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Does Interdisciplinary Collaboration Alter Student Perceptions of their Disciplines? A Case Study of a User-Centerd Design Experience for Mechanical Engineering and Early Childhood Education Students

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Does interdisciplinary collaboration alter students' perceptions of their disciplines? A case study of a user-centered design experience for mechanical engineering and early childhood education students

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Abstract
Interdisciplinary collaboration between undergraduate students in engineering and non-engineering disciplines is mutually beneficial. For the engineering students, such collaborations provide opportunities to practice effective communication and to utilize their technical expertise in a broader social and societal context; and, for the non-engineers, collaboration demystifies the engineering profession, contextualizes prior STEM knowledge, and, in some instances, allows for the physical realization of concepts through hands-on design and prototyping. The benefits of interdisciplinary collaboration are best realized when students view each other's respective skillsets and chosen professions as being valuable and necessary in achieving the ultimate goals of the group. The origin and nature of students' beliefs about dissimilar professions warrants further investigation, particularly as it relates to interdisciplinary collaborative experiences, which have the potential to reshape, either positively or negatively, *a priori* beliefs about peer collaborators.

The purpose of this case study was to characterize the impact of an interdisciplinary collaboration on engineering and non-engineering undergraduate students' perceptions of their peers in dissimilar professions. The setting for the study was a mid-sized, research-intensive land grant university in the eastern US, where second and third-year mechanical engineering (ME) and early childhood education (ECE) students were placed on interdisciplinary teams and tasked with designing and fabricating a novel toy for young children that promotes constructive play. Online surveys were administered prior to and after this one semester course and focused on: (1) *a priori* knowledge and experience of the other group's subject area; (2) effect of interdisciplinary project on interest in other group's subject area; and (3) perceptions of other group's profession and/or their skills.

Survey results showed that neither ME nor ECE students had *a prior* exposure to the other discipline. After completing the course, ME students perceived that they knew more about child development, play, and the design of children's toys, and ECE students reported they better understood the types of engineering disciplines. Interesting, ECE students less positively rated their ME counterparts post versus pre-course in the following areas: "very good at math & science," "hardworking," "good communicators," and "intense." Both ECE and ME students finished the course with balanced perceptions of their own disciplines relative to their counterparts. Both ECE and ME cohorts, on average, agreed that their counterparts' professions were equally legitimate and disagreed that there was a discrepancy in rigor between ECE and ME. ECE students solidly agreed that ME was a more valued discipline, although ME students were more neutral on this view.

These findings suggest that engineering students have little content knowledge or experience in disparate fields, such as in this case child development and education, and benefit from interdisciplinary collaboration both in terms of content knowledge and developing a healthy appreciation for outside expertise. The collaboration also benefited the non-engineering students by demystifying the field of engineering, potentially alleviating "imposter syndrome" by

normalizing team performance expectations, and providing some literacy of the engineering design process. In the case of early childhood education students, these altered perceptions of the engineering discipline may have impact on their self-efficacy for teaching science and engineering (Maier et al., 2013; Kallery 2004; Watters et al., 2000); as such their teaching in these two content areas may positively influence the perceptions of engineering by their future students, particularly females and minorities. This study adds to the growing body of research on the benefits of interdisciplinary collaboration at the undergraduate level, particularly as it relates to shifting perceptions of the involved disciplines (Brown et al., 2014; Burrows, 2015; Falloon and Trewern, 2013; Harris Willcuts, 2009; Jeanpierre et al., 2005; and Lee, 2004.

Introduction

Interdisciplinary collaboration between undergraduate students in engineering and non-engineering disciplines is mutually beneficial. For the engineering students, such collaborations provide opportunities to practice effective communication and to utilize their technical expertise in a broader social and societal context (Gruenther, 2009; Bailey, 2007; Hotaling, 2012). For the non-engineers, collaboration demystifies the engineering profession, contextualizes prior STEM knowledge, and, in some instances, allows for the physical realization of concepts through hands-on design and prototyping. The benefits of interdisciplinary collaboration are best realized when students view each other's respective skillsets and chosen professions as being valuable and necessary in achieving the ultimate goals of the group. The origin and nature of students' beliefs about dissimilar professions warrants further investigation, particularly as it relates to interdisciplinary collaborative experiences, which have the potential to reshape, either positively or negatively, *a priori* beliefs about peer collaborators.

This work represents a case study of a project-based collaboration between mechanical engineering and early childhood education students, which was motivated in no small part by national trends in K12 education. With the publication of the *Framework for K-12 Science Education* (National Research Council, 2012), emphasis is now placed on the integration of engineering principles and practices into formal science education. Understanding factors, such as the learning opportunities afforded in preservice education, is essential for preparing future educators to meet education standards. Research indicates the need for preservice teachers to be proficient with the engineering design process; this can be accomplished through systematic engagement in design problems and challenges that allow them to act as engineers while drawing on their own expertise about teaching and learning (Brophy et al., 2008; Hsu, et al., 2011).

The purpose of this study was to examine a semester-long interdisciplinary collaboration between mechanical engineering and early childhood education undergraduate students to determine if interdisciplinary collaboration impacted participants' perceptions of one another's fields. Previous research on collaborations between K-12 teachers and STEM faculty have focused on middle grades (grade 6-8) or secondary education (grade 9-12) – see for example, for example, Brown et al. (2014), Burrows (2015), Falloon and Trewern, (2013), Harris Willcuts, (2009), Jeanpierre et al. (2005), and Lee, (2004). Few studies have investigated partnerships between engineers and early childhood educators. In this study, we hypothesized:

(1) Engineering students would have little to no experience and relatively negative perceptions of early childhood education and child development relative to their own discipline, but perceptions would become more positive through collaboration, and

(2) Early childhood education students would have little to no experience with engineering but highly positive perceptions of the field. Through collaboration, their perceptions of engineers and engineering would be high before collaboration and remain high.

Science and Engineering in Early Childhood Education

With the publication of the *Framework for K-12 Science Education* (National Research Council, 2012), emphasis is now placed on the integration of engineering principles and practices into formal science education. Understanding factors, such as the learning opportunities afforded in preservice education, is essential for preparing future educators to meet education standards. Research indicates the need for preservice teachers to be proficient with the engineering design process; this can be accomplished through systematic engagement in design problems and challenges that allow them to act as engineers while drawing on their own expertise about teaching and learning (Brophy et al., 2008; Hsu, et al., 2011). Moreover, Hotaling et al (2012) suggested that engineering should be holistically connected to the intellectual components of the fields for which designs are produced. Working collaboratively on interdisciplinary teams affords engineering students with opportunities to experience and demonstrate criteria of successful engineers, including the ability to integrate mathematics, science, and engineering; design products and processes that meet the needs of users; demonstrate ethical responsibility and communicate effectively.

Like their elementary counterparts, early childhood educators often report negative attitude towards teaching science, lack of confidence due to inadequate science knowledge, and lack of resources including instructional time, classroom space and instructional materials (Maier et al., 2013; Kallery 2004; Watters et al., 2000). Nonetheless, several projects have reported successful outcomes in integrating science and engineering into early childhood education. Van Meetren and Zan (2010) outlined the use of block centers in early childhood classrooms to engage children in engineering design of ramps and pathways. Brophy and Evangelou (2007) found children's design activities were sophisticated; they were constructing beyond a visual representation to an actual structure. Data indicated young children employed details of physical properties to allow them to create increasingly complex designs that worked within the governing properties of physics. In sum, engineering design-based instruction can support students in developing initial or deeper conceptual understanding, depending on context, of domain-specific content knowledge and support proficiency in science and engineering practices (Brophy et al., 2008; NRC, 2012; NGSS Lead States, 2013; Roth, 1996).

Methods

Context and Participants. This study took place at a medium-sized land grant university in the eastern United States. Students from two separate undergraduate programs, Mechanical Engineering (ENG) and Early Childhood Education (ECE) participated in the study. Participants were enrolled in one of three courses; namely, ENG students were enrolled in a 200-level design course that covered 3D drafting and modeling, while ECE students were enrolled in either a 400-level course on inclusive curriculum and assessment for infants and toddlers, or a 400-level course on integrated early childhood teaching that emphasized science curriculum, instruction and assessment for young children, birth through primary grades. See Appendix A for institutional IRB approval.

Participants were randomly assigned to interdisciplinary teams that consisted of three or four ENG students and one or two ECE students. The teams were tasked with designing, constructing, and field testing a novel toy that was intended to promote constructive play (Drew, et al., 2008) among toddlers and preschool-aged children. In preparation for this project, ECE students were provided with instruction on hands-on prototyping techniques and ENG students were provided with instruction on play and child development. Student teams were expected to meet at least weekly outside of normal class time to work on their toy projects. Teams were evaluated on project deliverables including a toy design proposal with rationale for how it aligned with the developmental needs of a particular age group and a final design report that included field notes from testing with children targeted by their toy design (see Appendix B for sample assignment guidelines given to students). Figure 1 illustrates several final projects submitted by the interdisciplinary teams.

Data Sources and Analysis. Online surveys using Qualtrics were administered to ENG and ECE students at two time intervals: at the start of the semester before projects were introduced (pre) and at the end of the semester after all project deliverables were submitted (post). Survey questions for both groups focused on several key issues: (1) *a priori* knowledge and experience of the other group's subject area, e.g., childhood development for engineering students (pre-survey only); (2) effect of interdisciplinary project on interest in other group's subject area (post-survey only); and (3) perceptions of other group's profession and/or their skills (pre- and post-surveys). All matched survey items (pre- and post-) were forced choice with 5-pt Likert scales. Some pre-survey items had 3-point Likert scales.

Pre- and post-survey responses were compared using repeat-measures one-way ANOVA (JMP Pro v12). For post-course survey data only, responses common to both ECE and ME groups were compared using one-way ANOVA. Items that were only included on either the pre- or post-surveys were analyzed using descriptive statistics.

Figure 1. Sample toy design projects submitted by interdisciplinary ENG-ECE teams. Shown from left to right: pull-toy snail with rotating "shell," ECE student working with young child on a toy that highlights basic shapes, and a young child assembling a bathtub "coral" mini-reef toy.

Results

The response rate for all surveys was high, with 45 of 47 ECE students responding (40 pre-post matched pairs) and 137 of 147 ME students (95 matched pairs). Prior to this course, 87% of ME students reported no exposure to child development theory in K-12 or college coursework. They also had little experience with young children, interacting with them, on average, monthly and mostly at family gatherings (51% respondents). Prior to the course, ECE students stated that they had little or no interest in pursuing engineering (2.31±1.40 on 5-pt Likert) nor they did receive encouragement to do so (1.18±0.39 on 3-pt Likert); and they interacted with engineers once or twice annually. None of the ECE students in our study had taken engineering courses prior to or during college.

After completing the course, ME students perceived that they knew more about child development, play, and the design of children's toys (Table 1). After the course, they also less strongly agreed that their ECE counterparts would have relatively stronger interpersonal and communication skills, rating them as similar skill levels to their own. Moreover, after the course, ECE students reported they better understood the types of engineering disciplines (Table 2); ECE students had lower perceptions of engineering students personal characteristics after the course, as indicated by lower mean scores related to ME students as "very good at math & science," "hardworking," "good communicators," and "intense."

Table 1. *Comparison of pre- and post-survey responses by ME students. All items included a 5-pt Likert scale: Strongly agree (5), Somewhat agree (4), Neither agree nor disagree (3), Somewhat disagree (2), Strongly disagree (1).*

	Pre		**Post**		**Repeat Measures ANOVA**		
Survey Items	***M***	**SD**	***M***	**SD**	***F* (DF)**	***p***	**Effect Size**
How much do you know about the following?							
Interacting with young children (birth to 8 years)	3.91	0.61	3.78	0.61	1.01 (95)	0.316	
Child development	2.46	0.51	3.03	0.51	30.71 (95)	<0.001	0.57
Play and the types of play	2.41	0.49	3.31	0.49	80.37 (94)	<0.001	0.89
Purposeful design of children's toys to promote play	2.38	0.50	3.82	0.50	203.97 (95)	<0.001	1.45
What is your overall perception of individuals who specialize in education?	4.11	0.39	4.20	0.39	1.10 (95)	0.296	
Please state your agreement with the following statements. Compared to my colleagues in engineering, I believe education students…							
Have better interpersonal skills.	3.96	0.45	3.76	0.45	4.75 (94)	0.032	0.20
Are in a more rigorous discipline.	2.23	0.54	2.32	0.54	0.73 (95)	0.396	
Have better oral and written communication skills.	3.68	0.52	3.36	0.52	8.68 (95)	0.004	0.31
Work harder at their chosen profession.	2.79	0.45	2.84	0.45	0.32 (95)	0.572	
Are more valued by society.	2.73	0.51	2.82	0.51	0.82 (94)	0.369	
Can understand and interpret data	2.56	0.44	2.49	0.44	0.65 (95)	0.422	

trends.						
Are equally legitimate professionals.	4.17	0.53	4.09	0.53	0.46 (95)	0.501

Table 2. *Comparison of pre- and post-survey responses by ECE students. All items included 5-pt Likert scale.*

	Pre		Post		Repeat Measures ANOVA		
Survey Items	***M***	**SD**	***M***	**SD**	***F* (DF)**	***p***	**Effect Size**
How much do you know about the following?							
The different disciplines of engineering	2.34	0.64	3.07	0.64	13.29 (40)	<0.001	0.73
Math and science concepts in engineering	2.44	0.52	2.73	0.52	3.07 (40)	0.077	
The engineering design process	2.22	0.87	2.61	0.87	2.05 (40)	0.160	
What an engineer does day-to-day	2.39	0.78	2.63	0.78	1.00 (40)	0.323	
The characteristics necessary to become an engineer	2.73	0.94	2.54	0.94	0.44 (40)	0.509	
Career options for engineers	3.02	0.94	2.61	0.94	1.99 (40)	0.167	
Please state your level of agreement with the following statements. Engineers are…							
Very good at math & science	4.83	0.31	4.44	0.31	15.85 (40)	<0.001	0.39
Hardworking	4.71	0.35	4.46	0.35	4.99 (40)	0.031	0.24
Diverse	4.00	0.56	3.98	0.56	0.02 (39)	0.889	
Able to fix anything	3.34	0.47	3.32	0.47	0.03 (40)	0.868	
Creative	4.39	0.38	4.17	0.38	3.43 (40)	0.071	
Good communicators	3.71	0.55	3.29	0.55	5.88 (40)	0.020	0.41
Intense	3.90	0.34	3.61	0.34	7.59 (40)	0.009	0.29
What is your overall perception of engineers and the engineering profession?	3.84	0.38	3.92	0.38	0.42 (36)	0.520	
Please state your agreement with the following statements. Compared to my colleagues in education, I believe engineering students…							
Have better interpersonal skills.	2.41	0.44	2.44	0.44	0.03 (40)	0.860	
Are in a more rigorous discipline.	3.07	0.49	2.95	0.49	0.64 (40)	0.430	
Have better oral and written communication skills.	2.32	0.56	2.29	0.56	0.02 (40)	0.891	
Work harder at their chosen profession.	2.24	0.43	2.22	0.43	0.03 (40)	0.855	
Are more valued by society.	3.98	0.53	4.00	0.53	0.02 (40)	0.884	
Can understand and interpret data trends.	3.71	0.47	3.68	0.47	0.03 (40)	0.868	
Are equally legitimate professionals.	4.34	0.43	4.44	0.43	0.53 (40)	0.472	

Both ECE and ME students finished the course with balanced perceptions of their own disciplines relative to their counterparts (Figure 2). Both ECE and ME cohorts, on average, agreed that their counterparts' professions were equally legitimate and disagreed that there was a discrepancy in rigor between ECE and ME. ECE students solidly agreed that ME was a more valued discipline, although ME students were more neutral on this view. On average, ME students stated that they were more likely to take ECE coursework after completing this course (2.38±1.22 on 3-pt Likert). However, this trend did not hold for ECE students, who stated that they were less likely to take ME coursework (1.43±0.69 on 3-pt Likert), despite some increased interest in engineering and STEM following the course (3.40±1.01 on 5-pt Likert).

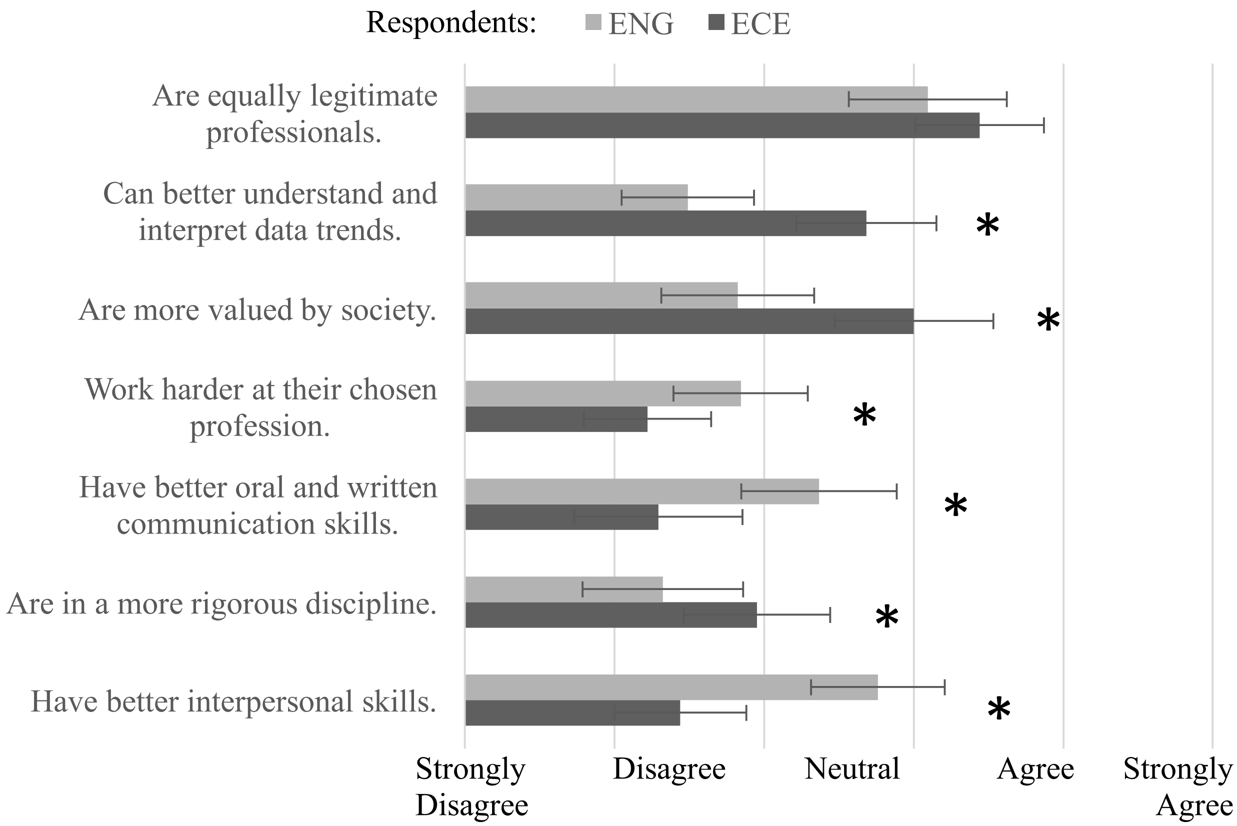

Figure 2. Post-course survey responses from ME (n=95) and ECE (n=40) cohorts to: "Please state your level of agreement with the following statements. Compared to my colleagues in [ME/ECE], [ECE/ME] students…" Bar chart represents $M \pm$ SD for ME vs. ECE students using one-way ANOVA (*p<0.05).

Discussion and Implications

These findings suggest that engineering students have little content knowledge or experience in disparate fields, in this case child development and education, and benefit from interdisciplinary collaboration both in terms of content knowledge and developing a healthy appreciation for outside expertise. The collaboration also benefited the non-engineering students by demystifying the field of engineering, potentially alleviating "imposter syndrome" by normalizing team performance expectations, and providing some literacy of the engineering design process. In the case of early childhood education students, these altered perceptions of the engineering discipline may have an important carry-over effect with their future students, particularly women and minorities.

Standards for the preparation of teachers for engineering education proposed by Reimers, Farmer, and Klein-Gardener (2015) indicate that professional development for teachers should address the fundamental nature, content, and practices of engineering in order to promote engineering content knowledge. Professional development experiences that allow interdisciplinary teams of teachers to engage in engineering design activities serve to promote connections among STEM disciplines (Donna, 2012), especially science and mathematics. The intervention used in this study was intended to promote collaboration among early childhood education and engineering students in order to enhance knowledge of one another's disciplines.

Gruenther et al. (2009) and Bailey (2007) reported that engineering students on multidisciplinary teams had significant gains in their understanding of the importance of user wants and design constraints than did students on single discipline teams. These findings and ours suggest that engineering students benefit from interacting with those outside of their discipline, and in the case of this study, wherein engineering students interacted with early childhood education students. Moreover, our results indicated that preservice teachers (i.e., ECE students) perceived they had a better understanding of engineering after participating on interdisciplinary teams with engineers. Enhancing early childhood educators' perceptions of science and engineering is important, as previous research indicates that they often have negative beliefs and attitudes about these fields and are reluctant to teach science and engineering content and skills to students (Choi, 2003; Choi and Ramsey, 2009).

This study supports previous research on scientist-educator collaborations, which indicate for educators the benefits include increased content knowledge, increased confidence as scientists, and for scientists the benefits include a better understanding of PK-12 education and ability to communicate to non-scientific audiences (Caton et al., 2000; Drayton and Falk, 2006; Kim and Fortner, 2007, 2008; Munson et al., 2013; Nelson, 2005; Paleaz and Gozalez, 2002).Moreover, both teachers and scientists/engineers work in professions based on bodies of research and the connections between theory and practice (Tanner et al., 2003). As such, interdisciplinary partnerships and collaborations based on mutual respect for one another's professions ultimately benefit children served by P-12 education. Such collaborations produce artifacts (in our case, toy prototypes, but in others, curricula and student-centered instruction) that can be used to engage young children in STEM, which can ultimately be used to promote knowledge and interest in those fields (Katehi et al., 2009; Munson et al., 2013).

This study contributes to research on beneficial collaborations among educators and scientists by extending into the field of engineering. Results from this work should inform preservice teacher education and research in the field, adding to our collective understanding of the contexts for professional learning and the interactions of preservice teachers with those in STEM fields. Our study supports research conducted by others and extends the field by adding to our collective knowledge of learning opportunities that support preservice teachers' knowledge and skills in engineering and engineering students' knowledge of the contexts and needs of end-users of their designs.

Future Directions

We intend to extend upon this preliminary study by interviewing both ENG and ECE students in small focus group interviews in order to investigate in more detail the potential mitigating factors and perceptions of both sets of students as they worked together on interdisciplinary projects. In particular, interview data from participants will help the research team in untangling the multifarious variables that contributed to the average declines in perceptions between both sets of students, such as the decline in the average perception of interpersonal and communication skills. We anticipate that interviews will clarify and extend upon the analysis of survey data, and will inform our efforts in strengthening ENG students' knowledge of end user design and ECE students' knowledge of engineering design principles for integrated STEM education in early childhood classrooms. Moreover, we will gather data on interactions among members of the interdisciplinary design teams, and subject these data to discourse analysis in order to observe the types and nature of interaction among ECE and ENG students. These data will be used to triangulate the results of the analysis of survey data and will support revisions and enhancements to learning opportunities afforded to students in future offerings of these courses.

References

Bailey, R. (2007). Effects of industrial experience and coursework during sophomore and junior years on student learning if engineering design. *Journal of Mechanical Design, 129*(4), 662-667.

Brophy, S., & Evangelou, D. (2007, June). *Precursors to engineering thinking.* Paper presented at the American Society of Engineering Education Annual Conference and Exposition, Honolulu, HI.

Brophy, S. B., Klein, S. S., Portsmore, M., & Rogers, S. (2008). Advancing engineering education in PK-12 classrooms. *Journal of Engineering Education, 97*(3), 369–387.

Brown, J. C., Bokor, J. R., Crippen, K. J., Koroly, M. J. (2014). Translating current science into materials for high school via a scientist-teacher partnership. *Journal of Science Teacher Education, 25,* 239-262.

Burrows, A. (2015). Partnerships: A systematic study of two professional developments with university faculty and K-12 teachers of science, technology, engineering, and mathematics. *Problems of Education in the 21st Century, 65,* 28-38.

Choi, H. (2003). Early childhood teachers' attitudes toward science teaching: A scale validation study. *Education Research Quarterly, 27*(2), 33-42.

Choi, S., & Ramsey, J. (2009). Constructing elementary teachers' beliefs, attitudes, and practical knowledge through an inquiry-based elementary science course. *School Science and Mathematics, 109*(6), 313-324.

Donna, J. D. (2012). A model for professional development to promote engineering design as an integrative pedagogy within STEM education. *Journal of Pre-College Engineering Education Research, 2*(2), 2-11.

Drayton, B., & Falk, J. (2006). Dimensions that shape teacher–scientist collaborations for teacher enhancement. *Science Education, 90*, 734–761.

Drew, W.F, Christie, J, Johnson, J.E., Meckley, A. M. & Nell, M. L (2008). Constructive play: A value-added strategy for meeting early learning standards. *Young Children, 63(*4), 38-44.

Falloon, G., & Trewern, A. (2013). Developing school-scientist partnerships: Lessons for scientists from forests-of-Life. *Journal of Science Education and Technology, 22*(1), 11–24.

Greunther, K., Bailey, R., Wilson, J., Plucker, C., & Hashmi, H. (2009). The influence of prior industry experience and multidisciplinary teamwork on student design learning in a capstone design course. *Design Studies, 30,* 721-736.

Harris Willcuts, M. (2009). Scientist-teacher partnerships as professional development: An action research study (3382136 Ed.D.), Washington State University, United States—Washington.

Hotaling, N., Fass, B., Bost, L., Hermann, C., & Forest, C. (2012). A quantitative analysis of effects of a multidisciplinary engineering capstone design course. *Journal of Engineering Education, 101*(4), 630-656.

Hsu, M.-C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research, 1*(2), 5-12.

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching, 42*(6), 668–690.

Katehi, Linda; Pearson, Greg; & Feder, Michael (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

Kim, C., & Fortner, R. (2007). Educators' views of collaboration with scientists. *American Secondary Education, 35*(3), 29–53.

Kim, C., & Fortner, R. (2008). Great Lakes scientists' perspectives on K–12 education collaboration. *Journal of Great Lakes Research, 34*, 98–108.

Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. *Journal of Research in Science Teaching, 41*(1), 65–93.

Munson, B. H., Martz, M. A., & Shimek, S. (2013). Scientists' and teachers' perspectives about collaboration. *Journal of College Science Teaching, (43)*2, 30-35.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, D.C.: National Academies Press.

Nelson, T. (2005). Knowledge interactions in teacher–scientist partnerships: Negotiation, consultation, and rejection. *Journal of Teacher Education, 56*, 382–395.

Pelaez, N., & Gonzalez, B. (2002). Sharing science: Characteristics of effective scientist–teacher interactions. *Advances in Physiology Education, 26*, 158–167.

Reimers, J. E., Farmer, C. L., & Klein-Gardner, S. S. (2015). An introduction to the standards for preparation and professional development for teachers of engineering. *Journal of Pre-College Engineering Education Research, 5*(1), 40-60.

Roth, W. M. 1996. Knowledge diffusion in a grade 4–5 classroom during a unit on civil engineering: An analysis of a classroom community in terms of its changing resources and practices. *Cognition and Instruction, 14*(2), 179–220.

Tanner, K. D., Chatman, L., & Allen, D. (2003). Approaches to biology teaching and learning: Science teaching and learning across the school-university divide – cultivating conversations through scientist-teacher partnerships. *Cell Biology Education, 2,* 195-201.

Van Meetreren, B., & Zan, B. (2010). Revealing the work of young engineers in early childhood education. STEM in Early Education and Development Conference, Cedar Falls, IA. Paper retrieved from: http://ecrp.illinois.edu.udel.idm.oclc.org/beyond/seed/zan.html

Appendix A. IRB Documentation

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

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DATE:	August 22, 2016
TO:	Amy Trauth-Nare
FROM:	University of Delaware IRB
STUDY TITLE:	[945926-1] A self-study of teaching methods used to promote collaboration between early childhood education and engineering undergraduates on interdisciplinary design projects
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	August 22, 2016
REVIEW CATEGORY:	Exemption category # *(2)*

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will put a copy of this correspondence on file in our office. Please remember to notify us if you make any substantial changes to the project.

If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.

cc:

Appendix B. Toy design project guidelines given to students in this study.

MEEG202: Sophomore Design

Design Project: We Build (Little) Engineers

Introduction

Our department's motto is We Build Engineers, and we think it's time for you all to chip in with this effort, too. Your overarching design project for this course will be to design, build, and test a novel toy for young children that gets them engaged and excited about engineering. We want out-of-the-box thinking here, gang, not the staid old toy trucks, regular blocks, and stacking towers; and your designs must be as inclusive as possible, e.g., gender, ethnicity, ability and socioeconomic status. Lastly, given that our course partner this year is Melissa and Doug®, your toys must be consistent with their design philosophy and complement their existing product line.

Design Process Details

Phase 1: Problem Definition

Background & Motivation

Perform benchmarking, background research, and user-centered research (UCR) to better motivate the project goal below. We expect you to thoroughly investigate Melissa and Doug's existing product line, as well as their competitors' to identify a "gap" in engineering-themed toys for this age group.

Project Scope (Given)

Your overarching design project for this course will be to design, build, and test a novel toy for young children that gets them engaged and excited about engineering.

Constraints (Given)

- Meets Standard Consumer Safety Specification for Toy Safety (ASTM 963-11)
- Deadline for Functional Prototype (End-of-Semester)
- Project Budget ($20 provided by Department, not including Studio stock materials and/or equipment usage such as 3D printer. All other expenses are on you)
- Sufficiently Complex Manufacturing (see Phase 3, Manufacturing Plan)

Wants: This is a partial list, and it is not prioritized. Use UCR, benchmarking, and background research to generate complete list of prioritized wants.

- Inclusive
- Supports children's play and development
- Novel
- Consistent with Melissa and Doug® design philosophy & product line
- Durable
- Flexible design that enables children to use the toy in multiple ways

Metrics: Generate complete list of Metrics associated with Wants and Constraints. Target values must be adequately referenced.

Phase 2: Concept Generation & Selection

Concept Generation
Generate three unique and viable concepts for your toy design that fit the project scope and have the potential to meet constraints and address end-user and sponsor wants. Generate patent-art quality line drawings of all three concepts that complement 1-paragraph (3-4 sentence) descriptions of each concept. Your team will present these concepts in two different forums: (1) Midterm Crit – 3 minute oral presentation with 3 slides max (one per concept), which will be reviewed by faculty and sponsor; and (2) Phase 2 section of Design Report.

Concept Selection
Use feedback from Midterm Crit as well as Decision Matrix of your choosing (Pugh or Weighted) to select your final design from amongst your three concepts.

Phase 3: Design
You must design and construct a functional prototype of your toy design using materials and manufacturing processes that are as close to your intended final design as possible, considering the capabilities of our Design Studio. The prototype must be safe for field testing with actual children, and it must include sufficiently complex manufacturing processes (see Manufacturing Plan below)

Specifically, in Phase 3, you will be expected to produce:

Engineering Details

- *Engineering Drawings*: CAD parts and assembly for entire design. Generate dimensioned drawings for all parts, as well as standard, labeled assembly drawings.
- *Tolerances & Fits*: Tolerances must be justified based on selected manufacturing processes for all part dimensions. Fits for mating or articulating parts must be calculated and specified.
- *Engineering Justification*: Engineering justification must be provided for all selected standard hardware, e.g., fasteners & bearings, as well as materials selection. Structural analysis – either Finite Element Analysis (from CAD) or basic strength of materials calculations – are required for material selection on major parts, as well as critical standard hardware. CAD assemblies should be used for volume and weight calculations. It is expected that you will apply basic knowledge from Statics, Dynamics, and Strength of Materials in your design.

Manufacturing Plan
- Three manufacturing practices are required for your design, and you must be able to articulate a manufacturing plan for your prototype.
- Manufacturing processes may include:
  - Mill operations
  - Multiple carpentry operations such as sawing, router, drill, or sander
  - Installing multiple fasteners or other hardware with hand or power tools
  - 3D printing
  - Laser cutting
  - CNC Router
  - Plastic molding and/or hot wire foam cutting

- Vacuum forming
- Sewing
- Soldering and/or substantive wiring

Phase 4: Design Validation
You are expected to validate your design with as many of your design metrics as possible while still preserving the integrity of your prototype. For instance, destructive mechanical testing to measure durability is not recommended if you are manufacturing only one copy of your prototype.

Based on the given constraints and recommended wants, you are expected to perform, at minimum, the following design validation tests:

- Sharp edge, pinch, and choke tests in accordance with ASTM 963-11
- Some test of durability, including, at minimum, drop and compression testing per ASTM 963-11
- Cost analysis
- Field testing with end-user feedback from multiple child subjects

Project Timeline

The following timeline is recommended for successful completion of this project. Refer to tasks in previous sections. Relevant class activities for different tasks for the project are shown. Your Peer Leaders will monitor your team's progress in accordance with this timeline. Final project deliverables (see next section) are marked with an "X".

Description	Week of Course														
	1	2	3	4	5	6	7	8*	9	10	11	12	13	14	15
Team Assignment & Project Orientation															
Phase 1: Problem Definition															
Phase 2: Concept Generation & Selection															
Design Crit (Concepts)						X									
Design Report: Phase 1 & 2 Draft							X								
Phase 3: Design															
Engineering Details															
Manufacturing Plan															
Design Crit (Paper Design)										X					
Prototyping															
Design Crit (Prototype & Test Plan)												X			
Phase 4: Design Validation															
Design Showcase															X
Design Report: Final															X
Peer Evaluation							X			X		X			X

* Spring Break

Project Deliverables & Evaluation

The Design Project is worth 30% of your course grade. There are multiple deliverables, each worth a different percentage of this grading component, e.g., design report = 30%x30% = 9% total grade.

- Design Crit (3x) – group presentations, 10% each
- Design Report – 30% for final version, preliminary grade issued on midterm draft (Phase 1&2)
- Prototype – 25%
- Design Showcase: Poster & Pitch – 15%
- Peer Evaluation (4x) – applied to all deliverables

Resources

- Design Report Template
- Design Report Grading Rubric
- Grading Rubrics for each of three Design Crits