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Work-in-Progress: A Collaborative Model of Teaching and Learning for Undergraduate Innovation Education

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Introduction:

A student's education today should reflect the evolving innovative nature of our society. While innovation was previously viewed as an economic driver or technological concept in the 20th century, modern times have innovation permeating into all branches of society, intending to seek and develop new knowledge and ideas (Lindfors & Hilmola, 2016). With this inclusion of innovation in society, students should be provided educational opportunities to develop innovation skills or practices that can better prepare them for the professional world as well as for making both societal and personal impact. Attempts to incorporate innovation education have been attempted in the past (Bartholomew, Strimel, Swift, and Yoshikawa, 2018; Strimel, Kim, and Bosman, 2019), with outcomes spanning from developing social responsibility within students (Thorsteinsson, 2014), to supplying students with skills to bring innovative behavior into their future careers (Maritz, de Waal, Buse, Herstatt, Lassen, & Maclachlan, 2014). Researchers have found that innovation capabilities are not typically a by-product of traditional comprehensive education and without specific curriculum to cultivate innovation practices among students across majors, many may be missing out on valuable knowledge and skillsets (Lindfors & Hilmola, 2016). Addressing this concern, a new undergraduate program at a large research-intensive university has been developed to provide students with the time, resources, and opportunities to enhance their innovation capabilities through co-teaching and co-learning from faculty and students from differing academic units. This novel approach specifically involves the collaborative teaching (i.e., multiple instructors in the same classroom at the same time) of innovation practices with faculty across the disciplines of liberal arts, engineering technology, and business management/entrepreneurship. Examining this approach to collaborative teaching across academic units is the focus of this study and preliminary results will be shared in this paper.

Background and Research Questions

Innovation education is a developing field that requires a solid understanding in order to best provide students opportunities to develop innovation mindsets and capabilities. The gap between the ever-evolving world and current undergraduate learning is continually expanding, with current undergraduate education remaining siloed in separate focus areas, limiting students' opportunities to learn and develop innovation practices that cross disciplinary boundaries (Birx, 2019). Many strategies for incorporating innovation-focused learning for undergraduate students have been attempted (Bartholomew, Strimel, Swift, & Yoshikawa, 2018; Strimel, Kim, & Bosman, 2019), but there remains a need for novel approaches that will develop undergraduates' innovation habits through transdisciplinary learning environments and authentic experiences (Haldane, 2018). One strategy that is being employed to help transform undergraduate learning in the pursuit of innovation is a cross-college collaborative teaching and learning approach. This collaborative model for teaching undergraduate innovation includes co-teaching and co-learning with faculty and students across academic units/colleges, over multiple semesters, to foster a community of practice to nourish their own innovative ideas and learning of cross-disciplinary innovation practices. By bringing together the colleges of liberal arts, business management, and engineering technology, the program attempts to blend the disciplines to promote shared practices of innovation that are more authentic as well as provide broader access to these practices to students regardless of their backgrounds/majors. However, this study focuses on understanding the influence this program has on students' perceived learning and development of innovation skills such as integrative learning, teamwork, and problem-solving.

Collaborative learning (CL) as an approach to learning has been shown to benefit students socially, psychologically, and academically (Laal & Ghodsi, 2011), and as such, incorporating this strategy within innovation education may help provide students with richer learning experiences. Specifically, CL has been found to develop social support for learners, build diversity in understanding concepts, develop learning communities, increase student self-esteem, reduce student learning anxiety, and promote critical thinking skills, among other benefits (Laal & Ghodsi, 2011; Johnson & Johnson, 1989; Pantiz, 1999). CL is often a key component of transdisciplinary learning, a method of engaging students with peers outside of their discipline. Transdisciplinary learning creates collaborations between education and society while emphasizing knowledge integration and joint problem definition for students (Biberhofer & Rammel, 2017). Transdisciplinary learning is produced from the outcome of interdisciplinary work, pushing individuals to go beyond simply working and communicating with those from other disciplines to the point that the acquisition of knowledge and skills occurs between individuals (Park & Son, 2010).

Within this study, CL and transdisciplinary learning take the form of a co-teaching and co-learning model of education that is situated within a more authentic learning environment with students across all majors and faculty working together from business, engineering technology, and liberal arts. Co-learning is an approach that allows students to work together in diverse groups and gives both high and low ability learners across various subjects the opportunity to learn from each other (Sultan, Hussain, & Kanwal, 2020). On the other hand, co-teaching is a collaborative model of teaching wherein two or more instructors work together to teach the same course. A strong correlation has been found between the perceptions of collaborative teaching and the motivation for student achievement (Anwar, Asari, Husniah, & Asmara, 2021), providing insight into the potential effectiveness of this method of teaching. By combining these strategies for teaching, this model has a goal to move toward providing a more transdisciplinary learning experience by leveraging the context of innovation, hoping to achieve this by having students work consistently together with those from other disciplines across multiple semesters. Having students work closely with each other, while instructors from various colleges/disciplines provide feedback and guiding thoughts, is positioned to encourage students to discuss critically with their peers opportunities for developing innovative solutions to valid problems. Students are given the opportunity to express their opinions and knowledge to supply information that their group members may not have considered due to their backgrounds. The transdisciplinary nature of the program extends to the instructors as well. Instructors from varying disciplines work to develop, organize, and teach the courses simultaneously with one another. This approach can potentially provide both students and instructors with a broader background of knowledge and more diverse viewpoints than any single instructor may have. However, it is now important to better understand how this model for undergraduate innovation education can influence student innovation capabilities as well as the motivation for learning which can be critical now as many question the value of higher education.

While the benefits of CL and transdisciplinary learning have been discussed, the importance of such skills should be addressed. 21st century skills have been promoted thoroughly and there are many reasons for why they are crucial in the modern world. Kay and Greenhill (2010) identified three main shifts that have inspired the movement for these skills as 1) changes in the economy and society that have reshaped the way we live, 2) an increase in global competitiveness has United States students struggling to keep up, and 3) companies shifting the way they do business due to technological and economic changes, leaving workers with more responsibility to contribute to both productivity and innovation. The Partnership for 21st Century Skills (2011) identifies global awareness, creativity, critical thinking, communication skills, contextual learning ability, and information and media literacy as key subjects and themes for student success. Students need these skills, "to successfully face rigorous higher education coursework, career challenges, and a globally competitive workforce," (Partnership for 21st Century Skills, 2011, p. 1). Similarly, throughout the 21st century, innovation thinking, as an outcome of innovation education, has been a focus and is identified to involve creative thinking, critical thinking, reflective thinking, and decision making (Nakano & Wechsler, 2018). As CL has been found to develop critical thinking and problem-solving skills in students (Laal & Ghodsi, 2011), by incorporating CL into a classroom setting, along with the benefits of transdisciplinary learning identified by Bartholomew, Strimel, Swift, and Yoshikawa (2018), students can have the opportunity to develop these innovation skills, preparing them for the demands of the 21st century.

For the purposes of this study, two research questions were developed:

> RQ1: What are the perceptions of a collaborative teaching and learning model for innovation-focused undergraduate learning, including cross-college co-teaching and co-learning, for enhancing student learning?
>
> RQ2: What is the perceived influence of a collaborative teaching and learning model for innovation-focused undergraduate learning, including cross-college co-teaching and co-learning, on student abilities in integrative learning, teamwork, and problem solving?

Research question one will utilize semi-structured interviews as the primary data source, while research question 2 will use survey responses on a 5-point Likert scale as the primary data source. Collected open-ended survey responses will be used to supplement the findings for both questions.

Methods:

The primary data source for research question one was semi-structured interviews, conducted with students who had recently completed one of the two core curricular installments of the program. Participants were recruited from this pool of students, all of whom had completed a discipline-focused introductory design/innovation course prior to entering the collaboratively taught curriculum for the program. Students ranged from freshmen to senior class. Recruitment of students was completely voluntary, with no benefit given to those who volunteered. For research question two, A pre-, post-, and retrospective pre-survey was developed using the validated AAC&U VALUE (2009a;b;c) rubrics to assess students' self-efficacy in three specific innovation skills. These three skills have been connected to innovation education, and include integrative learning, problem solving, and teamwork. Surveys are distributed to students at the beginning and end of the two core curriculum installments. Student participation was once again voluntary, although students were asked and reminded to fill out the surveys, no direct benefit was given to those who chose to participate. As this study is a work-in-progress, only preliminary data responses will be analyzed.

Preliminary Findings

Findings for this work-in-progress study come from the preliminary data collected in Spring 2021. As this was the first semester data were being collected, only the post-/retrospective pre-survey was administered. The organized survey data was uploaded to SPSS, a quantitative data analysis program, and analyzed for statistical significance, if any, between the post- and retrospective pre-surveys to each prompt. With the goal of comparing the two sets of data, a non-parametric test, specifically a Wilcoxon Signed Ranked Test was used. The results were analyzed in regards to the null hypothesis, that there is no statistically significant difference between survey responses for each prompt. A significance value of ≤ 0.05 identifies a significant difference between paired responses, while a value above 0.05 signifies an insignificant difference. A significant difference means the null hypothesis is rejected, demonstrating that students' self-perceived abilities in the constructs of integrative learning, problem solving, and teamwork may have shifted in response to their innovation-focused learning experience.

Table 1. Participants' College and Class

		Number of Students
College	Agriculture	3
	Engineering	4
	Health and Human Science	4
	Liberal Arts	4
	Management	1
	Polytechnic	43
	Science	2
Class	Freshmen	2
	Sophomore	10
	Junior	15
	Senior	34

Students in the Spring 2021 semester were asked to respond to the post- and retrospective pre-survey and asked to volunteer to be interviewed. 54 students completed both the post- and retrospective pre-surveys, including the 5-point Likert-scale (i.e., 'Strongly Disagree' = 1 and 'Strongly Agree' = 5) prompts as well as the open-ended questions, with their distribution of majors/colleges and class standings shown in Table 1.

Within the *integrative learning* construct, it is separated into five sub-constructs with two prompts per sub-construct. These sub-constructs include Connections: Experience, Connections: Discipline, Transfer, Integrated Communication, and Reflection and Self-Assessment. Each prompt, along with the related analysis outcomes, can be found in Appendix A. For each prompt, the mean rating for both the retrospective pre- and post-surveys were identified, as well as the z-score, significance value, and whether the prompt would reject or retain the null hypothesis. As stated above, the spring 2021 semester compared the retrospective pre- survey with the post-survey. Of the ten 5-point Likert-Scale prompts, all showed significant differences between them, resulting in all ten rejecting the null hypothesis. The biggest change in means comes from prompt four, draw conclusions by combining examples, facts, or theories from multiple fields of study or perspectives, with a difference in means of 0.79, while the smallest change, while still significant, was from prompt one, synthesize connections among experiences outside of the formal classroom, with a difference of 0.50.

Within the *problem-solving* construct, it is separated into six sub-constructs with one to three prompts per sub-construct. These sub-constructs include Define Problem, Identify Strategies, Propose Solution/Hypotheses, Evaluate Solutions, Implement Solutions, and Evaluate Outcomes. All ten of the prompts and the associated analysis results can be seen in Appendix B. Problem solving was analyzed the same way as integrative learning, resulting in the same identifying values. When comparing the retrospective pre-survey to the post-survey, all ten prompts showed significant differences between them, resulting in all ten rejecting the null hypothesis. The biggest shift in means comes from prompt four, propose solutions/hypotheses that are sensitive to contextual factors, with a difference in means of 0.80, while the smallest change, while still significant, was from prompt two, identify multiple approaches for solving the problem, with a difference of 0.33.

Lastly, for the *teamwork* construct, it is separated into five sub-constructs with one to three prompts per sub-construct. These sub-constructs include Response to Conflict, Constructive Team Climate, Individual Contributions, Facilitating Team Member Contributions, and Contributing to Team Meetings. All ten of the prompts and the affiliated analysis outcomes can be seen in Appendix C. The same analysis was conducted as the previous constructs, with the same values identified for these prompts. When comparing the responses of the retrospective pre-survey and post-surveys, nine of the ten prompts showed significant differences between them, resulting in all but prompt six, complete all assigned tasks thoroughly and by the deadline, rejecting the null hypothesis. The biggest change in means comes from prompt nine, notice when someone is not participating and invite them to engage, with a difference in means of 0.55, while the smallest significant change was from prompt two, be helpful in managing and resolving conflict in a way that strengthens the team, with a difference of 0.28.

Each survey, along with the Likert-scale prompts, presented 3 or 4 open-ended response questions at the end. These questions differed between the post-, and retrospective pre-surveys, with the questions focusing on students describing their expectations, what they're excited for, and reflect on the quality and value of their experience. An interesting response that appeared multiple times was students who expected to dislike the course or felt forced to take it ending up really enjoying the experience. Students had responses such as, "this course was a requirement for me; however, it ended up being one of my favorite classes at [the university]," as well as, "I had to participate in this experience for my major. With that being said, I have looked into adding [the program] to my degree," showing a shift in perspective about the experience as a whole. There was an understandable expectation for these collaboratively taught innovation courses that students would have to interact with technology and learn various prototyping skills as well. Due to the diversity of students who participate in this program, many come from colleges and majors that have very little, if any, technical skills knowledge required. Because of this, students expressed anxiety or intimidation coming into the course due to their lack of technical skills, stating, "based on what was in the materials kit… I will admit that I was somewhat intimidated by what was in the kit, as I haven't had any experiences with coding since middle school and know next to nothing about circuitry," and some stated a lack of excitement because of this expectation, stating, "no, I was not excited for this experience due to the fact that I am not the most creative person and not the most tech savvy".

On the post-survey, students were asked to evaluate the experience and appraise the quality, detailing any aspect that stood out to them. Many students commented on how the experience helped them expand their ways of thinking, with one student saying, "This experience taught me to broaden my thinking and not be so constrained when thinking of a solution to a given problem," while another student said, "this experience transcended the classroom and taught me how to become a better thinker, innovator, and designer of technology for people." There were also many statements about the transdisciplinary nature of the experience, reflecting on how the course presented diverse knowledge via multiple strategies that enhanced student learning. One student stated, "it is a great experience that can be applied across many different fields and alternative scenarios," highlighting the transdisciplinary influence and the ability to apply this knowledge to many real-world contexts.

The semi-structured interviews were primarily used to answer research question 1, aiming to understand the perceptions of the co-teaching and co-learning model, as well as the cross-college collaboration, used throughout the program. Both current students and alumni of the program were asked to be interviewed, with 12 alumni and 13 students consenting to being interviewed. Preliminary themes were identified from the data and can be seen in Table 2.

Table 2. Codes for the Themes Identified in the Interviews and Open-Ended Responses

Parent Code	Theme	Example
Co-Learning	Emulates the real world	"When you get out of school, you got to be able to communicate and get information from a bunch of different groups of people right, even when you're not always going to work with the same person"
	Benefits brainstorming	"We came from different backgrounds even though we were freshmen and sophomores, we like knew what we were doing in our different fields. So, it's nice when we had like the brainstorming days, we would have like 100 plus ideas, because we were all over the place"
	Ability to share knowledge and learning	"Everybody knows their professional knowledge from their major, and they will share with you, and it's mostly something you never heard before or never touched before"
Co-Teaching	Benefits different teaching approaches	"They [co-teaching faculty] might teach the same courses but they teach it differently, and the way you might understand it from somebody else you might not understand it from another person."
	Multiple perspectives on feedback	"[Having] teachers from multiple backgrounds, they actually have different… experience with their professional field… I can learn like different experiences from them"
	Helps apply learning from other classes	"For my labs or something for electrical engineering… I'm just following like a manual like what to do… this is like something I'm actually doing on my own"

Cross-college Collaboration	Translate knowledge	"I was introduced to a lot of software… when I did switch, just being able to adjust to using different software, because in pharmacy… kind of like reading and math stuff"
	Practical application for degree	"It gave me another source of practical experience to go with my engineering degree"

Discussion

The data gathered from this research lead to some interesting conclusions, as well as suggestions for developing this program further. First, the fact that all but one prompt presented in the surveys resulted in a significantly positive shift suggests that that a collaboratively taught innovation program can help students develop their self-efficacy in the three constructs of integrative learning, problem solving, and teamwork. However, this data may be partially skewed due to the relatively small sample size and lack of a pre-survey, a consideration that will be addressed later in the research process. The one prompt with no significant difference between student responses relates to completing tasks in a timely manner. Within this program, students are given general timelines and assignment deadlines, but due to the unique nature of their projects, it is an expectation that groups will use autonomy in creating deadlines to ensure the project is completed on time. This lack of a traditional classroom schedule may have been an influence on this prompt. Overall, this program employs a collaborative form of teaching and learning; however, it cannot be assumed that this method is the sole reason for the shifts in students' self-efficacy, as the transdisciplinary nature and authentic learning environment students are presented with may influence these shifts as well. That being said, from the interviews and open-ended responses, students identify the co-teaching and co-learning model as a benefit to their learning.

Multiple students discuss how this model allowed them to meet people they would not have met otherwise. For example, one student states, "now I've met people in different majors, and made friends with people that I wouldn't have normally met," which is a beneficial by-product of this model. While the collaborative model is primarily intended to promote integrative thinking and knowledge transfer, this benefit that transcends outside of an educational setting provides additional merit to the efficacy of the program. Meeting people is not only a social benefit, but one student identified the potential professional connections that they made, saying, "it has become like an entire experience… and [I] have those people in my corner that I can contact if needed." Building relationships that can be mutually beneficial in multiple contexts may provide another layer of value developed from this program.

Generally, students acknowledged a development in their confidence to both complete a task and to use a variety of tools and resources. Examples of statements about confidence include, "I had never really seen myself as tech savvy but these classes made me feel a lot more confident," and, "this experience… taught me how to become a better thinker, innovator, and designer of technology for people." By helping students develop their competencies and confidence, many of them referenced their future careers and how this program gave them the time and opportunity to succeed. Many students that participated had never experienced a class with a required lab component or any sort of hands-on, project-based learning assignments in college, granting them new knowledge and experiences they may not have received within their degree program. Some students identified the ability to translate these learned skills to their future careers, such as, “This experience was important to me for my future career (speech pathologist) where I will need to be empathetic of situations that can differ from my own.” Others identified that specific skills may not transfer to their careers, but the innovation mindset will, with one student saying, “As a logistics intern, I probably won’t be doing as much like design work… this class really made my creative juices flow a lot more than I think other classes that I’ve taken.” As these skills have been identified as important for individuals entering the workforce in the 21st century, the fact students are identifying their own growth will hopefully allow them to enter their careers confident and able to contribute effectively. While students are developing confidence, there still remains an opportunity to research the need for these skills in the workforce and whether these students are retaining this confidence as they begin their careers. Defining innovation within industry can be challenging, but supplying students with the knowledge and tools to be innovative will hopefully benefit these fields.

Lastly, a potential drawback could be the inconsistency of the model of teaching. Inherently, each semester of the program will have a different group of students with different backgrounds. The diversity of backgrounds of students is expected to fluctuate between iterations, although the benefits of co-teaching and co-learning are expected to remain. Ensuring that the topics discussed are beneficial to all students, regardless of academic background, is crucial to enable as many students as possible to learn and grow from their experience.

Conclusion

The need for innovators in the modern professional world calls for undergraduate education to rise to the challenge. While multiple strategies have been employed, a collaborative form of teaching and learning, in conjunction with an authentic, transdisciplinary learning environment, can be used to develop innovation knowledge and capabilities within students. It is important to identify effective strategies for teaching students how to be innovative, as these individuals will be called upon in the coming years to move the world forward. The preliminary data in this study seems to show that a cross-disciplinary collaborative teaching approach involving co-teaching and co-learning can assist students in developing competencies in these innovation skills. While this shift in self-efficacy may show student growth, more opportunities for research into understanding how this development enhances or impedes learning or how it will impact the workforce remains.

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References

Anwar, K., Asari, S., Husniah, R., Asmara, C. H. (2021). Students’ Perceptions of Collaborative Team Teaching and Student Achievement Motivation. *International Journal of Instruction, 14*(1), 325-344.

Association of American Colleges and Universities (AAC&U) (2009a). Integrated learning VALUE rubric. https://www.aacu.org/value/rubrics/integrative-learning.

Association of American Colleges and Universities (AAC&U) (2009b). Problem solving VALUE rubric. https://www.aacu.org/value/rubrics/problem-solving.

Association of American Colleges and Universities (AAC&U) (2009c). Teamwork VALUE rubric. https://www.aacu.org/value/rubrics/teamwork.

Bartholomew, S., Strimel, G., Swift, C., Yoshikawa, E. (2018). Cultivating a family of innovators through design thinking. *Children's Technology and Engineering.*

Biberhofer, P., Rammel, C. (2017). Transdisciplinary learning and teaching as answers to urban sustainability challenges. *International Journal of Sustainability in Higher Education, 18*(1), 63-83.

Birx, D. L. (2019). Rethinking higher education: Integration as a framework for change. *Phoenix Rising: Seeing Tomorrow Today in Higher Education, 2019*(185), 9-31.

Bosman, L., Kim, E., Strimel, G. (2019). Informed Design through the Integration of Entrepreneurial Thinking in Secondary Engineering Programs. *Journal of STEM Education: Innovation and Research, 19*(5), p. 32-39.

Haldane, A. G. (2018, May 23). *Ideas and Institutions – A Growth Story* [Speech audio transcript]. Bank of England. https://www.bankofengland.co.uk/-/media/boe/files/speech/2018/ideas-and-institutions-a-growth-story-speech-by-andy-haldane

Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and Competition Theory and Research.* Interaction Book Co. Publishing.

Kay, K., Greenhill, V. (2010). Twenty-First Century Students Need 21st Century Skills. In G. Wan & D. Gut (Eds.), *Bringing Schools into the 21st Century. Explorations of Education Purpose, vol 13* (pp. 41-65). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0268-4_3

Laal, M., Ghodsi, S. M. (2012). Benefits of collaborative learning. *Procedia – Social and Behavioral Sciences, 31,* 486-490

Lindfors, E., Hilmola, A. (2015). Innovation learning in comprehensive education? *International Journal of Technology and Design Education, 26,* 373-389.

Maritz, A., de Waal, A., Buse, S., Herstatt, C., Lassen, A., Maclachlan, R. (2014). Innovation education programs: toward a conceptual framework. *European Journal of Innovation Management, 17*(2), 166-182.

Nakano, T. C., Weschler, S. M. (2018). Creativity and innovation: Skills for the 21st Century. *Esudos de Psicologia (Campinas), 35*(3), 229-236

Panitz, T. (1999). Benefits of Cooperative Learning in Relation to Student Motivation. In M. Theall (Ed.) *Motivation from within: Approaches for encouraging faculty and students to excel, New directions for teaching and learning.* Josey-Bass Publishing.

Park, J., Son, J. (2010). Transitioning toward Transdisciplinary Learning in a Multidisciplinary Environment. *International Journal of Pedagogies & Learning, 6*(1), 82-93.

Partnership for 21st Century Skills. (2011). Framework for 21st century learning. Retrieved fromhttp://www.p21.org/index.php?option=com_content&task=view&id=254&Itemid=120

Sultan, S., Hussain, I., Kanwal, F. (2020). Individual versus Collaborative Learning: A Strategy for Promotoing Social Skills and Academic Confidence among Students. *Journal of Educational Research, 23*(1).

Thorsteinsson, G. (2021). Innovation education to improve social responsibility through general education. *TILTAI, 4*

Appendix A

Integrative Learning Retrospective and Post-Survey Results *(N = 54)*

Sub-Construct	Mean Retro	Mean Post	Z Score	P-Value	Reject/Retain
Connections: Experience					
Synthesize connections among experiences outside of the formal classroom	4.43	4.93	-3.003	.003	Reject
Deepen understanding of fields of study to broaden my own points of view	4.41	5.05	-3.425	.001	Reject
Connections: Discipline					
Independently create a whole out of multiple parts	4.44	5.00	-2.937	.003	Reject
Draw conclusions by combining examples, facts, or theories from multiple fields of study or perspectives	4.39	5.18	-3.661	.000	Reject
Transfer					
Adapt and apply skills, abilities, theories, or methods gained in one situation to new situations	4.46	4.98	-2.835	.005	Reject
Solve difficult problems or explore complex issues in original ways	4.44	4.98	-2.845	.004	Reject
Integrated Communication					
Fulfill assignments by choosing a format, language, or graph that enhances meaning	4.22	4.82	-2.606	.009	Reject
Make clear the interdependence of language and meaning, thought, and expression	4.31	4.85	-2.706	.007	Reject
Reflection and Self-Assessment					
Envision a future self	4.35	5.13	-3.879	.000	Reject
Make plans that build on past experiences that have occurred across multiple and diverse contexts.	4.43	5.18	-4.126	.000	Reject

Note. 5-point Likert scale: 1-Strongly Disagree to 5-Strongly Agree

Appendix B

Problem Solving Retrospective and Post-Survey Results *(N = 54)*

Sub-Construct	Mean		Z Score	P-Value	Reject/Retain
	Retro	Post			
Define Problem					
Demonstrate the ability to construct a clear and insightful problem statement	4.40	4.87	-3.679	.000	Reject
Identify Strategies					
Identify multiple approaches for solving the problem	4.80	5.13	-2.604	.009	Reject
Propose Solutions/Hypotheses					
Propose one or more solutions/hypotheses that indicates a deep comprehension of the problem	4.57	5.05	-2.976	.003	Reject
Propose solutions/hypotheses that are sensitive to contextual factors	4.50	5.30	-3.607	.000	Reject
Be conscious of ethical, logical, and cultural dimensions of the problem when proposing a solution	4.60	5.05	-3.155	.002	Reject
Evaluate Solutions					
Evaluate solutions deeply and elegantly	4.55	5.10	-3.988	.000	Reject
Consider history of the problem, review logic/reasoning, examine feasibility of a solution, and weigh impacts of a solution	4.48	4.88	-2.549	.011	Reject
Implement Solutions					
Implement the solution in a way that addresses multiple contextual factors of the problem	4.55	4.93	-2.421	.015	Reject
Evaluate Outcomes					
Review results thoroughly	4.55	4.98	-2.863	.004	Reject
Use results to inform potential future work	4.78	5.17	-2.408	.016	Reject

Note. 5-point Likert scale: 1-Strongly Disagree to 5-Strongly Agree

Appendix C

Teamwork Retrospective and Post-Survey Results *(N = 54)*

Sub-Construct	Mean		Z Score	P-value	Reject/Retain
	Retro	Post			
Response to Conflict					
Address destructive conflict directly	4.28	4.78	-2.557	.011	Reject
Be helpful in managing and resolving conflict in a way that strengthens the team	4.57	4.85	-1.992	.046	Reject
Constructive Team Climate					
Treat team members with respect	5.08	5.38	-2.576	.010	Reject
Convey a positive attitude about the team and its work	4.98	5.37	-3.019	.003	Reject
Provide assistance and/or encouragement to the team	4.90	5.35	-3.567	.000	Reject
Individual Contributions					
Complete all assigned tasks thoroughly and by the deadline	4.87	5.10	-1.748	.080	Retain
Be proactive with helping others complete their tasks	4.72	5.23	-3.437	.001	Reject
Facilitating Team Member Contributions					
Constructively build upon and develop the contributions of others	4.85	5.32	-3.375	.001	Reject
Notice when someone is not participating and invite them to engage	4.53	5.08	-3.478	.001	Reject
Contributing to Team Meetings					
Help the team move forward by articulating the merits of alternative ideas	4.80	5.15	-2.713	.007	Reject

Note. 5-point Likert scale: 1-Strongly Disagree to 5-Strongly Agree