Transforming Student Learning through Industry - Driven Software Development Projects

Alex Q. Chen
Infocomm Technology Cluster
Singapore Institute of Technology
alex.q.chen@singaporetech.edu.sg

Indriyati Atmosukarto
Infocomm Technology Cluster
Singapore Institute of Technology
indriyati@singaporetech.edu.sg

Serena Hui Lin Goh
Infocomm Technology Cluster
Singapore Institute of Technology
af_serena_goh@singaporetech.edu.sg

***Abstract*— Preparing students well for the Information Communication Technology (ICT) industry is challenging as the needs of the industry constantly evolve. As society becomes more receptive to technological solutions, their appetite for more complex and impactful solutions increases too. To cope with this changing demand and better prepare students entering the workforce, we propose a blended learning method with real-life medium-level complexity industry projects and industry clients in a Software Engineering specialization course that emphasizes applied learning with authentic assessment. The interaction with real-life industry clients with real problem statements exposes students to the uncertainty of software requirement gatherings and the design process of medium-level complex software engineering projects. This paper reports on the experience of these proposed approaches and students' self-perceived responses to the implementation. Our study results show significant improvement in students' self-perceived rating for preparedness for real-world industry problems after completing the project and an increase in the rating for most lifelong learning skills.**

Keywords—authentic assessments, real-life industry projects, software design

I. INTRODUCTION

Universities have been educating students with Information Communication Technology (ICT) skills that the industry requires. Many skills and knowledge imparted to the students are often lost after the classroom course ends as students struggle to find their applicability. The industry is often unwilling to dedicate resources to uncertain work with little economic return as these resources are considered running costs. These experiences made us wonder how learning at a workplace differs from a formal educational environment during undergraduate studies.

Applied learning concepts are emphasized and practiced at Singapore Institute of Technology [1]. Many courses in the university use problem statements from the industry for authentic assessments using a blend of Problem-based Learning (PBL), critical, and social pedagogies. The institution's distinctive Integrated Work Study Programme (IWSP) is a credit-bearing academic course with authentic learning opportunities for students to develop work-related skills that include in-depth domain-specific and transferrable skills[2][3]. A sound curriculum framework is crucial to prepare students for their work attachment and success in the industry.

The Bachelor of Engineering with Honours in Information and Communications Technology (ICT) majoring in Software Engineering (ICT-SE) is a 4-year direct honours degree programme. The programme trains students to become highly specialized professionals with deep technical skills. The curriculum includes foundational courses offered in the first year, while software engineering specialization courses are offered in the second year and third years, culminating with a 12-month IWSP experience. The long duration of the IWSP enables employers to propose meaningful job positions for the students to make impactful contributions to the employer's organization. This unique opportunity allows the employer and the student to evaluate options for future employment in the organisation. The classroom knowledge and practical use of skills acquired in both the foundational and specialization courses serve as a crucial base for students to enhance their readiness for IWSP.

Our approach in this paper is implemented in the ICT2106 Software Design course. This specialization course is offered in the second year of the ICT-SE programme and focuses on the design techniques to engineer software systems. Many of the methods taught are best appreciated when designing larger and more complex systems. It uses blended learning methods coupled with a real industry project to help students apply the concepts taught in the course. Defining software system complexity can be subjective and vary depending on context. Generally, software with medium-level complexity can be described as a program with a moderate number of features and functions based on the degree of interdependence among the different components within the software system.

Topics covered in the course include the different levels of software design, software architecture, software architecture patterns, SOLID design principles[4], design patterns, design notation, evaluation methods and associated software tools. The course runs for 12 weeks with five contact hours per week (3 hours lecture + 2 hours lab). The course's learning outcomes include students being able to implement the detailed design for software system components and specify the internal interfaces between components.

Applying classroom knowledge and work-related skills is crucial for achieving success in the workplace, yet recent research suggests that many students need help to develop these skills. This paper presents an experience report on introducing a real medium-level complexity industry project in a software engineering specialization course to address this issue. Working with an actual industry project collaborator gave students a rare opportunity to engage with real industry problems, making this project a novel approach to teaching software engineering practices evaluated with students' self-assessment on life-long learning. The study aimed to ascertain how useful introducing an actual industry project was for the students to prepare for a software engineering career after graduation. Our investigation aims to address the following two questions:

1. How do we deploy medium level complex industry projects to Software Engineering courses for blended pedagogies?
2. How does deploying medium level complex industry projects enhance students' for real-life industry problems?

Overall, this study contributes to the literature by providing a comprehensive understanding of how integrating

2023 IEEE Frontiers in Education Conference (FIE) | 979-8-3503-3642-9/23/$31.00 ©2023 IEEE | DOI: 10.1109/FIE58773.2023.10343262

industry projects into Software Engineering module can enhance students' preparedness for their future careers.

II. Literature Review

Researching in computing education is a hybrid field combining technical knowledge about computing with various disciplines such as cognitive science, psychology, economics, and general education. This combination can disorient the research as meaningful findings may appear in various specialist research venues [5]. There is an ever-growing need to provide realistic industry projects for Information Communication Technology (ICT) to prepare students for the industry [6]. The author's institution employs blended applied learning pedagogies [1] with Integrated Work Study Programme (IWSP) to prepare our students to be work-ready. In the ICT2106 Software Design course, we use Team-based Learning and Problem-based Learning with real-world industry projects and engaging with actual industry clients.

A. *Applied Learning Pedagogy*

Generally, Applied Learning pedagogies use a reflective and experiential approach that takes students out of traditional classroom settings to nurture learning and develop students' knowledge in the area [7]. The refined Applied Learning concepts [1] were used in this paper to combine academic knowledge and skills with real-world applications in the industry and community. The advantages of Team-based Learning (TBL) have been reported to be a valuable learning experience that encourages students to develop their communication skills, communication tools knowledge, and share subject knowledge [8]. Often blended learning leverage combining different learning approaches to facilitate the student learning experience and improve students' learning progression and knowledge retention, especially during the COVID pandemic [9]. Our study mixed many of the pedagogies discussed and superimposed the method to selectively use industry statements that balance the industry's needs and the depth of the projects required for the course.

The usage of technologies proliferates in teaching pedagogy and delivery[10] [11]. These educational technologies complement educators rather than water down their role [12]. Due to the COVID pandemic, digital tools for communication, team management, and team-based learning have shown their importance for almost all teaching pedagogy. For ICT2106, Slack was used for communication between the instructors and within project teams. The GitHub Project feature assisted the students with their team and task management. For code versioning, GitHub was used.

Simpson et al. [13] implemented several enhancements to their yearlong Team Project course to allow students to experience a more realistic environment for the practice of Software Engineering methods. It was noted that the changes resulted in several demonstrable successes such as students being more motivated in the course as the engage with real world customers on a project with real impact. The industry customers were also noted to enjoy the opportunity to interact with students with the possibility of acquiring a prototype at relatively low cost.

Generally, studies have shown that using blended pedagogies with real industry projects has better-prepared students for work. The study from Pažur Aničić [6] indicated the need for a more holistic and strategic approach, including career development support within formal processes of higher education for future ICT professionals. Known challenges for using industry projects in teaching pedagogies include teaching methods and assessment practices. We believe that striking a balance between the industry's needs and the level of depth and rigorousness is crucial.

B. *Projects Complexity*

One of the most challenging tasks when designing the project for most software engineering courses is the consistency of the project's complexity between teams. On the one hand, it is essential to maintain a similar level of complexity between the cohort and the various project teams. On the other hand, the second dichotomy is that every project is unique. Software complexity means different things to many people, and evaluation metrics are required to quantify the projects and ultimately to shortlist the appropriate projects for the Software Design course. The notion of software complexity is important for the Software Design course as the skills taught in the Software Design module are more relevant in software projects of medium-level complexity.

To determine the software complexity of the industry projects, we examined the expected input data and process data for the project and determined what are the desired outcomes. This method takes reference to the Basili's [14] approach. Basili defined software complexity as measuring the resources expended by another system in interacting with a piece of software. Kearney et al. [15] measured complexity through various metrics such as the theory of programming, anticipating the use, and properties such as robustness, specificity, normativeness, and prescriptiveness. Kearney et al. concluded that users of the complexity measures must be aware of the limitations of every measure and approach the applications cautiously. There is no one size to fit all. For object-oriented programs (including those written using design patterns), the well-known suite of Object-Oriented metrics proposed by Chidamber and Kemerer [5] can be used to measure complexity as well. The design phase of the software development life cycle plays an instrumental role in fostering quality in software [16]. Minimizing the software's complexity to make it more understandable and maintainable is one approach.

III. Methodology

Our study investigates students' attainment and learning experience by working on actual industry team projects as part of their assessment for the ICT2106 Software Design course. To implement the Applied Learning pedagogy, a team project was added as part of the course's continuous assessment for students to apply the classroom knowledge covered in the course and experience the rigorous software design and development processes. Students in the course were organized into teams of five or six members. Each team was deliberately presented with unprecise project specifications to allow students to experience a more realistic software development lifecycle starting from requirement elicitation and negotiation. The team project's specification was formalized from the problem statements provided by the industry partners. These specifications were further refined to ensure that the overall scope of the problem is a medium-level software engineering complexity to allow students to appreciate the software design techniques covered in the course.

The course's structure and the students' capabilities were explained to the industry partners to adjust their expectations.

Specifically, the industry partners were cautioned not to anticipate a fully deployable product but rather a proof of concept, and they should be willing to offer a learning experience to the students without any expectation of reciprocation. All industry partners were contented with the arrangement and did not anticipate receiving a deployable product in return, as there were no monetary exchanges.

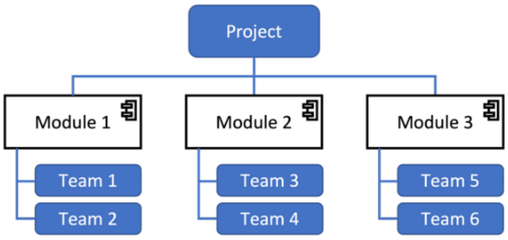


Fig. 1. Team project distribution

As the industry projects were of medium-level complexity, every project was divided into three modules. The scope of the work for each module was assigned to two teams (see Fig.1), and these two teams are expected to independently agree on the work distribution within the module. The expected final deliverable of the project was an integrated proof-of-concept. With these expectations, teams had to communicate and coordinate with each other to produce an integrated software at the end. The industry collaborator acted as an industry client. The project was run on agile software practice, structured into two simulated sprints of six weeks each. The sprints are noted to be longer than usual industry practices, as the students not only need to implement the project but also acquire classroom knowledge. All project work was done on campus. Students met their industry clients at the start of the first sprint to clarify requirements and presented their prototypes during the Sprint review meeting at the end of each sprint. After completing the second sprint, their ideation prototypes were handed in as their final submissions.

Once a week, students met face-to-face for two hours during the lab sessions. Students were also expected to work on the project outside of class hours. The other communications were conducted via E-mail, Slack, and various messaging tools. Students were asked to report their self-perceived skills levels before and at the end of every sprint.

Sixty-three participants enrolled in the study and were invited to report their self-perceived skill levels by completing surveys at three different time points throughout the module's duration: pre-project, mid-project (Week 6) and post-project. These surveys coincided with the Sprint Review meetings with industry clients. The course instructors played an observer role during the Sprint Review meetings. Formally, students were assessed by the course instructors based on their requirements gathering, design documents, and client interaction.

Using learner's self-perceived rating in a survey can offer several advantages over using objective rating such as grades: 1) when learners are asked to rate their own performance, they tend to feel more invested in the process and be more motivated to accurately reflect on their abilities; 2) self-perceived ratings may provide a more accurate reflection of a learner's abilities because they take into account factors that may not be apparent to an outside observer; and 3) by reflecting on their own abilities, learners may become more aware of their strength and weaknesses.

The surveys were designed to evaluate students' work-related skills. The pre-project survey serves as the baseline of students' perceived work-related skills at the start of the project. The mid-project survey was aimed to provide insights into the student's progress in their learning journey while working on a real-life industry project. Finally, the purpose of the post-project survey was to capture the final evolution of the students' work-related skills after the project.

The survey questions were designed as a hybrid of Bloom's taxonomy and industry preparedness related work [2] [17]. The questions were categorized into 3 categories: (1) Self-awareness related to teamwork and collaboration, (2) industry preparedness, and (3) lifelong learning skills, including problem-solving, critical thinking, creativity, adaptability, communication, and collaboration. The complete set of survey questions are listed in Table I and II.

TABLE I. PRE-PROJECT SURVEY QUESTIONS

*1	How would you rate yourself as a team player?
2	How would you rate yourself in terms of communication with your teammates?
*3	What are some potential challenges you might face while working with your team?
4	Have you ever worked on real-life industry problems in school before? If so, please briefly describe the problem you worked on.
5	How prepared are you to work on a real-life industry problem now? (1- not prepared at all; 7 – very prepared)
6	What challenges do you foresee with working on a real-life industry problem?
7	What do you hope to gain or learn from this project?
*8	How would you rate yourself with being equipped with the following lifelong learning skills? (1 – not equipped at all; 7 – very well-equipped) Problem solving; Critical Thinking; Creativity; Adaptability; Communication; Collaboration

Asterisk (*) indicates common questions

TABLE II. MID AND POST-PROJECT SURVEY QUESTIONS

*1	How would you rate yourself as a team player?
2	How would you rate the level of teamwork within your team?
3	How would you rate the level of communication between your team and other teams?
*4	What are some of the challenges you faced while working with your team
5	What are some of the challenges you faced while working with other teams
6	How prepared are you to work on a real-life industry problem after this sprint?
7	What are some aspects that this sprint has prepared you for working in the industry?
*8	How would you rate yourself with being equipped with the following lifelong learning skills? (1 – not equipped at all; 7 – very well-equipped) Problem solving; Critical Thinking; Creativity; Adaptability; Communication; Collaboration

Asterisk (*) indicates common questions

IV. RESULTS

The survey results for quantitative and qualitative data responses at each project phase are presented in this section. The mean and standard deviation were calculated for each quantitative question. A word cloud is generated based on the responses to the qualitative questions. In addition, the top 5 words extracted from the responses were ranked in a table next to the word cloud. The results were further analyzed, and amalgamated findings were presented in Section V.

A. Results of pre-project survey

The pre-project survey consisted of 13 questions: 10 quantitative and 3 qualitative questions (Q3, Q6, and Q7) to allow participants to elaborate on their responses.

Quantitative results of pre-project survey - In Q4, out of 63 students, only 17 students (27%) had real-life industry experience. Most students rated themselves positively as a team player and believed they had strong communication skills. However, most felt unprepared to work on a real-life industry problem. On average, students were confident with their lifelong learning skills prior to their team project, with an average overall rating of 4.83/7 across all six skills. The complete quantitative results showing the mean and standard deviation of the pre-project survey can be found in Table III (Pre-Project Mean and SD).

Qualitative results of pre-project survey - Analyzing the qualitative responses for the pre-project survey questions (Q3, Q6, and Q7), students found to have concerns adapting to real-world industry projects as they transitioned from school assessment to authentic assessment.

Students were asked to elaborate on their potential challenges in working on real-life industry problems in Q3 and Q6. Concerns primarily surfaced around apprehension of adaptation to changes due to the increase in the project's complexity when tackling real-life industry problems. The top two concerns reported were communication with the industry clients and meeting clients' requirements.

"Communication with client, external parties or non-technical colleagues."
"Perhaps the design and requirement gathering might be a challenge due to the lack of experience we have."

Most students anticipated that there might be potential challenges in communication with their teammates and with other teams. Time management was another challenge identified as the students took 4-5 other courses concurrently. Below is one of the student responses.

"Working as a 10-member team might be challenging especially in the communication and finding a common time for meetings."

Word clouds of the top 20 keywords from the pre-project survey's Q3 and Q6 responses were compiled in Fig.2(a) and Fig.3(a), respectively. These results highlighted that students' top challenges were the complexity of teamwork, communication, and time management. Fig.2(b) and Fig.3(b) further distinguish the top five keywords, and "communication" was consistently found in the top five.

Students were asked what they hoped to learn from this course before starting the project in Q7. Fig. 4(a) shows the word cloud of the most popular keywords for the response to the question. Most students expressed excitement towards embarking on projects with real clients and were looking forward to learning how software engineering practices are carried out in the industry, as seen in some of these quotes:

"Learn how to design a proper system that is widely acceptable by the industry."
"Gain insights into what real life industry issues are and the differences versus school."

Before embarking on this course project, most of the students had never experienced working with real clients, nor had they worked on mid-scale projects with large teams.

"I want to experience working with a bigger group of people as previously I only did projects or worked with groups of less than 10 persons."

The students were hoping to gain relevant experience and soft skills in preparation for work attachment in their subsequent academic year, as emphasized in the response:

"I hope to gain people, leadership and project management skills to be ready for workplace projects."

B. Results of mid-project survey

Similar to the pre-project survey, the mid-project survey results for the quantitative and qualitative questions were analyzed separately.

Quantitative results of mid-project survey - Results of the quantitative questions in the mid-project survey are presented in Table IV (Mid-Project Mean and SD). Overall, the students still rated themselves positively in terms of being a team player (5.13) and were satisfied with the level of teamwork within their team after the first sprint (5.7). However, they rated inter-team communication slightly lower than in the pre-project survey (4.76), and still did not feel very prepared for real-life industry problems even after completing one sprint (3.83).

Qualitative results of mid-project survey - There were several observations from analyzing the qualitative questions in the mid-project survey (Q4, Q5, and Q7) as detailed below.

Looking at responses to Q4 and Q5, students generally found the process of gathering user requirements challenging as this was their first experience working with industry clients, who changed their requirements a few times throughout the first six weeks. The frustration was conveyed in their survey response:

"There were a lot of unclear and constantly changing requirements, and the client meetings were quite confusing."

Additionally, students had to grapple with communication issues both within their team and with other teams when negotiating their module's boundaries. The students also had to learn to discuss how to spread the workload and plan for time management. These challenges are summarized concisely in the word clouds shown in Fig. 5 (a) and Fig. 6(a). There was a clear overlap in challenges identified by students both intra-team and inter-team. Students elaborated on the challenges in their response:

"The main challenge faced while working with other team is that it is extremely hard to get 25 people on the same page."
"Some teams are not in sync with the rest. Had to re-do deliverables multiple times due to miscommunication."

Pre Q3: What are some potential challenges you might face while working with your team?

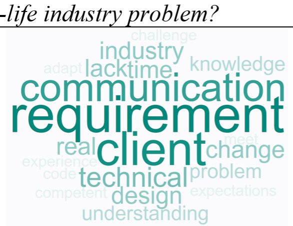
(a)

#1: team
#2: communication
#3: time
#4: work
#5: hard

(b)

Fig. 2. Pre-project survey Q3. (a) Word cloud capturing top 20 most common words. (b) Top 5 most used words in response.

Pre Q6: What challenges do you foresee with working on a real-life industry problem?



(a)

#1: requirement
#2: client
#3: communication
#4: change
#5: design

(b)

Fig. 3. Pre-project survey Q6. (a)Word cloud capturing top 20 most common words. (b) Top 5 most used words in response.

Pre-Q7: What do you hope to gain or learn from this project?

(a)

#1: design
#2: industry
#3: experience
#4: skill
#5: team

(b)

Fig. 4. Pre-project survey Q7 (a) Word cloud capturing top 20 most common used words. (b) Top 5 most used words in response.

Mid Q4: What are some of the challenges you faced while working with your team?

(a)

#1: requirement
#2: work
#3: time
#4: communicate
#5: issue

(b)

Fig. 5. Mid-project survey Q4. (a) Word cloud capturing top 20 most common used words, (b)Top 5 most used words in response

Mid Q5: What are some of the challenges you faced while working with other team?

(a)

#1: communication
#2: features
#3: time
#4: requirement
#5: boundary

(b)

Fig. 6. Mid-project survey Q5. (a) Word cloud capturing top 20 most common used words in responses, (b) Top 5 most used words in response

In Q7 of the mid-project survey, students were asked if there were any aspects in the recently completed sprint that prepared them for working in the industry. Despite the challenges faced during Sprint 1, the students felt that these challenges would indeed prepare them in the areas of communication with the client especially during the requirements gathering phase.

"Client meetings. The difficulties with requirement elicitation and preparation for demos."
"The challenges working with larger teams. How important is communication and clear separation of work."

Overall, students felt more mentally prepared in managing their clients and handling the requirements as indicated in the top 5 keywords of their responses: client, requirements, team, communication, and design.

C. Results of post-project survey

The post-project survey results were analyzed separately based on the type of question after the team project has ended.

Quantitative results of post-project survey – Table V shows the results of quantitative results of the post-project survey. Students rated themselves positively as team players, and in terms of the level of intra-team teamwork and the inter-team communication. More importantly, students felt better prepared for real-life industry work after the 12 weeks.
Qualitative results of post-project survey - In the post-project survey Q4 and Q5, about 30% of students responded that they did not face any challenges during Sprint 2. For those who did, once again, majority indicated that communication was a huge challenge. Some of the students' response included:

"Teams were not in sync, so communication become hard, and other teams were over promising but under delivering."
"Understanding other team's difficulties and issues."

The top challenge identified in Q5 remained as communication, but they acknowledged that by the end of Sprint 2, there was significant improvement.

"Communication at first was quite messy, however, at the end improved significantly."

The other pressing issue that students faced by the end of the project was to integrate codes across the various modules. Due to the complexity and scale of the problem, coupled with miscommunication along the way, the students found the integration of codes extremely challenging despite having a common GitHub repository.

Students were asked once again in Q7 of the post-project survey if there were any aspects that the recent sprint (Sprint 2) has prepared them for working in the industry. Similar to the mid-project survey results, students expressed that the lessons learned from having good communication with the client and team members would help them prepare better for work in the near future. In addition, students felt that working on a project with medium-level complexity has equipped them with better time management and people management skills, as seen in their response:

TABLE III. STATISTICAL ANALYSIS OF PRE AND MID-PROJECT QUANTITATIVE SURVEY RESPONSES

	Survey Questions	Pre-Project			Mid-project		Paired samples t-test				Pearson correlation
		Mean	SD		Mean	SD	t	df	p		
1	How would you rate yourself as a team player? (1- Extremely bad; 7 - Extremely good)	5.25	0.87	↓	5.13	1.53	0.86	62	0.39		0.45
2	How prepared are you to work on a real-life industry problem now? (1- not prepared at all; 7 - very prepared) *How would you rate yourself with being equipped with the following lifelong learning skills? (1 - not equipped at all; 7 - very well-equipped)*	3.75	1.31	↑	3.83	1.26	-0.34	62	0.74		0.32
3	Problem solving	4.86	0.8	↓	4.16	1.88	3.73	62	**0.0004**	**Significant**	0.19
4	Critical Thinking	4.68	0.74	↓	4.44	1.54	1.32	62	0.19		0.1
5	Creativity	4.65	0.81	↓	4.05	1.50	4.09	62	**0.0001**	**Significant**	0.42
6	Adaptibility	5.03	0.93	↓	4.35	1.81	4.07	62	**0.0001**	**Significant**	0.38
7	Communication	4.81	1.19	↓	4.46	1.96	1.9	62	0.06		0.33
8	Collaboration	4.97	0.81	↓	4.48	1.48	3.25	62	**0.001**	**Significant**	0.38

TABLE IV. STATISTICAL ANALYSIS OF MID AND POST-PROJECT QUANTITATIVE SURVEY RESPONSES

		Mid-project			Post-project		Paired samples t-test				Pearson correlation
		Mean	SD		Mean	SD	t	df	p		
1	How would you rate yourself as a team player? (1- Extremely bad; 7 - Extremely good)	5.13	1.53	↑	5.38	0.95	-1.99	62	0.05		0.6
2	How would you rate the level of teamwork within your team? (1- Extremely bad; 7 - Extremely good)	5.7	1.02	↓	5.57	1.28	0.88	62	0.38		0.44
3	How would you rate the level of communication between your team and other teams? (1- Extremely bad; 7 - Extremely good)	4.76	2.31	↑	5.11	1.91	-1.76	62	0.08		0.41
4	How prepared are you to work on a real-life industry problem after this sprint? (1- not prepared at all; 7 - very prepared) *How would you rate yourself with being equipped with the following lifelong learning skills?* (1 - not equipped at all; 7 - very well-equipped)	3.83	1.6	↑	4.49	1.29	-4.72	62	**0.00001**	**Significant**	0.57
5	Problem solving	4.16	1.88	↑	4.9	1.47	-4	62	**0.0001**	**Significant**	0.35
6	Critical Thinking	4.44	1.54	↑	5	1.35	-3.32	62	**0.0015**	**Significant**	0.39
7	Creativity	4.05	1.5	↑	4.76	1.57	-4.2	62	**0.00008**	**Significant**	0.41
8	Adaptibility	4.35	1.81	↑	4.86	1.29	-2.85	62	**0.01**	**Significant**	0.36
9	Communication	4.46	1.96	↑	4.86	1.45	-2.12	62	**0.04**	**Significant**	0.36
10	Collaboration	4.48	1.48	↑	4.92	1.49	-2.56	62	**0.01**	**Significant**	0.36

TABLE V. STATISTICAL ANALYSIS OF PRE AND POST-PROJECT QUANTITATIVE SURVEY RESPONSES

	Survey Questions	Pre-Project			Post-project		Paired samples t-test				Pearson correlation
		Mean	SD		Mean	SD	t	df	p		
1	How would you rate yourself as a team player? (1- Extremely bad; 7 - Extremely good)	5.25	0.87	↑	5.38	0.95	-0.88	62.00	0.19		0.28
2	How prepared are you to work on a real-life industry problem now? (1- not prepared at all; 7 - very prepared) *How would you rate yourself with being equipped with the following lifelong learning skills? (1 - not equipped at all; 7 - very well-equipped)*	3.75	1.31	↑	4.49	1.29	-3.97	62.00	0.00	**Significant**	0.26
3	Problem solving	4.86	0.8	↑	4.9	1.47	-0.29	62.00	0.77		0.28
4	Critical Thinking	4.68	0.74	↑	5	1.35	-1.83	62.00	0.07		0.10
5	Creativity	4.65	0.81	↑	4.76	1.57	-4.20	62.00	0.00	**Significant**	0.41
6	Adaptibility	5.03	0.93	↓	4.86	1.29	1.06	62.00	0.29		0.24
7	Communication	4.81	1.19	↑	4.86	1.45	-0.25	62.00	0.81		0.11
8	Collaboration	4.97	0.81	↓	4.92	1.49	0.30	62.00	0.77		0.31

"Get to experience challenges of working in a larger project, coordinate and negotiate the work between teams"

V. Discussion and Analysis

We performed integrated analysis of the quantitative and qualitative data to help us formulate the eventual findings to answer our two questions:

1. *How do we deploy medium level complex industry projects to Software Engineering courses for blended pedagogies?*

As detailed in Section I, a medium-level complex industry project was deployed as one of the continuous assessment components in the ICT2106 Software Design course. The problem statements for the industry projects were solicited from industry collaborators. The project allowed students to practice the software design techniques they learned and apply them to a real-life software engineering problem.

The following are the instructors' reflection:

- The 12-week course period is too short to guide and implement an actual software engineering project of medium-level complexity fully. Following Software Development Life Cycle (SDLC), the Design phase could only start after requirements gathering. The instructors needed to manage requirements gathering activity and guide students to apply the software design techniques taught to them. Students had a busy schedule and did not have the opportunity to dedicate their time to work on the project fully.

- As commonly occurring in real software engineering industries, the client requirements changed throughout the 12-week period resulting in students' frustration.
- Both students and industry clients seemed to have high expectations from each other. Despite the initial guidelines provided, the industry clients expected students to deliver all working features, while students expected industry clients to compromise on their expectations. More communication with industry client is needed to align expectations.
- Scheduling logistics posed to be a challenge in running the project. The students' busy course schedules did not allow a lot of opportunities for them to meet up with their team members. It was challenging for students to maintain the momentum and energy to complete the project.

2. *How does deploying medium level complex industry projects enhance students' preparedness for real-life industry problems?*

Analyzing the overlapping survey questions across the different project time points resulted in the opportunity to compare and correlate the analysis. Quantitative comparison between the different project phase was conducted. The comparison was performed using the paired Student's t-test, a statistical parametric test on the means of quantitative data, in this case the survey quantitative responses. The statistical t-test aimed to show whether there is any significant different in the self-reported skills at the different time points. Qualitative analysis was conducted on the feedback gathered from the three surveys, focusing on two main aspects, mainly the challenges faced by the students and their perceived preparedness for working in the industry.

A. *Comparison across different project phases*

The surveys' results are further analyzed from a quantitative and qualitative comparison perspectives to provide more insights to the results presented.

1) *Quantitative comparison*

Comparison of pre and mid-project survey results

Table III shows the statistical analysis results of the pre-project and mid-project correlated survey responses. An increase in the mean for preparedness for real-life industry problems (3.75 versus 3.83), while a drop in the self-assessed rating after Sprint 1 was noticed when comparing the identical questions in the pre-project to the mid-project survey. A significant difference in the self-assessed lifelong learning skills related to problem-solving, creativity, adaptability, and collaboration is noticed. These results can be explained by the challenges students mentioned in the mid-project survey and how students came to terms with their capabilities and reality. Based on the paired samples t-test, there is a significant decrease in problem-solving, creativity, adaptability, and collaboration lifelong learning skills. The consistent dip across all categories can be explained by the fact that the first sprint is, for most students, their first experience interacting with real industry clients, handling clients' changing requirements, and struggling to establish a suitable collaboration mode.

Comparing the qualitative responses across the pre- and mid-surveys shown in Section IV, the potential challenges anticipated by the students before the project started were similar to those listed after Sprint 1 in the mid-survey. Most notably, communication was commonly identified as a challenge during both surveys.

Comparison of mid and post-project survey results

Following the dip in the lifelong learning skills at the mid-project survey results, there was an improvement in the self-perceived student ratings across all lifelong learning skills. As shown in Table IV, there was a significant improvement in all the self-assessed lifelong learning skills. There was also a significant improvement in students' self-perceived readiness for real-life industry projects.

During Sprint 2, once the client's requirements were confirmed and have stabilized, the students picked up momentum in their software design and implementation. With improved communication among team members and across teams, the students felt more assured of their preparedness for real-life industry problems.

Comparison of the pre and post- survey results

Table V shows a significant improvement in the students' self-perceived readiness to work on real-life industry projects. The self-perceived readiness had a consistent increase throughout the project phases (3.75, 3.83, 4.76), communication (4.81 versus 4.86) and problem-solving (4.86 versus 4.90). Conversely, there was a decrease in students' self-perceived ratings for adaptability (5.93 versus 4.86) and collaboration (4.97 versus 4.92). These decreases could be due to student realization that they are not as adaptable as they initially thought, and the experience made them realize that collaborative work was difficult. However, the learning experience has built their confidence to be better team players, as reflected in their score (5.25 versus 5.38).

Comparing students' self-perceived lifelong learning skills at the start of the project to the end of the project, an improvement in most of the lifelong learning skills can be observed from the analyzed results in Fig. 11 and Table IV. Though there was a notable dip in the mid-term survey across all lifelong learning skills, the self-rating had significantly improved towards the end of the project.

2) *Qualitative comparison*

On challenges faced in the project

According to the feedback gathered, the potential challenges identified by the students at the start of the project were largely like what they experienced during the two sprints. Communication was a major challenge especially during Sprint 1 but there was significant improvement by the end of Sprint 2 as the students learnt how to better express themselves and practiced active listening.

On perceived industry experience and preparedness

The overall sentiment was increasingly positive from the start until the end, suggesting that the project has enhanced students' preparedness for real-life industry problems,

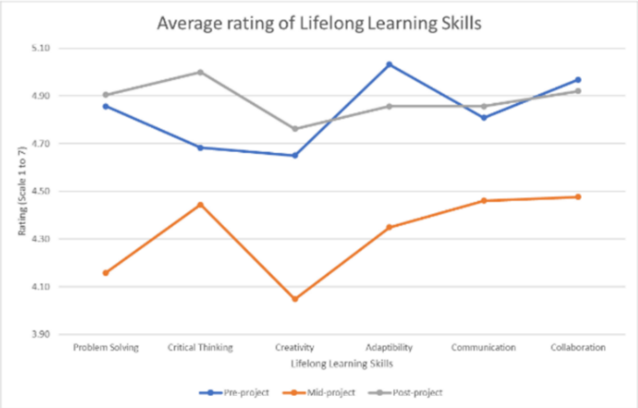


Fig. 11. Analyzing the average rating of lifelong learning skills across the different project phases

specifically communication, time management and people management skills.

The qualitative findings were in-line with the quantitative findings where there was a **significant improvement** in the mean for industry preparedness (3.75 versus 4.49). The following statement from a student succinctly summed up how most students felt:

"This experience allows me to work on a relatively huge project that requires different teams to integrate together, which I had never done before. This project has helped me mentally prepare myself for what's coming in the industry."

B. Key Insights and Future Work Directions

Amalgamating the results and analysis led us to the following key insights:

- Throughout the 12-week project duration, students went through an individual growing process **from structured academic to realistic industry chaos**.
- Project **integration and implementation** were vital to **industry projects** but not essential to the module's learning objectives. The handover process to industry collaborators should be approached with caution for future collaborations. Striking a balance between learning outcomes and industry requirements is crucial.
- Students may lack the experience **prioritizing** tasks to face the challenges. The mid-project survey results suggested that students were realigning their expectations. The results showed that exposure to realistic industry project scenarios was shaping the way tasks were dealt with and the students **evolved** with the experience gained from the project.
- From anecdotal observations, students took the industry clients' meetings more seriously compared to when teaching staff played the role of the client. Students were better prepared and more **professional** in their verbal and written communication. Results showed that there was a significant improvement in students' preparedness for real-world industry problem.

Reflecting upon the key insights, we conclude the following actionable summary:

- We need to be **selective** when choosing the industry clients for the course project. We also need to carefully manage the client's expectation that the final output of the project would likely be an ideation prototype.
- Industry clients must be **introduced** to the students as **early** as possible to allow students to build their relationship with their clients and make the project more relatable. The introduction establishes a more immersive experience for the students and prompts them to build up their empathy towards the client, the project, and their teammates.
- Bonus marks could be offered to incentivize students to build a rounded project for areas that are not part of the learning objectives, producing a final output that is more deployment ready for the industry.
- The evaluated course (Software Design) focuses on the Design phase of the Software Development Life Cycle (SDLC). Hence, the requirements-gathering process could start earlier or in an earlier course to allow students firm up the requirements before the start of the course - allowing them more time to focus on the design and implementation phases and align better with the course's learning objectives.

Overall, introducing industry projects as an authentic assessment for the course has not only enhanced students' technical skills, allowing them to apply software engineering knowledge such as design, documentation, project management, and the usage of online collaborative tools, but also enhanced students self-perceived transferable soft skills, including communication, collaborative work, and thinking agility.

VI. Conclusion

This paper presents an experience report of applying blended learning with a real-life medium-level complexity industry project as part of an authentic second-year software design course assessment. We presented the main quantitative and qualitative results in a comprehensive consolidated fashion allowing readers to understand better and appreciate the student's learning experience. Results show that the learning experience has increased students' self-perceived rating in all work-related skills, including problem-solving, critical thinking, creativity, adaptability, communication, and collaboration. Overall, the student's learning journey resulted in an increased sense of readiness to work on real-life industry problems.

Acknowledgment

Ethical clearance for this study was granted by the institution's IRB.

VII. References

[1] M. S. M. Lim, Y. L. Foo, H. T. Loh and X. Deng, Applied Learning in Higher Education: Perspective, Pedagogy, and Practice, Informing Science, 2020.

[2] S. M. Lim, Y. L. Foo, M.-F. Yeo, C. Y. X. Chan and H. T. Loh, "Integrated Work Study Program: Students' Growth Mindset and Perception of Change in Work-Related Skills," *International Journal of Work-Integrated Learning,* vol. 21, no. 2, pp. 103-115, 2020.

[3] C. Lam and M. F. Yeo, "Singapore Institute of Technolog - Integrated Work Study Programme (IWSP) Model," in *Practical Learning in Hospitality Education*, Queensland, The University of Queensland, 2021.

[4] R. C. Martin, Design Principles and Design Patterns, ObjectMentor.com, 2000.

[5] S. Fincher and K. Fisler, "Exploring questions and answers in computer science education," *Communications of the ACM,* vol. 65, no. 7, p. 9, 2022.

[6] K. Pažur Aničić, B. Divjak and K. Arbanas, "Preparing ICT Graduates for Real-World Challenges: Results of a Meta-Analysis," *IEEE Transactions on Education,* vol. 60, no. 3, pp. 191-197, 2017.

[7] T. R. &. T. K. R. Jones, "Contextualizing Bilingualism: Emerging From the Classroom to the Community," in *Handbook of Research on Multilingual and Multicultural Perspectives on Higher Education and Implications for Teaching*, IGI Global, 2022, pp. 87-133.

[8] D. Pauleen, S. Marshall and I. Egort, " ICT-supported team-based experiential learning: classroom perspectives," *Education + Training,* vol. 46, no. 2, pp. 90-99, 2004.

[9] H. Singh, "Building Effective Blended Learning Programs," in *Challenges and Opportunities for the Global Implementation of E-Learning Frameworks*, IGI Global, 2021, p. 9.

[10] S. Hicks, "Technology in Today's Classroom: Are you a Tech Savvy Teacher?," *The Clearing House: A Journal of Education Strategies, Issues, and Ideas,* vol. 84, no. 5, pp. 188-191, 2011.

[11] A. Chen, Y. . Lim, L. Lu, C. Lo and D. Arisandi, "Digitalization of Traditional Marking," in *The Asian Conference on Education and International Development*, 2018.

[12] N. W. Kai, "Educational technology in schools meant to complement, not dilute, teachers' roles," 03 November 2021. [Online]. Available: https://www.straitstimes.com/singapore/politics/educational-technology-in-schools-meant-to-complement-not-dilute-teachers-roles. [Accessed 31 August 2022].

[13] R. Simpson and T. Storer, "Experimenting with Realism in Software Engineering Team Projects: An Experience Report," in *IEEE Conference on Software Engineering Education and Training (CSEE&T)*, Savannah, GA, 2017.

[14] V. Basili, "Quantitative Software Complexity Models: A Panel Summary," in *IEEE Workshop on Quantitative Software Models for Reliability, Complexity and Cost*, 1979.

[15] J. P. Kearney, R. L. Sedlmeyer, W. B. Thompson, M. A. Gray and A. M. A., "Software complexity measurement," *Commun ACM,* vol. 29, no. 11, p. 1044–1050, 1986.

[16] N. Qamar and A. A. Malik, " Impact of Design Patterns on Software Complexity and Size," *Mehran University Research Journal of Engineering and Technology,* vol. 39, no. 2, pp. 342-352, 2020.

[17] C. Smith, F. S, L. Russel and P. Cretchley, "The impact of work integrated learning on student work-readiness," Office for Learning & Teaching, Sydney, Australia, 014.

[18] Y. Kao, L. DeLyser and A. Hubbard, "Assessing the Development of Computer Science Pedagogical Content Knowledge in the TEALS Program," in *ACM Technical Symposium on Computing Science Education (SIGCSE)*, 2016.