An Analysis of Course Impacts from a Design Factory Methodology

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Abstract

Colleges are continuing to engage students in collaborative design courses on cross-disciplinary projects. The courses are engaging computer science and information systems students on entrepreneurial projects with other disciplinary students. The authors of this analysis discuss expanded findings from a course on design factory methodology that is focusing on collaborative design and cross-disciplinary entrepreneurship involving students as participants on self-directed teams. The findings from the perceptions of the students highlight generally increased learning of a marketable repertoire of skills. The study will be beneficial to professors in schools of computer science and information systems considering pedagogical practices to be more current with industry needs.

Keywords: active learning, design factory methodology, diversity, entrepreneurship, industry requirements, information systems curriculum, self-directed teams

1. BACKGROUND OF PAPER

Active learning continues to engage college students (Obenland, Munson & Hutchinson, 2012). Centric to learners, the concept engages college students in a collaborative experience of learning as active members in the learning (Sendall, Stowe, Schwartz & Parent, 2016). College students evidently learn more from an active collaborative cross-disciplinary learning approach than as passive participants in the learning (McDonald, Holmes & Prarter, 2019). The approach enhances course knowledge such that students apply the learning beyond the classroom (Adkins, 2018). Active learning is beneficial especially for a community of diverse students.

Collaborative learning establishes an appreciation for a community of cross-diverse students. College students experiencing interactions with a diversity of other personalities of other students are impacted positively in learning skills (Garibay, 2015). Computer science and information systems students may be impacted positively from a heterogeneity of perspectives of business, dance, health, law and liberal arts non-computer science and information systems students, especially on innovation on classroom projects involving active design thinking (Gurin, Dey, Hurtado & Gurin, 2002). Industry is in need of students having a diverse mindset of thinking that is not mere groupthink (Bass, 2020). Collaborative learning forms a foundation for the

learning of collaborative design thinking skills of students.

Colleges can help students in learning collaborative design thinking beyond the discipline of hard skills (Matthee & Turpin, 2019). Courses in collaborative design thinking can impart a critical diversity of soft skills in complementing hard skills in technology. The skills include collaboration, diversity and empathy, creative and critical thinking, flexibility and management to problem solving needed on entrepreneurial projects (Morman, 2019), if not a passion for the projects (Kuratko & Morris, 2018), non-fictitious or fictitious projects. The difficulty for instructors in computer science and information systems is how to integrate collaborative design thinking beyond its concept (Brown, 2008) into the curriculum (Matthee & Turpin, 2019), so in the paper the authors analyze comparative findings from a course on design factory methodology (Bjorklund, Laakso, Kirjavainen & Ekman, 2017), an enhancement of agile methodology that is integrating collaborative design thinking skills. This paper introduces the potential of a design factory methodology (Bjorklund, et.al., 2017) for preparing students in schools of computer science and information systems for industry requirements.

2. INTRODUCTION TO COURSE

The course analyzed in the paper is 3-credit *Collaborative Design Innovation Thinking* begun in the semester of winter / spring 2019 (i.e. January – May 2019) that is applying active collaborative learning in the Seidenberg School of Computer Science and Information Systems of Pace University. *Collaborative Design Innovation Thinking* is based on design factory methodology from Aalto University, in Helsinki, Finland (Bjorklund, et.al., 2017). *Collaborative Design Innovation Thinking* is a cross-disciplinary course, encouraging experiential learning (Jones & English,2004) and engaging students as consultants, functioning and learning, on big idea disruptive entrepreneurship projects (Gans, 2020) as members of self-directed teams. The experiences formed in the course from the projects are founded further from problem-based and project-based learning practices (Vogel, 2009). The course comprises diverse experiences of computer science and information systems students and liberal arts, health and business students, fostering inclusion on the teams (Williams & Mihaylo, 2019).

The learning objectives of *Collaborative Design Innovation Thinking* contain the following:

- Experience challenging collaborative but competitive dynamics in designs of big idea entrepreneurship projects;
- Experience design factory methodology on ideation processes of product storyboarding and product prototyping projects;
- Experience and learn marketable skills, including collaboration, communication, creative thinking, critical thinking, diversity, emotional intelligence, empathy, entrepreneurship, flexibility, management and problem solving, in collaborative design thinking skills, from interactions with cross-disciplinary students;
- Experience design factory methodology on industrial perspectives on the entrepreneurship projects and the potential prototyping solutions; and
- Experience entrepreneurship pitch presentations of functional product prototyping solutions.

The outline of the 14 3-hour *Collaborative Design Innovation Thinking* session syllabus contains the following:

Orientation

Challenges and Fears
Collaborative Culture for Design Entrepreneurial Mind and Process
Expectations and Experiences on Design Projects and Factors for Innovation Projects
Design Factory Methodology
Potential of Inter-Disciplinary Teams on Product Innovation Projects

Organization

Expectations of Industry on Big Idea Products
- Funding Perspectives on Big Idea Projects
- Gathering Perspectives on Big Idea Projects
- Gathering and Learning Project Requirements in Stages
- Parameters of Product Projects in Semester

Process

- Brainstorming on Big Idea Products
- Storyboarding Big Idea Product Scenarios
- Prototyping Big Idea Product Simulations
- Prototyping Big Idea Product Specifications

- Prototyping Big Idea Product Prototypes in Stages

- Product Development Process
- Rapid Application Development (RAD) and Iteration Steps
- Pitch Presentation Standards

Production

- Final Big Idea Product Prototypes
- Gala Pitch Presentations of Big Idea Product Prototypes
- Recognition of Students and Student Teams

The first author of the paper, the course professor, is functioning not as a lecturer but as a mentor, individually to students and collectively to the groups of teams (DiYanni, 2018), in a climate helping the students and the teams in design factory methodology (Bjorklund, et.al., 2017), in order to improve their design thinking skills, in on-line spaces (Limbach & Waugh, 2005), such as the Academic Blackboard Collaborate – Discussion Board - e-Education 2019 Suite.

The professor requires Passion-Based Co-Creation (Bjorklund, et.al., 2017) and Range: Why Generalists Triumph in a Specialized World (Epstein, 2019) as the *Collaborative Design Innovation Thinking* texts.

Collaborative Design Innovation Thinking in fall 2019 (i.e. September – December 2019) in the Seidenberg School contained n=5 entrepreneurship fictitious organizational projects (i.e. non-client partners) akin to the curricular projects of information systems (Bakir, Humpherys & Dana, 2019), of mostly n=5 members a project team, in the course of n=26 students. Following initial iterations of planning teams, the professor determined the member students of the final semester teams, from a deliberate diversity of demographics, disciplines, genders and status, for inclusive learning on the teams (Garibay, 2015). The demographics included 4 African-American, 9 American Caucasian, 5 Asian-American, 1 European, 5 Hispanic and 2 Middle-Eastern students. The disciplines included 7 business, 11 computer science and information systems, 1 health and 7 liberal arts students. Finally, the genders included 9 female, 24 male and 3 non-identified students; and the status were 2 freshmen, 9 sophomore, 12 junior and 3 senior students.

The product projects in fall 2019, which were decided by a consensus of members of each of the student teams, included a book exchange operation, a concert management system, an experiential multimedia museum, a fingerprint scanner system and a homeless meal service, which in design, development and implementation of prototyping solutions were the responsibilities of the specific teams.

The professor monitored the progress of the projects through mini-presentations and reflection reports, monthly and weekly, of the students and of the teams without interfering with the responsibilities of the teams (Sendall, Stuetzle, Kissel, & Hameed, 2019). For fun the professor informally monitored the design thinking skills of the students through creative and critical thinking and problem solving puzzles and riddles in the semester (Stangroom, 2009). Moreover, the students monitored their progress on the projects with contractual reports, monthly and weekly, with Microsoft Project Professional 2019, and with the reflection reports, on their semester tasks.

At the end of *Collaborative Design Innovation Thinking* in fall 2019, the prototyping solutions were presented as persuasive pitch presentations to an audience of fictitious venture capitalists at the university, with the professor grading participant performance of the students at 50%, and the performance of the team at 50%, of the final grade in the course.

3. FOCUS OF STUDY

The focus of the paper is the effectiveness in fall 2019 of *Collaborative Design Innovation Thinking* in the increased learning of a marketable repertoire of skills by especially computer science and information systems students. Important are the learning outcomes of not only the hard skills of technology but also the human soft skills by such students (Reilly, 2019). Learning soft skills may not be frequently included in courses other than *Collaborative Design Innovation Thinking* for computer science and information systems students, and even for liberal arts, health and business students, nor in life processes for these students (Ravenscraft, 2020), which may be a justification for the learning of soft skills. Learning outcomes more than skills of technology are required of computer science and information systems students by industrial organizations (Horn, 2020), which need notably design thinking skills (Elsbach & Stigliami, 2018). The focus of this paper is on the learning outcomes of skills from active collaborative learning in the course in fall 2019 of *Collaborative Design Innovation Thinking*.

For dimensions of study, the authors apply comparative factors of learning outcomes of skills from an earlier semester study of winter / spring 2019 (Joseph & Lawler, 2019), founded from the following literature:

- Collaboration (Bjorklund, et.al., 2017) – factor from which students perceived improved fruitful engagement skills;

- Communication (Gedeon & Valliere, 2018) – factor from which students perceived increased interaction and listening skills with other students;

- Creative Thinking (Felder & Brent, 2016) – factor from which the students perceived increased experimental ideation skills with other students on their teams;

- Critical Thinking (Felder & Brent, 2016) – factor from which the students perceived increased interpretative logical skills;

- Diversity (Bjorklund, et.al., 2017) – factor from which students perceived increased intercultural inter-disciplinary skills with other peer students;

- Emotional Intelligence (Coleman, 2005) – factor from which students perceived increased interpersonal motivational relationship skills with other peer students;

- Empathy (Bjorklind, et.al., 2017) – factor from which the students perceived increased interpersonal sensitivity skills with other students on their teams;

- Entrepreneurship (Gedeon & Valliere, 2018) – factor from which students perceived increased improvised influencing skills on innovation options with other students and increased persuasion skills on their teams;

- Flexibility (Gedeon & Valliere, 2018) – factor from which the students perceived increased group negotiation and perspective skills, notably in stressful situations;

- Management (Gedeon & Valliere, 2018), factor from which the students perceived increased organizational and personal planning skills, such as time management; and

- Problem Solving (Felder & Brent, 2016) – factor from which the students perceived increased optimal resolution skills on their teams.

The findings of this study for fall 2019 will be beneficial to notably professors in schools of computer science and information systems contemplating pedagogical practices in collaborative design thinking.

4. METHODOLOGY OF STUDY

The methodology of this new study evaluated the perceptions of the students in *Collaborative Design Innovation Thinking* in the Seidenberg School of Computer Science and Information Systems of Pace University, from a quantitative survey and qualitative reflections of the students.

From the aforementioned n=11 factors of learning skills, the perceptions of the n=26 undergraduate students in fall 2019 were evaluated by the first author at the beginning and at the end of the semester. The business, computer science and information systems, health and liberal arts students furnished their perceptions of the progression of their skills on the projects in fall 2019 from factor-definition pre-tested Likert-like instruments of survey, rating quantitatively their skills from a very high (5) impact to a very low (1) impact or zero (0) scaling on the skills and from 8 yes or no inquiry statements on their skills. The perceptions of the n=26 students were further evaluated to the perceptions of the skills of n=27 students in *Collaborative Design Innovation Thinking* in winter / spring 2019 (Joseph & Lawler, 2019). The perceptions in both semesters were evaluated moreover qualitatively from the final reflection reports of the semesters of the students by the aid of the second author.

The data from the surveys in fall 2019 were interpreted quantitatively in Microsoft EXCEL 2016 V16.0 and IBM Statistics V24.0 (Adams & Lawrence, 2019) by the third author, focusing on the computer science and information systems students, for the findings of this study.

5. DISCUSSION OF FINDINGS FROM STUDY

The findings from the perceptions of the *Collaborative Design Innovation Thinking* students are indicating generally increased skills from collaborative learning in fall 2019.

Perceptions of the n=26 all discipline students are indicating overall ratings of the n=11 skills at the end of the fall semester (ranging 5.00-4.00 [i.e. 0.00/5.00), in contrast to the ratings of the skills at the beginning of the semester (2.00-4.00), as in Table 1A of the Appendix of this paper.

Perceptions of the consolidated n=15 business, health and liberal arts students are indicating the ratings of the skills at the end of the fall semester (4.71-4.14), in contrast to the ratings of the skills at the beginning of the semester (1.47-3.73), as in Table 3A. The perceptions of the n=11 computer science and information systems undergraduate students are indicating the overall ratings of the n=11 soft skills at the end of the fall semester (4.77-4.19) in contrast to the ratings of the skills at the beginning of the semester (2.00-3.73), as in Table 2A.

The perceptions of the computer science and information systems students at the end of the fall 2019 semester (4.77-4.19) continue to be as positive as the earlier perceptions of the students at the end of the winter / spring 2019 semester (4.71-3.36), as in Table 2B; the perceptions of the consolidated business, health and liberal arts students at the end of the fall 2019 semester (4.71-4.14) continue to be as equally positive as the perceptions of the students at the end of winter / spring 2019 (3.00-5.00), as in Table 3B; and the perceptions of all discipline students continue to be favorably positive (5.00-4.00) as the perceptions of the students at the end of winter / spring 2019 (4.56-3.22), as in Table 1B.

The findings from *Collaborative Design Innovation Thinking* are impactful in that the perceptions of the n=11 computer science and information systems students are indicating to be positive in the ratings of the skills of collaboration (4.50), communication (4.62), creative thinking (4.77), critical thinking (4.65), diversity (4.19), emotional intelligence (4.35), empathy (4.38), entrepreneurship (4.65), flexibility (4.27), management (4.23) and problem solving (4.35) at the end of the fall 2019 semester, as in Table 2A, contrasting more positively to the ratings of the design soft skills thinking at the beginning of the semester and mostly more positively to the ratings of these skills at the end of the winter / spring 2019 semester, as in Table 2B; and the perceptions of the consolidated n=15 business, health and liberal arts undergraduate students in the ratings of these skills are contrasting positively to the beginning of the fall 2019 semester, as in Table 3A and to the end of the winter / spring 2019 semester, as in Table 3B.

The n=11 computer science and information systems students in the fall 2019 semester are further indicating that the n=11 skills that they learned as members on their project teams will be helpful on other project teams in the school (n=10 students [yes]) and on organizational projects (n=9 students [yes]), and that, preparatory to the projects on the teams, the riddles of the semester were and will be further helpful in their creative and critical thinking and problem solving skills (n=7 students [yes]), in-demand science, technology, engineering and mathematics (STEM) traits (Pearl, Rayner, Larson & Orlando, 2019)

Interestingly, a high number of the fall 2019 students (19/26), notably the computer science and information systems students (11), had not interfaced with other students of the other schools of the university, nor with other undergraduate students on teams, prior to *Collaborative Design Innovation Thinking*, similar to the students in the winter / spring 2019 semester.

Learning increased collaboration (4.50) and communication (4.62) skills, in fall 2019, in interfacing with liberal arts, health and business students, was helpful to the computer science and information systems students in increasing their boundaries of disciplines beyond technology. Learning diversity (4.19), emotional intelligence (4.35) and empathy (4.38) design thinking skills as generalist students (Epstein, 2019), in interfacing with the business, health and liberal arts students, was helpful to the computer science and information systems specialist students (Epstein, 2019) that may be initially insensitive to other students not skilled in technology. Learning entrepreneurship (4.65), flexibility (4.27), management (4.23) and problem solving skills (4.35) interdependently, in interfacing with the other students, was important to the computer science and information systems students that may be characteristically perceived as mere monolithic technologists, intolerant of non-technologists, on nuances of solutions of technologies (Bason & Austin, 2019).

Collaborative Design Innovation Thinking was involving the fall 2019 computer science and information systems students in the collaborative learning of a multiplicity of perspectives and skills with the non-computer science and information systems students on their self-directed teams that precluded groupthink on the teams (Bass, 2020).

Furthermore, the n=26 all discipline students that included the n=11 computer science and information systems students in fall 2019 are indicating largely that the projects of their n=5 teams were fun but interesting (n=21 students [yes]), and that they were not intimidated (n=25

students [no]) by the non-lecture pedagogy of the professor.

The positivism of the n=26 all discipline fall 2019 students is promoted in the realization of reflection reports (Barnett, 1997), in a sampling of spirited statements of the students in Table 4.

Finally, the correlations and the frequency distributions of the perceptions of the fall 2019 undergraduate students of *Collaborative Design Innovation Thinking* are documented in Tables 5 and 6 of the Appendix.

6. IMPLICATIONS OF STUDY

The computer science and information systems students are continuing to learn in-demand skills beyond mere technology. The impact of learning skills, such as collaboration, creative thinking and critical thinking on cross-disciplinary teams, is the students can decidedly expand their industry marketability to organizations that need soft skills (Deming, 2019). From such skills, computer science and information systems students can even function holistically as members of society (Dilley, Kaufman, Kennedy & Plucker, 2015) as digital disruptions intrude on norms. Though the importance of learning the hard skills of technology induces the initial potential of the students, the importance of learning the soft skills influences the future potential for these students. Professors in computer science and information systems can contribute to the marketable skills of their students by including active collaborative learning practices.

The students are learning in diverse multi-disciplinary teams formed from other schools of the university. The impact of active collaborative learning skills, such as communication, diversity, emotional intelligence, empathy and flexibility, is the students in engagement with other students can expand their innovation perspectives on new robust systems (Woods, 2020). Literature is indicating learning outcomes of new perspectives beyond the correctness of practices of representation (Garibay, 2015). New perspectives of non-computer science and information systems students may realize the full potential of technologies (Green, 2020). The computer science and information systems students are learning moreover the perspectives of marginalized students, such as transgender students (Hewlett & Yoshino, 2016), as these students are included as members on the project teams. Professors can contribute to diversity models of projects by including the active inclusive learning practices of the course.

The culture of active collaborative learning in *Collaborative Design Innovation Thinking* is deliberately designed by the instructor as a mentor to the students. The environment of inclusive learning is driven by the professor furnishing inclusive learning pedagogy (Klawe, 2019) and influencing practices (Ambrose, Bridges, DiPietro, Lovett & Norman, 2010). The impact of the professor is influencing the initiatives of the undergraduate students in learning the design thinking skills, such as entrepreneurship, management and problem solving, as members of self-directed teams (Pascarella, Hagedorn, Whitt, Yeager, Edison, Terenzini & Nora, 1997). The mentor professor is a motivator to the students so that they perform in the main as spirited students on their teams (Tappert, Leider & Li, 2019). It is notable that the professor is open and respectful of not only the computer science and information systems students but also the other students of the university for one community of students (Garibay, 2015). Other professors in computer science and information systems can contribute more as motivators to project student teams by initiating these practices.

In active collaborative learning, the computer science and information systems students in the course are effectively engaging on the projects on the self-directed teams. In engaging on the projects, the students have to be individually learning the multiplicity of the soft skills in order to perform proficiently the project tasks beyond requirements of technologies, as indicating in the literature (Bonwell & Eison, 1991). The importance of this learning method, inherently not from lectures of the professor on the design factory methodology (Bjorklund, et.al., 2017), is the reliance of the students, in interactions with the other students, in learning on their own the soft skills on their self-regulated teams. Students may prefer this learning method of self-study on such teams. Professors in computer science and information systems may explore in courses of design thinking the feasibility of learning practices involving more self-study by students.

Finally, the computer science and information systems students, and the non-computer science and information systems students, are engaging in active collaborative learning reflection. In engaging on the projects, the students are posting their progress on reflection reports. The importance of the reflection reports is that the students are inherently reporting on the design thinking skills they are learning or not learning on the projects, and, especially the computer science and information systems students, they are

writing about this. This method of self-reflection (Barrett, 1997) is an important modus of the professor in monitoring the progress of the students on their self-regulated teams. Professors may include practices of self-reflection reporting in monitoring the repertoire of the skills of their students.

7. LIMITATIONS AND OPPORTUNITIES IN RESEARCH

The findings from this paper are from perceptions of a relatively small sample of students. The focus on meaningful products for non-partner pseudo organizations may not be as meaningful as for real organizations (Connolly & Begg, 2006). Focusing further on issues of students on the teams may be meaningful in a future study. Nevertheless, the expanded findings from *Collaborative Design Innovation Thinking* are of an increasing learning of marketable skills by the students. Notably, the computer science and information systems students, in interactions with inter-disciplinary non-computer science and information systems students, are learning on the projects skills beyond mere technology. Though the findings may not be generalized without caution, they offer opportunities for further research by the authors and by other professors interested in the agile methodology practices of design thinking skills, which the authors are currently pursuing with the Pace University Small Business Development Center in New York City.

8. CONCLUSION OF PAPER

Collaborative Design Innovation Thinking is a beneficial course for cross-disciplinary students. Computer science and information systems students are learning increasing marketable skills other than technology. From design factory methodology, non-computer science and information systems students are also learning an increasingly repertoire of skills with the computer science and information systems students as members on the inter-disciplinary teams. Most of the members are partnering as novice participants on the project self-directed teams. Perceptions of the students, notably the computer science and information systems students, are indicating to be positive in the range of the semester skills in the course. Perceptions from the pitch presentations of the project results from the design thinking skills of the undergraduate students are further indicating to be positive in the study. Though the project results are for pseudo organizations, real organizations are proposed for the School of Computer Science and Information Systems for winter / spring 2021. In conclusion, the *Collaborative Design Innovation Thinking* findings of this paper are generating insights promising for scholars pursuing pedagogical practices in design thinking skills.

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APPENDIX

Table 1A: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – All Students (n=26) **– Fall 2019***

Fall 2019				
	Beginning of Semester		End of Semester	
Factors (Skills)	Means	Standard Deviations	Means	Standard Deviations
Collaboration	3.00	1.31	5.00	0.81
Communication	3.00	1.22	5.00	0.70
Creative Thinking	3.00	1.31	5.00	0.43
Critical Thinking	2.00	1.41	5.00	0.63
Diversity	2.00	1.79	4.00	0.94
Emotional Intelligence	3.00	1.47	4.00	0.89
Empathy	2.00	1.98	4.00	0.94
Entrepreneurship	3.00	2.11	5.00	0.69
Flexibility	4.00	1.12	4.00	0.96
Management	2.00	1.94	4.00	0.91
Problem Solving	3.00	1.24	4.00	0.85

*September – December 2019

Legend of Rating Scaling: (5) – Very High Impact [from Perceptions of Learned Skills by Students], (4) High Impact, (3) Intermediate Impact, (2) Low Impact, (1) Very Low Impact, and (0) No Impact

Table 1B: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – All Students – Fall 2019 (n=26) **vs. Winter / Spring 2019**** (n=27)

Fall 2019 vs. Winter / Spring 2019				
	Fall 2019 - End of Semesters – Winter / Spring 2019			
Factors (Skills)	Means	Standard Deviations	Means	Standard Deviations
Collaboration	5.00	0.81	4.33	1.18
Communication	5.00	0.70	4.04	1.13
Creative Thinking	5.00	0.43	4.52	0.80
Critical Thinking	5.00	0.63	4.33	0.88

Diversity	4.00	0.94	4.33	0.96
Emotional Intelligence	4.00	0.89	n/a	n/a
Empathy	4.00	0.94	3.22	1.65
Entrepreneurship	5.00	0.69	4.56	.085
Flexibility	4.00	0.96	3.93	1.11
Management	4.00	0.91	4.00	1.11
Problem Solving	4.00	0.85	4.48	0.85

**January – May 2019

Table 2A: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – Computer Science and Information Systems Students (n=11) **– Fall 2019**

Fall 2019				
	Beginning of Semester		End of Semester	
Factors (Skills)	Means	Standards Deviations	Means	Standard Deviations
Collaboration	3.12	1.31	4.50	0.81
Communication	3.15	1.22	4.62	0.70
Creative Thinking	2.88	1.31	4.77	0.43
Critical Thinking	2.31	1.41	4.65	0.63
Diversity	2.00	1.79	4.19	0.94
Emotional Intelligence	2.81	1.47	4.35	0.89
Empathy	2.35	1.98	4.38	0.94
Entrepreneurship	2.69	2.11	4.65	0.69
Flexibility	3.73	1.12	4.27	0.96
Management	2.46	1.94	4.23	0.91
Problem Solving	3.46	1.24	4.35	0.85

Table 2B: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – Computer Science and Information Systems Students – Fall 2019 (n=11) **vs. Winter / Spring 2019** (n=14)

Fall 2019 vs. Winter / Spring 2019				
	Fall 2019 - End of Semesters – Winter / Spring 2019			
Factors (Skills)	Means	Standards Deviations	Means	Standard Deviations
Collaboration	4.50	0.81	4.14	1.46

Communication	4.62	0.70	3.86	1.41
Creative Thinking	4.77	0.43	4.50	0.76
Critical Thinking	4.65	0.63	4.36	0.84
Diversity	4.19	0.94	4.71	0.73
Emotional Intelligence	4.35	0.89	n/a	n/a
Empathy	4.38	0.94	3.36	1.78
Entrepreneurship	4.65	0.69	4.29	0.99
Flexibility	4.27	0.96	3.93	1.21
Management	4.23	0.91	4.07	1.21
Problem Solving	4.35	0.85	4.43	0.94

Table 3A: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – Business, Health and Liberal Arts Students (n=15) **– Fall 2019**

Fall 2019				
	Beginning of Semester		End of Semester	
Factors (Skills)	Means	Standards Deviations	Means	Standard Deviations
Collaboration	3.00	1.20	4.29	0.91
Communication	3.40	0.99	4.57	0.76
Creative Thinking	2.87	0.74	4.71	0.47
Critical Thinking	2.60	1.12	4.57	0.65
Diversity	1.47	1.96	4.43	0.94
Emotional Intelligence	2.73	1.53	4.21	0.98
Empathy	2.40	2.06	4.43	0.94
Entrepreneurship	2.47	2.26	4.57	0.76
Flexibility	3.73	1.22	4.14	1.03
Management	2.40	1.99	4.14	0.95
Problem Solving	3.27	1.34	4.50	0.77

Table 3B: *Collaborative Design Innovation Thinking* Factor Perceptions of Skills – Business, Health and Liberal Arts Students – Fall 2019 (n=15) **vs. Winter / Spring 2019** (n=13)

Fall 2019 vs. Winter / Spring 2019				
	Fall 2019 - End of Semesters – Winter / Spring 2019			

Factors (Skills)	Means	Standards Deviations	Means	Standard Deviations
Collaboration	4.29	0.91	4.50-4.67	0.84-0.58
Communication	4.57	0.76	4.50-4.33	0.84-0.58
Creative Thinking	4.71	0.47	4.67-4.33	0.82-1.15
Critical Thinking	4.57	0.65	4.33-4.29	1.03-0.95
Diversity	4.43	0.94	4.00-3.86	1.10-1.07
Emotional Intelligence	4.21	0.98	n/a	n/a
Empathy	4.43	0.94	3.17-3.00	1.83-1.41
Entrepreneurship	4.57	0.76	5.00-4.71	0.00-0.76
Flexibility	4.14	1.03	4.33-3.57	1.03-0.98
Management	4.14	0.95	4.33-3.57	1.03-0.98
Problem Solving	4.50	0.77	4.67-4.43	0.82-0.79

Table 4: *Collaborative Design Innovation Thinking* Reflection (Sampling) Statements of Students – Fall 2019

Student	Major	Reflection Statements
A.A.	Computer Science	"Class challenged me a lot and members of my [project] team to determine a [big] issue and to figure how to solve it … not any easy [issue] but a big issue … excited to dream a perfect product … for the project … fostered innovations because [members of the team] and [the] professor had no inhibitions … a rewarding solution."
A.P.	Information Systems	"… Enriching experience … never imagined at first that I would have met great [members] from all schools [of the university]."
B.A.	Information Systems	"… Members of [my] team from different majors … diversity invoked [an] interesting … brainstorming process [for] prototyping the system."
C.G.	Liberal Arts	"[Learned] creative processes and dynamics for [a] successful solution and system."
K.E.	Information Systems	"Grew in facets of skills … in awe of ideation [at course end] … huge self-improvement in learning the

		art of the pitch … met amazing people [on my team] … no other course [in the school] in which I learned the soft skills to make the hard skills count in the [industrial] landscape."
M.C.	Management	"… Connections with members of my team … course [furnished] a realistic representation of how projects are [done] in industrial [organizations]."
M.K.	Liberal Arts	"Having to mesh with a group of people to do one [project] was a big feat … inspired by the interests of the other people on the team … interesting project all semester."
N.G.	Management	"… Better than I expected … freedom … never in a course [in the university] where students led projects with a structure [like this]."
S.H.	Information Systems	"… Different majors and different personalities were great for [our] area of study."
ZF	Management	"Course is different dramatically and more diverse than all other courses [in the university] … diversity is key … learned multiple brains … are better than one brain on a project … a first for me … learned how to function as a group on a team [for the first time]."

Table 5: *Collaborative Design Innovation Thinking* Correlations of the Study

(Kendall's tau_b Correlations) - All Students (n=26) **– Fall 2019**

Factors (Skills)	Collaborate	Communicate	Creativity	Criticality	Diversity
Collaboration	-	-	-	-	-
Communication	0.360	-	-	-	-
Creative Thinking	0.274	0.534**	-	-	-
Critical Thinking	0.084	0.219	0.217	-	-
Diversity	-0.144	0.076	0.083	0.216	-
Emotional Intelligence	-	-	-	-	-
Empathy	-	0.235	0.484*	0.153	0.290

Entrepreneurship	0.396*	0.537**	0.355	-0.070	0.033
Flexibility	-0.006	-0.007	-0.059	-0.313	-0.035
Management	0.202	-0.224	-0.061	0.075	-0.065
Problem Solving	-0.271	-0.239	-0.014	0.007	0.050

Factors (Skills)	Emotion	Empathy	Entrepreneur	Flexibility	Management
Collaboration	0.194	-	-	-	-
Communication	0.325	-	-	-	-
Creative Thinking	0.201	-	-	-	-
Critical Thinking	0.471*	-	-	-	-
Diversity	0.018	-	-	-	-
Emotional Intelligence	-	-	-	-	-
Empathy	0.128	-	-	-	-
Entrepreneurship	-0.108	0.064	-	-	-
Flexibility	-0.095	0.240	0.315	-	-
Management	-0.087	0.162	-0.250	0.035	-
Problem Solving	-0.103	-0.081	-0.410*	-0.367	-0.083

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 6: *Collaborative Design Innovation Thinking* Frequency Distributions of the Study – All Students (n=26) **– Fall 2019**

Fall 2019					
Factors (Skills)	Collaborate	Communicate	Creativity	Criticality	Diversity
Rating Scaling					
(5) Very High Impact	69.3%	73.1%	76.9%	73.1%	53.9%
(4) High Impact	11.5%	15.4%	23.1%	19.2%	11.5%
(3) Intermediate Impact	19.2%	11.5%	-	7.7%	34.6%
(2) Low Impact	-	-	-	-	-
(1) Very Low Impact	-	-	-	-	-

Factors (Skills)	Emotion	Empathy	Entrepreneur	Flexibility	Management / Problem Solving
Rating Scaling					
(5) Very High Impact	61.6%	69.2%	77.0%	61.6%	53.8% 57.7%
(4) High Impact	11.5%	-	11.5%	3.8%	15.4% 19.2%
(3) Intermediate Impact	26.9%	30.8%	11.5%	34.6%	30.8% 23.1%
(2) Low Impact	-	-	-	-	-
(1) Very Low Impact	-	-	-	-	-