engagement in project-based inquiry explorations?* I thought it important to begin by establishing a baseline understanding of inquiry before the final inquiry project was implemented. This baseline documented the comfort levels of students as they moved forward toward implementing the final inquiry project and also helped to evaluate any conceptual changes in thinking that might have transpired, in order to answer the secondary question, *To what degree does inquiry practice undergo conceptual change as a result of engagement in project based inquiry explorations?*

Participants indicated they were more comfortable choosing their own topics of research and controlling how they would solve the problems on both Pre and Post Survey results. Since research supports greater student engagement and deeper understanding when students are allowed to make their own decisions the potential for deeper connections, learning and conceptual changes in thinking was high. However while only 30% of the participants had reported having any direct experience with inquiry outside of assigning inquiry projects to their own students, slightly more than half, 55% had reported previous experience implementing their own inquiry projects. This led me to believe that many of the participants were unclear as to what inquiry projects actually were. Many of the contributors provided textbook-like definitions when asked to define the word inquiry in Pre-Inquiry Surveys and just over 5% implicitly mentioned inquiry as one of the steps in the scientific method they taught as part of their courses and expected their own students to use. Twenty one percent of the participants cited time constraints and the need to cover district curriculum or preparation for standardized tests as reasons for not having time to do more inquiry with their own students but indicated that explicitly teaching the steps of the scientific method was still part of the official curriculum. Given that inquiry was only mentioned in connection with teaching the scientific method it would appear that prior to completing the inquiry projects these participants did not have an understanding of inquiry outside of a prescribed curriculum. Other students reported that they taught the way they had been taught and implied that inquiry was something one set aside time for or as in a required assessment.“ Many observations were made similar to this student’s “Our district requires us to follow a very

strict curriculum which does not include much wiggle room for much if any solid inquiry.” Or this one, “I try to help my students when they have questions but mostly I am focused on trying to complete one task or another, and limit my own steps to that. In reality I am a new teacher still struggling to have curriculum ready to teach students. I lecture and provide cook book lab activities.” Since only 30% of the participants reported having prior experience with inquiry this led me to assume that as science educators these participants assigned inquiry projects but may not have been familiar enough with the process to facilitate or know if their students were actually conducting inquiry. Six percent of student participants commented that exposure to Next Generation Science Standards (NGSS) was minimal and there was little application of these 21st Century standards in their schools. One student had lamented, “My school doesn’t really do anything with NGSS, and so I don’t.” Another student added, “Before this (final inquiry project) I had no experience at all. I was asking my students to do it a lot without really understanding what I was asking of them. I never realized that I had little understanding of what I was asking them because I hadn’t ever done it.” Post project definitions for inquiry were less formal and there was little mention of the scientific method, instead responses focused on using science and engineering practices and questioning. One response stated “ A process through which one can answer questions about the phenomena around them. Inquiry allows ownership and creativity of experiments and is not rigid and linear as the scientific method.” This shift in definitions focusing on a prescribed method to one of more open-ended understanding showed a conceptual change in the understanding of inquiry. It also illustrated that more

metacognition had taken place during the process than had been determined by the scoring rubric. “ I would think about my study when I was at home and then come into the classroom and change it. I never realized I could do that before. I don’t think I ever really thought about before”, was one comment. As another student put it this way “ Inquiry is the exploration of a problem or idea from multiple perspectives and with the goal of achieving a better understanding. It’s a process requiring continual reflection.”

Students self-reported greater understanding of inquiry after completing their final inquiry projects, and greater comfort in being able to control how they conducted their own projects. Students also reported greater engagement and motivation because they were more invested in the outcome. This correlated with previously stated research, which showed the more autonomy students are given the more engaged and invested. Students reported, "I was more genuinely interested in the results, as opposed to what I just had to do for a class" Another student commented, " Although I had a deadline, the pressure came from me. I could do it the way I wanted to, it was kind of invigorating."

Project-based learning ensures that a lot of metacognition is taking place. It would seem that the frequent opportunity for reflection as students worked through inquiry projects and the course in general created deeper engagement and allowed more profound connections to take place. This metacognition facilitated and supported changes in conceptual thinking. As the literature had pointed out the more metacognition that takes place the more students take ownership of their learning and if the engagement is sustained over a longer period it can create deeper and more long lasting understanding.

VALUE

I found it interesting that although only 30% of the participants showed evidence of conceptual changes to understanding as based on the inquiry project reflections; the Final Inquiry Rubric alone did not provide enough data to accurately assess this. Given the increase in comfort with the inquiry process as shown by the Post Inquiry Survey results and the comments made by students themselves, there was much more conceptual change in student's thinking than they realized. Many students reported that in putting themselves into the role of student, they experienced for the first time what their own students must experience when asked to do something they are unfamiliar with. For many this was eye opening and provided moments of epiphany. As one student stated, "Initially I was kind of waiting for someone to tell me how to start. I was confused at points and I realized that all this time I had not been patient with my students when they were dependent on me to tell them what to do. It was very eye opening for me." Many students reported that the process of struggling and working through it was empowering and a great confidence builder, personally and as educators. "I definitely know more and will be able to help facilitate more inquiry with students as a result." Another common theme was that even though inquiry takes time, it requires patience. "I think it will be easier for me to assign an inquiry project with less intervention or guidance. Students need time to plan, explore, reflect and process information throughout the inquiry process. I would definitely give students a lot of freedom in designing an inquiry project. I think I would keep it to a simple rubric and let them enjoy the process instead of worrying about the end result." was one final observation.

When I began this study I thought I would be evaluating whether students were more engaged when they had the opportunity to pick a topic they were more interested in, but it quickly became a sidebar to a more interesting thread. I had taken the same course these students were now taking. I was familiar with the format and assignments. Yet on many occasions I read a student's comment or a particular discussion thread and wondered if I had misunderstood the theory. I found myself re-reading the articles and watching the video presentations for clues that would reassure me or clear up my "muddy point." *Inquiry Through Science and Engineering Practices* is a masterful course, in which any science teacher regardless of level can expect to learn many methods and tools for facilitating inquiry learning in the classroom. The frequent requirement for reflection on one's work is invaluable. It was from course reflections that I gained many useful insights when I took the course, and later during my study. However I believe many of the most powerful lessons of the class can be lost if one is not receptive to the power of self-reflection. What became apparent to me in reading and listening to other teacher's comments is that many of us are so overwhelmed with the ever growing quantity of requirements we are continually charged with, that like our students, sometimes we just want to be told what to do. We want to know what to expect, and exactly what is expected of us. On the other hand we want to pick our projects, and the methods of research and have the freedom of choice. We also want to allow our students to experience the joy of inquiry and the wonder of learning. But we have become disillusioned and bitter as our plates are heaped high with meaningless, required curriculum designed to get through material, which concludes with a standardized test.

We want control, because that is something many of us don't have. Many times I speak to educators in urban schools who sneer at teachers in suburban schools or scoff when told that their children can become skilled at inquiry if allowed. I frequently hear their side commentary at professional development, or at conferences when they think that the wonderful ideas being presented are by people who are out of touch, or that these ideas "won't work with our kids." But the teachers I speak to who are most successful at implementing inquiry, don't all work in well-to-do districts, and their students aren't necessarily all the cherry-picked high-flyers. The successful teachers are the ones who are competent in their content but who also understand that inquiry is not about control. It's about knowing when to let go. What I realized as I read through projects on quilting, beer making, clouds and a dozen other varied topics was that inquiry was so much more than a science experiment. While it could be a straightforward research project, it could also be about learning a new skill. As one student had put it, it wasn't about the answer, it was all about the questions asked on the way. Or as my son often says, "Its not about the destination, its all about the journey."

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APPENDICES

APPENDIX A
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
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MEMORANDUM

TO: Stacey Mowchan and John Graves

FROM: Mark Quinn, Chair *Mark Quinn CJ*

DATE: November 17, 2014

RE: *"Is Motivation and Interest Increased during Self-Selected Project-Based Learning More than Teacher-Directed Topics for Graduate-Level Students Conducting Inquiry during an Online Inquiry Through Science and Engineering Practices Course?" [SM111714-EX]*

The above research, described in your submission of November 17, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B
PRE-INQUIRY QUESTIONS

This survey is part of a MSSE Graduate research study. Participation in this research is completely voluntary and participation or non-participation will not affect your grades or class standing in any way.

**Do you wish to participate? __YES __ NO __
 If yes, please continue with the survey.
 If no, thank you for your time and consideration.**

Please circle the answer which best describes your feeling about the following statements.

1. I like to choose my own problem and figure out how to solve it myself?
 strongly agree Agree Disagree Strongly Disagree
2. I am more motivated to continue working when I am told exactly what to do.
 strongly agree Agree Disagree Strongly Disagree
3. When I work through a problem I need to follow the steps that I first thought of and ignore separate questions that arise to stay focused don the original idea.
 Strongly agree Agree Disagree Strongly Disagree
4. When I work through problems I come up with new ideas and then follow through with them.
 Strongly agree Agree Disagree Strongly Disagree
5. When working through a problem I will avoid answering some questions if it means a conceptual change to my opinion.
 Strongly agree Agree Disagree Strongly Disagree
6. When I tackle a problem I document my thoughts as I go and frequently reflect on them, making changes if need be.
 Strongly agree Agree Disagree Strongly Disagree
7. I frequently reflect on my own practices and make changes even if it means taking a completely different focus.
 Strongly agree Agree Disagree Strongly Disagree
8. On a scale of 1-10 with 1 being non-existent and I can present at the next NSTA conference on the topic, my understanding level of science inquiry is
 1 2 3 4 5 6 7 8 9 10
9. My understanding level of science and engineering practices on a scale of 1-10 with 1 being non-existent and 10 being I can present at the next NSTA conference on the topic is
 1 2 3 4 5 6 7 8 9 10
10. What is you definition of inquiry?
11. How did the inquiry project change your idea about doing your own research?
12. As a result of the inquiry project, has your approach to solving a scientific problem changed how you would ask students to do a similar project?

Is there anything else you like me to know?

APPENDIX C
POST-INQUIRY SURVEY

This survey is part of a MSSE Graduate research study. Participation in this research is completely voluntary and participation or non-participation will not affect your grades or class standing in any way.

**Do you wish to participate? __YES __ NO __
 If yes, please continue with the survey.
 If no, thank you for your time and consideration.**

Please circle the answer which best describes your feeling about the following statements.

1. I like to choose my own problem and figure out how to solve it myself?
 strongly agree Agree Disagree Strongly Disagree
2. I am more motivated to continue working when I am told exactly what to do.
 strongly agree Agree Disagree Strongly Disagree
3. When I work through a problem I need to follow the steps that I first thought of and ignore separate questions that arise to stay focused don the original idea.
 Strongly agree Agree Disagree Strongly Disagree
4. When I work through problems I come up with new ideas and then follow through with them.
 Strongly agree Agree Disagree Strongly Disagree
5. When working through a problem I will avoid answering some questions if it means a conceptual change to my opinion.
 Strongly agree Agree Disagree Strongly Disagree
6. When I tackle a problem I document my thoughts as I go and frequently reflect on them, making changes if need be.
 Strongly agree Agree Disagree Strongly Disagree
7. I frequently reflect on my own practices and make changes even if it means taking a completely different focus.
 Strongly agree Agree Disagree Strongly Disagree
8. On a scale of 1-10 with 1 being non-existent and I can present at the next NSTA conference on the topic, my understanding level of science inquiry is
 1 2 3 4 5 6 7 8 9 10
9. My understanding level of science and engineering practices on a scale of 1-10 with 1 being non-existent and 10 being I can present at the next NSTA conference on the topic is
 1 2 3 4 5 6 7 8 9 10
10. What is you definition of inquiry?
11. How did the inquiry project change your idea about doing your own research?
12. As a result of the inquiry project, has your approach to solving a scientific problem changed how you would ask students to do a similar project?
13. Is there anything else you like me to know?

APPENDIX D
POST-INQUIRY INTERVIEW QUESTIONS

1. When asked to conduct a study do you feel more comfortable choosing your own study topics or being given a selection to choose from? Can you explain?
2. What opportunities have you had to design your own study from start to finish before this inquiry project?
3. Do you feel more invested in the outcome when you have freedom to choose your topics or methods of research?
4. Have weekly discussions helped you or affected your engagement or motivation?
5. How do you feel your knowledge of science inquiry has changed since you conducted your own inquiry project?
6. How do you feel your knowledge of science of engineering practices has changed since you conducted your own inquiry project?
7. How do you feel as a teacher facilitating and supporting inquiry with your own students since you conducted your own inquiry?
8. Is there anything else you would like to add?

APPENDIX E
FINAL INQUIRY RUBRIC

4	3	2	1	0
Investigation is clearly outlined as problem/question to be investigated	Project is vaguely focused to answer a question/problem	Investigation is somewhat outlined but problem/question is vague	Problem/question to be investigated is vague or open-ended	Project goal is identified but does not represent a problem or question
Prior-knowledge which led to problem/question is clearly related	Prior-knowledge explained but connection to problem/question is not clear	Prior knowledge is presented but does not relate to the problem/question	Some prior knowledge is inferred but not presented	No prior knowledge shown or necessary for investigation
Methods of investigation and the desired outcome are outlined	Methods are outlined but desired outcome may not be clear	Methods are not outlined but desired outcome is somewhat identified	Methods are outlined but not the outcome desired	Methods and outcome are not defined or outlined
Evidence of new Inferences resulting in new questions investigated shown		Questions are suggested but not investigated		No questions or new inferences suggested
Reflection provides evidence of student's metacognition in the inquiry process	Reflection shows some metacognition occurred during the inquiry process	Reflection show some metacognition during inquiry process but not evidence	Reflection talks about metacognition but is not related to the inquiry process	Reflection does not provide evidence of metacognition during the inquiry process
Reflection clearly indicates conceptual changes in understanding occurred during investigation		Reflection suggests but does not provide evidence of conceptual changes in understanding		Reflection does not show any conceptual changes in understanding occurred

Final
Inquiry
Rubric