Use of Design Sprint in PBL Modules -A Longitudinal Case Study Approach

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Abstract

Project Based Learning (PBL) modules have become an inevitable part in SE curriculums. Industry relevance of PBL mechanisms have further strengthened this crucial need. Design Sprint is well known as a PBL approach which enhances transferable skills in students. Design Sprint is also a widely used mechanism in software industry projects. Therefore, Design Sprint could be used to enhance the outcomes of SE undergraduate PBL projects. This study makes use of a longitudinal case study approach to investigate the effectiveness of using Design Sprint approach in a SE undergraduate module which used PBL. The study focusses a group of students(111) and academics (12) in SE degree program in a private higher education institute in Sri Lanka. Qualitative data gathered from the target audience in two distinctive occasions to investigate the effectiveness of Design Sprint in PBL projects.

Index terms— design sprint, PBL, SE.

1 Introduction

oftware Engineering (SE) is an ever-evolving field which introduces platforms, techniques and methodologies for the betterment of its students, employees and body of work. SE industry is a dynamic industry which demands students to pose transferable skills such as problem solving, analytical skills, communication skills, teamwork and acquiring new knowledge. Therefore, SE curriculums should be equipped with methods which strengthens these transferable skills.

Project Based Learning is one such approach used in SE curriculums especially for group projectbased modules. Via these PBL based modules institutes try to inculcate real-life project experience for their undergraduates to prepare them for their industrial aspirations Many SE industries utilize Design Sprint for their project endeavors (MARIN-GARCIA1 & JAIME, 2008) due to the quick and effective delivery of customer requirements. Design Sprint is a comprehensive approach where essential project elements such as designing, prototyping and real-time customer feedback gets merged in one single platform. Compared to other approaches, a sprint produces a deliverable within a shorter duration with Design Sprint (Knapp, Zeratsky & Kowitz, 2016). Due to its value additions; Design Sprint is more and more used in PBL methods. Therefore, it is suitable to embed Design Sprint in to PBL modules in SE curriculums as well.

The study investigates a group of students in their first year and second year of study following a PBL module. The same group of students (**??**11) is observed in these two occasions following a longitudinal study. The academics who have guided and instructed the group following these modules have also been targeted to collect data to further strengthen the findings. The case for the study was a private higher educational institute which offers SE degrees.

The study initiates by investigating literature and producing a theoretical framework which showcases performance indicators which is required to successful project engagement. Then a hypothesis was derived, and research questions were formed. Data gathered in two occasions via a longitudinal study and were analyzed via qualitative approaches.

2 a) Transferable Skills

MacKeracher & Marsh (2020) in their study of improving Australia's marine science postgraduate training system to meet the needs of the "Blue economy" has identified the following transferable skills which is required in MSc and PhD students: Weber, Borit, Canolle, Hnatkova, O'Neill, Pacitti & Parada(2018) defines transferable skills as "skills learnt in one context that are useful for another. They can serve as a bridge from study to work and from one career to another, as they enable subject and researchrelated skills to be applied and developed effectively in different work environments." The following table showcases transferable skills under competence categories such as career development, cognitive, communication, digital, enterprise and interpersonal. Adamopoulos (2019) explains that unlike any other type of education, higher education is always judged by based on the value it provides for its undergraduates. Furthermore, he adds that this value addition is strengthened based on how transferable skills are provided by higher education. He lists some of the most important transferable skills as teamwork, problem solving, decision making and critical thinking.

3 b) Transferable Skills needed for SE undergraduates

Transferable skills are the essential skill set that is necessary for a person to adopt to a new or a different situation. Transferable skills can be further described as the skills, knowledge and abilities developed in a certain situation which are applicable to another situation (Career and Employment Service, Macquarie University, 2019). These skills are also referred as soft skills and are undoubtedly valuable to employers in all sectors. Transferable skills can be categorized into Basic and Generic skills. Basic skills include basic literacy skills, basic numeracy skills, critical thinking skills, management skills, leadership skills, interpersonal skills, information technology skills, systems thinking skills and work ethic dispositions. Transferable skills are also described as generic skills which can be used in a great array of different jobs such as. literacy, leadership, problem-solving, teamwork, planning, emotional and labor skills (Nägele & Stalder, 2017).

Individuals who possess high transferable skills are highly valued by employers since it reduces the employer investment in employee skill development. It further increases the chances of securing one's employment (Nägele & Stalder, 2017).

Software Engineering (SE) is a field that constantly adopts new technological trends for better software development. To thrive in the field of SE, individuals must have strong technical skills, soft skills, and transferable skills. SE industry critically demands teamwork and networking skills (Santana et al., 2017). Therefore, it is essential that the SE curriculums interweave development of these skills to cater to the growing demands of the SE industry. According to the study by Gurcan & ?evik (2020). Communication skills is the highest rated skill needed in the SE industry. It is mainly because SE industry is based on communication between and within teams. Moreover, Matturro (2013) states Teamwork, Communication Skills, Proactive skills, Initiation skills, Analytical skills, Problem solving skills, and interpersonal skills ranks as the top required skills in SE industry. Therefore, imparting transferable skills SE curriculum is a vital segment.

4 c) Transferable Skills gained from PBL modules and its importance

Higher education is a phase in a student's life where a combination of skills is required to be instilled in them. These skills include cognitive skills, hard skills, problem solving, teamwork, soft skills and professional skills. It is not possible to grow these skills with just conventional learning and teaching mechanism ??Vogler, Thompson, Davis, Mayfield, Finley & Yasseri, 2018). One of the main objectives of providing a higher education for a student is to ensure that he/she is equipped with skills required to become employable. However, due to various factors it is clear to see a gap in employable skills such as soft skills in students with regards to following conventional learning and teaching methods ??Holmes, 2012). Therefore, higher education institutions must adopt learning and teaching methods which provides a structure, real-life-problem-solving method which builds employable skills in its students. Project Based Learning (PBL) is such a methodology.

Project Based Learning "is based on the premise that learning is a dynamic, interactive process, the final objective of which should be engagement with a real-world context" (Granado-Alcón, Gómez-Baya, Herrera-Gutiérrez, Vélez-Toral, Alonso-Martín & Martínez-Frutos, 2020). Dias & Brentley- ??ias (2017) defines Project Based Learning as "a kind of collaborative work carried out by a group of people within the confines of an academic program". ??ary (2015) discuss that PBL is a method very much suitable for Computing students to achieve their learning outcomes and long-term outcomes. The author further adds that PBL enrich Computing students in getting familiar with real-world problem solving. Sheppard S.D, Kelly.M, Colby & William (2008) agrees that PBL can be the "spine" of a Computing degree structure as it provides a solid foundation on problem solving professionalism where new knowledge is acquired very frequently. Humphrey (2005) indicates that PBL helps students to synthesize their basics and gradually produce the intended end-result and PBL can be applied to many Computing related curriculums to teach data structures, web and mobile development and algorithms. These technical areas are usually very challenging to teach with traditional teaching methods.

Arizona State University (ASU) is one of the success stories which showcases the applicability of PBL in to Computing higher education. At ASU, they have embedded PBL as the backbone in their Software Engineering Degrees. Undergraduates benefit from a plethora of skills as they engage in PBL based modules throughout

their semesters including system analysis, design and professional skills. **??**ary (2015) ASU further have noticed that since the incorporation of PBL into their Software Engineering degree curriculums they have gained many advantages such as higher acceptance rates from industries for their graduates and higher student satisfaction rates as they are able to enjoy and interact more in subject matters. **??**ary(2015) **??**009) identifies that PBL modules enhance several aspects of a student such as collaborative skills while working in groups, a positive attitude towards exploring and discovering knowledge and to develop aptitudes such as critical thinking. Adding to this discussion, Flores-Fuentes & Juárez-Ruiz(2017) declares that PBL modules improve the student's abilities in self-directed work, research, internalization of competencies while at work, presentation skills and use of many resources. The PBL methodology also focuses on the process of learning of a student via research and reflection aimed at problem solving (which is provided by the lecturer). This process includes students' actions which are coordinated in determining solutions and incorporating Sustainability in working both alone and in a group **??**Warr & West,2020). It is clear to see that these skills qualify as transferable skills and will come to the student's aid when they get employed.

There is numerous research which discusses the transferable skills provided for students via PBL modules. Granado-Alcón, Alonso-Martín, Vélez-Toral, Gómez-Baya, Herrera-Gutiérrez & Martínez-Frutos (2018) discuss that PBL modules develop effective learning strategies such as problem solving and inculcate cross-cutting skills transferable to new situations or other academic subject areas. **??**ioduser & Betzer(2007) further adds as they explain that, PBL method aids students to retain the competencies gained for a longer period. Acquiring new knowledge, accepting constructive learning and increased motivation are some of the other few transferable skills which can be installed in students via PBL method Willard & Duffrin (2021). In many instances, it is a requirement of the IT industry that its employees are able to acquire knowledge from many sources, integrate the acquired knowledge and go back to the initial problem with a more dynamic overall view. PBL trains its students to do just this **??**Braßler,2016). It is also crucial that the employees are comfortable in integrating knowledge when it comes to solving real-life problems at workplace. **??**olley(2017) in their research express how PBL method install this skill in students. Granado-Alcón, Gómez-Baya, Herrera-Gutiérrez, Vélez-Toral, Alonso-Martín & Martínez-Frutos (2020) in one of their studies has conducted a research to explore the competencies acquired by students via PBL methods. In their study they have used a total of 387 students following a module called "Higher Education Teaching Innovation Project" at the Universities of Huelva and Murcia in Spain. The study results indicate that, PBL aided the students to improve their ability to work in groups, improve their analytical skills, manage and integrate knowledge and ability to work with different individuals. Furthermore, the study results indicated that PBL aids the students to use tools in different disciplines and strengthen other transferable skills such as research abilities, autonomous learning and critical thinking. The study in their other observations, explains that PBL also plays an important role in enhancing student experience in learning and also to gain the ability to transfer their knowledge in to the required platforms.

5   e) Design Sprint original approach

Design Sprint is a new approach invented by J. Knapp for software product development (Knapp et al., 2016). This is a process of prototyping and testing SE solutions quickly via a structured five-day approach. This methodology is a partnered endeavor with Google ventures. World renowned companies such as Google, Uber, Slack, Facebook, Twitter, and Airbnb use this methodology for software development (Design Sprint SA, 2023).

Design Sprint is an efficient method which includes tools and mechanisms to come up with innovative solutions enriched with customer feedback. The customer centric process provides guidance as to set the stage for the whole process. This guidance is provided in an easy-to-understand five-day approach starting form initial preparation.

A design sprint is conducted by a facilitator also known as a sprint master and his/her first task is to clarify the problem and recruit a team to conduct the sprint. A sprint team comprise with 5-7 members, with diverse skillsets including a facilitator, a designer, a developer, a customer service representative, and a marketer at minimum (Knapp et al., 2016). Main roles involve,

? A facilitator, to ensure that the team stays on track ? A customer service representative, for user insight ? A designer, for their knowledge of design software and User Experience Design ? A developer, for their understanding of any technical limitations ? A marketer, who can determine if the solution has a market value ? A decider, who'll have the final word on decisions (assigned to one of the above) After the team is selected the 5-day process starts.

? Monday -Map, where the team understands the goal of the sprint involving all the stakeholders. The requirements will also be prioritized for the first sprint. The first phase understand, is where the participants understand the problem in hand and come up with their specific objectives. The second phase "sketch" is where the participants search for solutions for the identified problems in phase 1. During the third phase(decide) the team needs to pick one idea out of the many searched in the second phase. In order to pick one idea, the team will have to vote and then create storyboards in terms of the prototype of the system. During prototype phase the team come up with a suitable prototype for the picked design in the decide phase. The last phase test/validate is where the teams evaluate their prototypes.

Elena, Andrés, López-Vázquez & Fernández-Ibáñez (2022) in their study of "enhancing STEAM and engineering education through agile prototyping and testing ideas", targeting 56 first year students at the University of A Coruna has found out that, students are motivated to engage in PBL modules when using

165 design sprint and they also think that Design Sprint is a more multipurpose and useful tool that they can enjoy.
166 The study moves on to say that Design Sprint technique adds more value for PBL modules as it increases student
167 interactions and enhances the way students face challenges during PBL.

6   g) Performance criteria of SE group projects

169 Group projects facilitates students to develop both basic and generic skills required by employers. Khamis &
170 Sulong (2011) states that the strengths and weaknesses of group members can be identified through the peer
171 review and lecturer assessment from presentation sessions. These assessments further help to detect passive
172 students in group projects. They further point out the drawbacks of this approach. They claim that in peer
173 reviews students tend to give almost the same score to his/her group members. In lecturer assessment, it is
174 difficult to detect students' behaviors directly based on their presentations.

175 As stated by Marin-Garcia & Llore (2008) on their research on assessing teamwork in projects mention a set of
176 criteria to assess group processes. These criteria were presented by analyzing various publications. Their criteria
177 include amount or frequency of participation in the group, attendance at meetings, quality of participations
178 in the group or of documents presented, preparation of meetings, gathering and processing of information
179 prior to the meeting, meeting deadlines, interpersonal communication, delegating/ Leading without dominating,
180 accepting and assuming responsibilities, suitable handling of disputes, decisionmaking/Group problem-solving
181 and Creativity. Wateridge (1995) classified a set of performance criteria that is frequently used in industrybased
182 IT/SE projects. He investigates the key success criteria and the factors that influence the success or failure of
183 IT/SE projects. The main success criteria he outlines are meet requirement of users, accomplished purpose, meet
184 deadlines, complies with schedule, contributes to user satisfaction, and contributes to quality goal. **??**evlin (2004)
185 states that criteria for the assessing group work can be determined by lecturers, students or by both parties.
186 Moreover, she claims that groups are much more successful when students are also involved in assessment. She
187 suggests regular meeting attendance, equity of contribution, evidence of cooperative behavior, appropriate time
188 and task management, application of creative problem solving, use of a range of working methods, appropriate
189 level of engagement with task, development of professional competencies, evidence of capacity to listen and
190 responsiveness to feedback/criticism as the main performance criteria.

7   h) Use of Design Sprint for pedagogy

192 Soyupak's (2021) has conducted a study on embedding design sprint into industrial design education. This study
193 examines the potential usage of the design sprint framework, its strengths, weaknesses and how to use it as an
194 educational tool. Study was conducted via a design sprint workshop, for 12 industrial design students who are
195 currently in their 5th semester. Students were given an imaginary company and imaginary data with a problem.
196 Students selected the problem via a dot voting process. Usually, the ideal scenario for students is to start the
197 design process with a thorough user and market research, it is omitted and replaced by imaginary data. There
198 were 2 student groups and the first group focused on developing a thermos for mountain hikers and climbers which
199 is easy to carry, chargeable self-heating, easy to clean and easy to find. The second group intended to design
200 a thermos for the public with addressing stability problem and tilting, to visualize the remaining liquid inside,
201 tracking the product and with a way to easily handle it by visually impaired audience. Results indicated that
202 many students valued the design sprint approach compared to the traditional design studio approach because the
203 whole process is done in the studio environment with less intense having an outcome at the end of each stage.
204 Moreover, students valued their own peer's decision-making power compared to the decisions given by a jury of
205 experienced studio executives. As a negative point, students mentioned about the time limitation. Due to this
206 reason students had to develop 2D prototypes instead of 3D prototypes as required.

207 According to Arce et al.'s (2022) design sprint approach can be used in engineering Drawing classroom. The
208 study was conducted at the University of ACoruña, for 56 first-year students who follows the STEAM degree.
209 There were 18 groups in total. Their problem was to come up with solutions to the problems of masks during the
210 COVID pandemic. As a result, students designed mask ear-savers (10 projects), nose clips (3 projects), eyeglasses
211 rings (2 projects), and door openers (2 projects). It was conducted in both physical and online method using MS.
212 Teams. Moodle was used to provide instructions and to monitor student progress. The Moodle Workshop tool was
213 used for the prototype evaluation via a video. Evaluation rubrics consists of 3 segments such as co-evaluation,
214 heteroevaluation, and self-evaluation. Autodesk software is used to develop the prototype. After the project
215 completion a survey was used to evaluate student satisfaction. Results showed positive effects on grades. This
216 implies that the Design Sprint method has fostered an interactive learning environment. Additionally, students
217 felt less overloaded due to proper time management.

218 Ferreira & Canedo (2020) claims that Design sprint in combination with project-based learning (PBL) is an
219 effective method to implement high quality software products. They have conducted 2 exploratory case studies
220 with a customized reduced version of design sprint approach for IT undergraduate students. With the use of
221 2 case studies, they suggest that the minimalistic version they suggest in Design Sprint can be adopted into
222 any PBL unit. The results indicated that student experience is satisfactory and Design Sprint methodology
223 requires a considerable amount of time for learning and fxing, addressing students' delays, students' shyness,
224 and motivation issues. It is advisable to take measures to reduce these problems. Moreover, they state that

the duration of design sprint should be not less than 4 days and using cutting edge technology will fasten the process. Klynhout (2022) has conducted research on nurturing entrepreneurial skills in undergraduates using Design Sprint approach. Study is focused on understanding how the design sprint can be adopted by university degree programs of applied sciences to teach entrepreneurship. 22 students were participated during the 5-day design sprint and recorded their daily diary entries. Results indicated that "teaching through entrepreneurship" approach is supported via design sprint, and therefore students went through an actual and proper entrepreneurial learning process. Research concludes that design sprint can be used as a form of entrepreneurial education, and as a means of value creation outside the classroom. **??**021) details a pedagogical collaboration used for Music. The end product of the design sprint was the Mapping Sentiments through Music (MStM) application. The design sprint was conducted with a digital humanities librarian, a professor of music and digital media, and a second-year music student. Research concludes that both humanities and music composition can incorporate design sprint.

Ferreira & Canedo (2019) have conducted a study on Brazilian's higher education colleges on using Design Sprint for active learning in requirements engineering courses. They state that Design Sprint is a good approach because of its flexible structure and short duration. An exploratory case study approach was used with software engineering undergraduates for a requirement gathering phase. Results indicated that the reduced time was an issue. Survey results further indicated that 91% of students considered it is productive and 100% of students agreed it can foster creativity and problem solving.

Sumual et al. (**??**018) have used design sprint to design mobile applications. The study was conducted based on the data gathered from lecturers and students in higher education. The results implied using the Design Sprint for designing smartphone-based software will make the process efficient and effective.

According to Beyer & Pfister's (2021) study on using design sprint for visualization courses revealed that it can be used in both on campus and online environments. Researchers have customized the original design sprint method to suit teaching visualization courses. They have run two design sprints within the semester-long visualization course. The first sprint is guided and carried during the last 20 minutes of every lecture in the initial weeks of the semester. This provided students the opportunity of getting direct feedback in the class. The second sprint is conducted towards the end of the semester and students works on this sprint outside of class and submit the result as a final project. Results of the study states that using design sprint has increased the student engagement, improve the quality of the product and students get positive feedback regularly.

Winfield et al. (**??**022) study on integrating design sprint into education also have proven positive results. This study was conducted for a product design in Nottingham Trent University (NTU) including 10 academics, external industrial Clients (Futura Nova) and focus groups in healthcare. Students belonged to different years. (Cross cohorts) Main goal was to improve students professional and team building skills. Outcome is to develop a CAD project. Original design sprint was customized and additionally a pre-sprint phase was added to meet the knowledge gap. Outcomes are positive and allowed less confident students to engage equally. Their main issue was to mix and manage cross cohort students.

8 i) Longitidinal Studies

According to Van Belle, Fisher, Heagerty & Lumley (2004) a longitudinal study is "continuous or repeated measures to follow particular individuals over prolonged periods of time-often years or decades. They are generally observational in nature, with quantitative and/or qualitative data being collected on any combination of exposures and outcomes, without any external influenced being applied. Statistical analysis needs to be conducted in order to analyze the final findings and to come to conclusions of various instances and samples over time. Longitudinal studies enable achieving sequence of events, ability to exclude biasness of participants and relate events to various exposures.

However, there can be various challenges researchers need to face in conducting longitudinal studies due to its very nature. Risk of studies ending up incomplete due to not been able to conduct it for lengthy periods of time, high demand for resources and finances. **??**Newman, 2010) Longitudinal studies due to its nature is commonly utilized to analyze development of disease or relationships of risk factors over time **??**Caruana, According to Caruana, Roman, Hernández-Sánchez & Solli (2015) & (Thomas,2022) there are many study designs which can be followed in longitudinal studies; such as:

Prospective studies: Individual/ group of same participants trailed over a definite period of time. This type of design also eliminates the "recall bias". E.g., in a study where the relationship is analyzed between the number of study hours and the pass rate; none of the participants will recall the number of hours they have studied in the past. In the longitudinal study you may keep track of these variables in real-time.

Repeated cross-sectional studies: Each sampling occasion, the individual/ group of participants are different. E.g., a cross sectional longitude study has been conducted to find out the impact of Covid-19 lockdowns on mental health of a sample of 2000 citizens in Victoria. As per the result of this study, cross-sectional portion has showed that the percentage of participants with low life satisfaction was significantly higher in the sample which went through lockdowns compared to the one that did not. Longitudinal study results indicated that lower social connectedness was significantly associated with higher psychological distress. **??**

9   Methodology

The objective of the study is to find out whether Design Sprint workshop increase student performance in undergraduate SE group projects in PBL modules. According to the referred literature attributes that determine student performance are problem solving, teamwork, analytical skills, communication skills and acquiring new knowledge. Furthermore, these performance indicators are enhanced via certain measurable criteria.

The purpose of this study is to verify that the above criteria will be met/enhanced when design sprint methodology is introduced in to a PBL module. The study follows a prospective longitudinal mechanism where the same student group is observed within a period of time.

Qualitative data was collected from the student group as well as targeted lecture panel in two occasions. First occasion was before the design sprint workshop was conducted and then the second occasion was after the design sprint workshop. Data analysis was done using qualitative data gathered using observations, questionnaire and interviews.

10   a) Theoretical Framework

Based on the literature review conducted, it is noticed that undergraduate student performance is based on variables such as problem solving, teamwork, analytical skills, communication skills and the student's ability to acquire new knowledge. Accordingly, the following theoretical framework was designed: ( ) C b) Sample**13**

The research is an exploratory and longitudinal study in nature. The sampling technique is nonprobability sampling. The study was conducted at a private higher educational institution which offers degree programs in the streams of Computing, Business and Law. The research context is a first-year module called "software development & application modelling" (SDAM) and a second-year module called "Commercial Computing" (CC). Both modules are offered for Software Engineering students during the academic year of 2020-2021.

Rational of selecting the modules is that both modules are delivered across two semesters following the Project Based Learning method. In SDAM module students design and develop a software solution for a given scenario. In the CC module during the first semester, the students come up with a proposal for a given scenario. To obtain an effective proposal the student groups need to conduct a domain study, similar system study and analyze and choose a suitable technology. The proposal should contain a software solution to solve a problem within the scenario. In the second semester, the student groups will assume Agile roles for themselves and implement the proposed software solution in three sprints. Agile methodology contains main project roles such as Scrum Master, developer, business analyst and quality assurance engineer. Student groups contain four members each, assuming each role. Each sprint the students are to switch their roles so that every student receives the opportunity to act in all four roles at the end of the three semesters. The instructor/ lecturer for the module plays the role of the product owner and provides the scenario for the groups in the first semester. The groups will conduct sprint reviews at the end of each sprint, where each group will demonstrate their shippable products to the product owner and receive his/her feedback. The next sprint starts with the groups adhering to the previous sprint review feedback.

The student sample contained a total of 111 second year software engineering students. This same group of students had gone through SDAM in their first year and then CC module in their second year. According to Van Belle, Fisher, Heagerty & Lumley(2004) a longitudinal study is "continuous or repeated measures to follow particular individuals over prolonged periods of time-often years or decades"; therefore, this group of students is suitable for this study.

The study couldn't have been conducted targeting only a first-year batch as they lack PBL exposure. The batch needs to have completed the first year where they had no design sprint experience and second year where they were exposed to design sprint; in order to measure the impact of design sprint.

The lecturer sample contained a total of 12 lecturers. These lecturers teach modules in first-and second-year software engineering degree program at the selected higher educational institution.

11   c) Instrument Data was collected in couple of instances:

? Questionnaire and interview First instance: just after the assessment marking is completed for SDAM module in the first year, questionnaire and interview was used to collect data from both student and lecturer samples. Second instance: just after the assessment marking is completed for CC in the second year second semester, questionnaire and interview was used to collect data from both student and lecturer samples.

The questionnaire was designed based on the questionnaire used in the study "Project-based Learning and the Acquisition of Competencies and Knowledge Transfer in Higher Education" (Granado-Alcón, Gómez-Baya, Herrera-Gutiérrez, Vélez-Toral, Alonso-Martín & Martínez-Frutos, 2020). The questionnaire has been validated via qualitative analysis of reliability and validity. This was done via sending the questionnaire to 76 students to identify any repetitions/ unclear elements. Questionnaire was also sent to 6 experts and validated via individual aggregated method. (Granado-Alcón, Gómez-Baya, Herrera-Gutiérrez, Vélez-Toral, Alonso-Martín & Martínez-Frutos, 2020). In order to achieve quantitative validity exploratory factorial analysis has been conducted via extraction method and rotation method.

12 III.

13 Data Analysis Design

14 Results

15 a) First Instance

Data gathered using a questionnaire in the first instance where the student group has just received their The following are some of the results analyzed using graphical indicators: Furthermore, the study includes five main performance indicators. The results showcase the results obtained from one of the questions under each performance indicator.

16 Fig. 5: Performance Indicator: Problem Solving

One of the questions used to check the student's problem-solving ability was "PI1.1 When given a problem I have the ability to come up with a suitable solution". The above chart showcases the student ratings achieved for the question. The ratings indicate that almost 83% of the students have rated their ability to come up with a suitable solution as 1 or 2. Only around 12% of students have given themselves a rating of 4/5 indicating that they have the ability to come up with a suitable solution. It is clear to see that at this point the students lacked confidence in problem solving.

The second performance indicator which was checked using the questionnaire was "team work". The below chart depicts the student ratings received for the question "PI2.3 I can plan and organize tasks in group work" under teamwork. We could see that majority of the students (88%) have given themselves a very low rating of either 1/ 2 as they did not believe that they pose the ability of proper planning and organizing a group work. Very low number of students (7%) have rated themselves with high ratings of 4/5 claiming that they have the ability to properly organize and plan group work. The above chart showcases the student ratings obtained for the question "PI3.2 I can analyze given data and make suitable decisions". As per the above indication, 87% of students have rated themselves as having poor ability in making decisions. (1/2 rating) Only a very small number of students (8%) have rated themselves high (4/5) for having analytical skills to solve problems.

The performance indicator "communication skills" was also measured using several questions in the questionnaire. One such question was "PI4.3: I am able to express my ideas clearly". As per the below chart, 90% of majority have stated that they do not have the ability to express their ideas clearly and only 21% minority have rated as they have the ability to express their ideas.

17 Fig. 8: Performance Indicator: Communication Skills

The last performance indicator to determine student performance was "acquiring new knowledge." One of the questions to determine the responses was "PI5.1 I can learn new things easily by myself". However, as per the results below; 80% of students have stated that they do not think they have the ability to learn new things easily by themselves. Only 31% of students have stated that they have the ability to learn new things. The codes identified in the above table were used to analyze the interview responses. The following is some of the significant responses extracted from the lecturer's interview transcripts.

When presenting the responses, the following notations were used: The below notation indicates that it is the 1st respondent (Res1) from the Lecturers. E.g., LRes1

18 c) Interview Analysis Results of First instance

(Right after the group of students received their marks for the SDAM module in first year of study.)

19 i. Qualitative analysis on student's problem-solving ability

In order to analyze responses which indicated the student's problem-solving skills, the subcategories "Coming up with solutions", "Understanding user requirements", "Synthesizing information", "PBL module assessment marks" and "Active participation" was used from the Table 2.

LRes1: this is the fourth consecutive semester I am delivering SDAM. Our students don't seem to understand the learning outcomes of PBL modules. Many of the students invest minimum effort and merely submit a working prototype. (LRes1, personal communication, December 14, 2020).

LRes4: most of our students do not actively take part in the PBL module assessments. Many of them start the projects very later in the semester and end up with poor time management (LRes4, personal communication, December 14,2020).

20 ii. Qualitative analysis on student's teamwork ability

In order to analyze responses which indicated the student's teamwork, the subcategories "Contribution of work", "Planning and organizing" and "ability to work with others" were used from the Table 2.

LRes7: many of the groups of four had only 1 student who was working by himself/herself. Many do not contribute for their group work and the ones who work ends up covering up for the ones who do not. (LRes7, personal communication, December 14,2020).

LRes11: there are many groups where students do not have the passion to work with others. Many students are used to working in isolation. (LRes11, personal communication, December 14, 2020).

21   iii. Qualitative analysis on student's Analytical skills

In order to analyze responses which indicated the student's analytical skills, the subcategories "Pick viable solutions amidst options", "Presenting analyzed information" and "Decision making" were used from the Table 2.

LRes5: our students have very good presentation skills. But when it comes to presenting their ideas/proposed solutions they seemed to lack the flow and confidence (LRes5, personal communication, December 14,2020).

LRes11: many of our students do not wish to spend a lot of time in analyzing a scenario. They always wish to jump into the implementation phase. Due to this, many students come up with ineffective solutions that doesn't aid the users to solve their problems. (LRes11, personal communication, December 14,2020).

22   iv. Qualitative analysis on student's communication skills

In order to analyze responses which indicated the student's communication skills, the subcategories "Group communication", "Conflict resolving" and "Idea expression" were used from the Table 2.

LRes12: our students panic in an instance of conflict. many group members tend to contact us and request to change their groups as they do not wish to continue the project with their current group members. (LRes12, personal communication, December 14,2020).

LRes6: many students in groups stay quiet during meetings. Some students have very good technical abilities but as they do not express their ideas, they tend to be backwards in group work. (LRes6, personal communication, December 14,2020). In order to analyze responses which indicated the student's communication skills, the subcategories "Self-study", "Transferable skills" and "Soft skill development" were used from the Table 2. LRes8: most of our students wish that the lecturers teach them everything. Students do not wish to engage in self-study or any type of fact gathering/ reading. This is one of the reasons as to their assessments fail. (LRes8, personal communication, December 14,2020).

LRes10: many students do not see the opportunity to improve their skills in PBL modules. For most of them a project is a "One-time endeavor" and they do not understand the value of learning transferable skills. Therefore, we see the students repeating same mistakes which they made in first year in their second year as well. (LRes10, personal communication, December 14,2020).

Observation conducted during the design sprint workshop during the CC module Observation was used to gather data during the design sprint workshop. The original design sprint approach is a 5 day well planned process which includes all stakeholders of an industry-based project. The objective of the design sprint workshop was to implement a simple solution to match the given requirements by the researcher. For the purpose of this study, the original approach was customized to meet the learning objectives of the selected PBL module. Main customizations include introducing a pre-sprint stage, removing extra industry-based roles, and simplifying the sprint questions. During the pre-sprint stage students were informed in advance about the workshop and tasks they have to do. This was conducted in order to save the time of adjusting to a new learning criterion. Project roles related to budgeting and resource allocations are left out since these approvals are out of scope. Sprint questions were strictly limited to one because of the time limitations. Another major change from the original design sprint is allowing to use all technological devices during the workshop. This was allowed since students need to explore the problem and its background, investigate into possible solutions and conduct research on its development in the workshop.

Observation 1: More innovative solutions were invented -Students collaboration and enthusiasm was considerably high during the workshop compared to general unguided group work sessions they attend. Students focused on the given problem, formulated different possible ideas and selected the most suitable one. Students were more focused on understanding the user requirements and catering to them. In all groups dedicated one to two students were analyzing past systems and approaches with technological aid during the session. They were able to synthesize different solution pathways together to formulate a better and an efficient solution. This approach generated good outcomes and all student groups were able to meet the goal at the end of the workshop.

Observation 2: Improve teamworking skills -PBL modules are mostly based on teamwork and main goal of introducing design sprint is to achieve its maximum potential. All students were highly engaged in proper teamwork. As observed during the workshop they were communicating well with each other to understand the problem. When generating different ideas, they sometimes disagreed with each other and ultimately ended up with a partial agreement or formulated a new solution. Most team members were firm in communicating their ideas and viewpoints since they understood that mistakes in communication will lead towards more rework. The decision makers were assigning and delegating tasks for the appropriate members in the group and all of them adhered to it since their roles were pre-defined. All team members were responsible for a specific task as well as generic tasks. Within the group the tasks needed to be planned and organized as a team. In some teams this

was done by subgroups of two to three members and in some groups all teams members got together in planning their work. Overall, the teamwork was in its highest capacity during the workshop.

Observation 3: Improving critical thinking ability -Students were given a well-defined problem to design and implement a solution, during the workshop. They were first analyzing the problem and its context followed by the solution designs and its feasibility. All groups used internet and other electronic mediums as information gathering sources. Some groups were referring to the video tutorials and materials during the workshop. Students conducted investigation and comparisons on the possible development technologies before starting on development. All of them were required to analyze the problem and come up with user stories or use case diagrams to demonstrate the features. Then by analyzing them, students came up with possible designs during the Crazy 8's phase. They were observing the past data and past systems before stating implementation. Proper investigation led them to implement an efficient product. Critical thinking is involved in all stages of the workshop. Observation 4: Learning new knowledge -Students were conducting their own investigations during the workshop to come up with feasible solutions. This allowed them to learn new methods of designing, implementing, and testing products. Further, students who are fluent on certain tools and technologies tend to teach other students in the team. This ultimately led to a knowledge sharing platform allowing students to improve their knowledge and skills. Moreover, soft skills such as communication skills, leadership skills, listening skills, presentation skills and networking skills were heavily used during the workshop. One main observation was the large amount of peer learning encountered during the workshop. Students were very happy about this peer learning since it was a positive scenario occurred without intentional planning. These peer learning will surely aid the students in their later studies.

Observation 5: Detection of errors in early stages of product design -All team members were fully focused around finding a solution to the problem at the early stages (Monday to Wednesday). They all were focused on a single objective and collaboratively worked towards deriving solutions. Their specific tasks such as development, designing and testing started at a later stage. Hence, the errors were detected and solved in the early stages allowing less rework compared to the traditional way of development. Moreover, students were comfortable with each other because of the friendly set up. This led to proper communication among team members and indirectly impacted early detection of errors.

Observation 6: Equal respect is served for all ideas -All students in the group were assigned specific roles such as deciders, customer expert, technical experts (developers, quality assurance engineers) and design experts (business analyst). Therefore, everyone's ideas were respected and heard during the initial stages. Moreover, all members need to provide their own design using crazy 8's and the best ideas are selected using the voting system. None of the students complained about a discrimination or unfairness during the workshop. All students' voices were heard and treated equally in decision making.

Observation 7: Enjoying the work -Students enjoyed this new approach of design sprint very much. They were engaging with each other, solving issues and conflicts in a professional manner, and having fun at the same time. They were adopting to this new mechanism well and positive feedback was received at the end.

23 d) Second Instance

The second instance was where the student group was in their second year of study and just received their assessment marks for their PBL module (CC). Prior to this questionnaire, the students have gone through the design sprint workshop as well. The same questionnaire used (Appendix A) in the first instance was used for the second instance as well in order to maintain consistency. The purpose of this second instance data gathering was to check whether any of the performance indicators have improved via the design sprint workshop. The above indicates the student ratings for the question "PI1.1 When given a problem I have the ability to come up with a suitable solution". The ratings indicate that almost 81% of the students have rated them as 4/5. Only around 11% of students have given themselves a low rating indicating that they do not have the ability to come up with a suitable solution. It is clear to see an enhancement of problem-solving ability in students after the design sprint workshop.

The second performance indicator which was checked using the questionnaire was "team work". The below chart depicts the student ratings received for the question "PI2.3 I can plan and organize tasks in group work" under team work. We could see that majority of the students (86%) have given themselves a very high rating of either 4/5 as they believe that they pose the ability of proper planning and organizing a group work. Very low number of students (8%) have rated themselves with low ratings of 1/2 claiming that they do not have the ability to properly organize and plan group work. Design sprint workshop seems to have a positive impact on the student's team work. The above chart showcases the student ratings obtained for the question "PI3.2 I can analyze given data and make suitable decisions". As per the above indication, 86% of students have rated themselves as having high ability in making decisions. Only a very small number of students (10%) have rated themselves low (1/2) for not having analytical skills to solve problems. Design sprint workshop have seemingly improved their analytical skills.

The performance indicator "communication skills" was also measured using several questions in the questionnaire. One such question was "PI4.3: I am able to express my ideas clearly". As per the below chart, 70% of majority have stated that they do have the ability to express their ideas clearly and only 41% minority have rated

as they do not have the ability to express their ideas. Design sprint have increased the student's communication skills.

24 Fig. 13: Performance Indicator: Communication Skills

The last performance indicator to determine student performance was "acquiring new knowledge." One of the questions to determine the responses was "PI5.1 I can learn new things easily by myself". However, as per the results below; 82% of students have stated that they have the ability to learn new things easily by themselves. Only 29% of students have stated that they do not have the ability to learn new things. Design sprint have enhanced the skill of acquiring new knowledge in students. i. Qualitative analysis on student's problem-solving ability In order to analyze responses which indicated the student's problem-solving skills, the subcategories "Coming up with solutions", "Understanding user requirements", "Synthesizing information", "PBL module assessment marks" and "Active participation" was used from the Table 2. LRes1: we see a good improvement in students after the design sprint workshop. Students invest longer time on understanding the scenarios rather than jumping into implementations. (LRes1, personal communication, December 14,2020).

LRes4: after the design sprint work was done; we can see a good participation rate in achieving project milestones. Students are not procrastinating and are engaging in projects well.

(LRes4, personal communication, December 14, 2020).

25 ii. Qualitative analysis on student's teamwork ability

In order to analyze responses which indicated the student's teamwork, the subcategories "Contribution of work", "Planning and organizing" and "ability to work with others" were used from the Table 2.

LRes7: design sprint workshop seemed to have improved the way members contribute in group work. We can see that there are lot of groups where all the members contribute equally for their group work. (LRes7, personal communication, December 14,2020). LRes11: we can see that students tend to invest more time in working with their group members. We have less complaints about team members. We also saw that some students tend to stay back after lecture hours to help certain members in their groups. (LRes11, personal communication, December 14, 2020).

iii. Qualitative analysis on student's Analytical skills In order to analyze responses which indicated the student's analytical skills, the subcategories "Pick viable solutions amidst options", "Presenting analyzed information" and "Decision making" were used from the Table 2.

LRes5: it was a delight to sit through the sprint reviews of CC module. We can see a significant change in how students presented their shippable products after the design sprint workshop. (LRes5, personal communication, December 14,2020).

LRes11: we can see that students tend to do more background study and fact gathering especially in the 3rd sprint. (LRes11, personal communication, December 14,2020).

iv. Qualitative analysis on student's communication skills In order to analyze responses which indicated the student's communication skills, the subcategories "Group communication", "Conflict resolving" and "Idea expression" were used from the Table 2.

LRes12: after the design sprint workshop we can see that teams engage as they enjoy in groupwork. We can hear clear communications and less conflicts are reported. (LRes12, personal communication, December 14, 2020).

LRes6: we can see more students actively participate and elaborate their ideas in group meetings. (LRes6, personal communication, December 14,2020).

26 v. Qualitative analysis on student's ability to acquire new skills

In order to analyze responses which indicated the student's communication skills, the subcategories "Self-study", "Transferable skills" and "Soft skill development" were used from the Table 2. LRes8: after the design sprint workshop, I have received many emails from students requesting to clarify certain subject matters. This is a good indicator that they have done some self-reading on various topics. (LRes8, personal communication, December 14,2020).

V.

27 Discussion and Recommendations

The objective of the study was to find out whether Design Sprint workshop increase student performance in undergraduate SE group projects in PBL modules on problem solving, teamwork, analytical skills, communication skills and acquiring new knowledge. Furthermore, these performance indicators are enhanced via certain measurable criteria. Using these attributes, a theoretical framework was designed.

Thereafter the study progressed to verify that the above criteria will be met/enhanced when design sprint methodology is introduced in to a PBL module. The study was conducted as a prospective longitudinal mechanism where the same student group (111) was observed within a period of time. **??**2020) **??**2021) Qualitative data

was collected from the student group as well as targeted lecture panel (12) in two occasions. First occasion was before the design sprint workshop was conducted and when the group was in their first year of study following a PBL module called SDAM. The second occasion was after the design sprint workshop was conducted as the group followed a PBL module called CC. In order to gather data from students, questionnaire was used and to gather data from lecturers, interviews were used. Moreover, an observation was also conducted during the design sprint workshop.

According to the questionnaire results obtained and the interview results of lecturers in the first year (2020) for the SDAM module, we could see that the students fell behind in the skills of problem solving, teamwork, analytical skills, communication skills and acquiring new knowledge. After conducting the design sprint workshop, the second qualitative data gathered indicated that there was a clear improvement in the same skills.

28 VI.

29 Conclusion

The study investigated the value addition brought by Design Sprint in to PBL modules in SE curriculums. The results indicated a considerable performance enhancement in students after introducing them to Design Sprint workshop. Transferable skills such as problem solving, analytical skills, communication skills, teamwork and acquiring new knowledge are proven to be improved via Design Sprint approach. The authors suggest that this study could be further strengthened using a statistical approach. It is also suggested to generalize this approach to other PBL projects in similar fields.
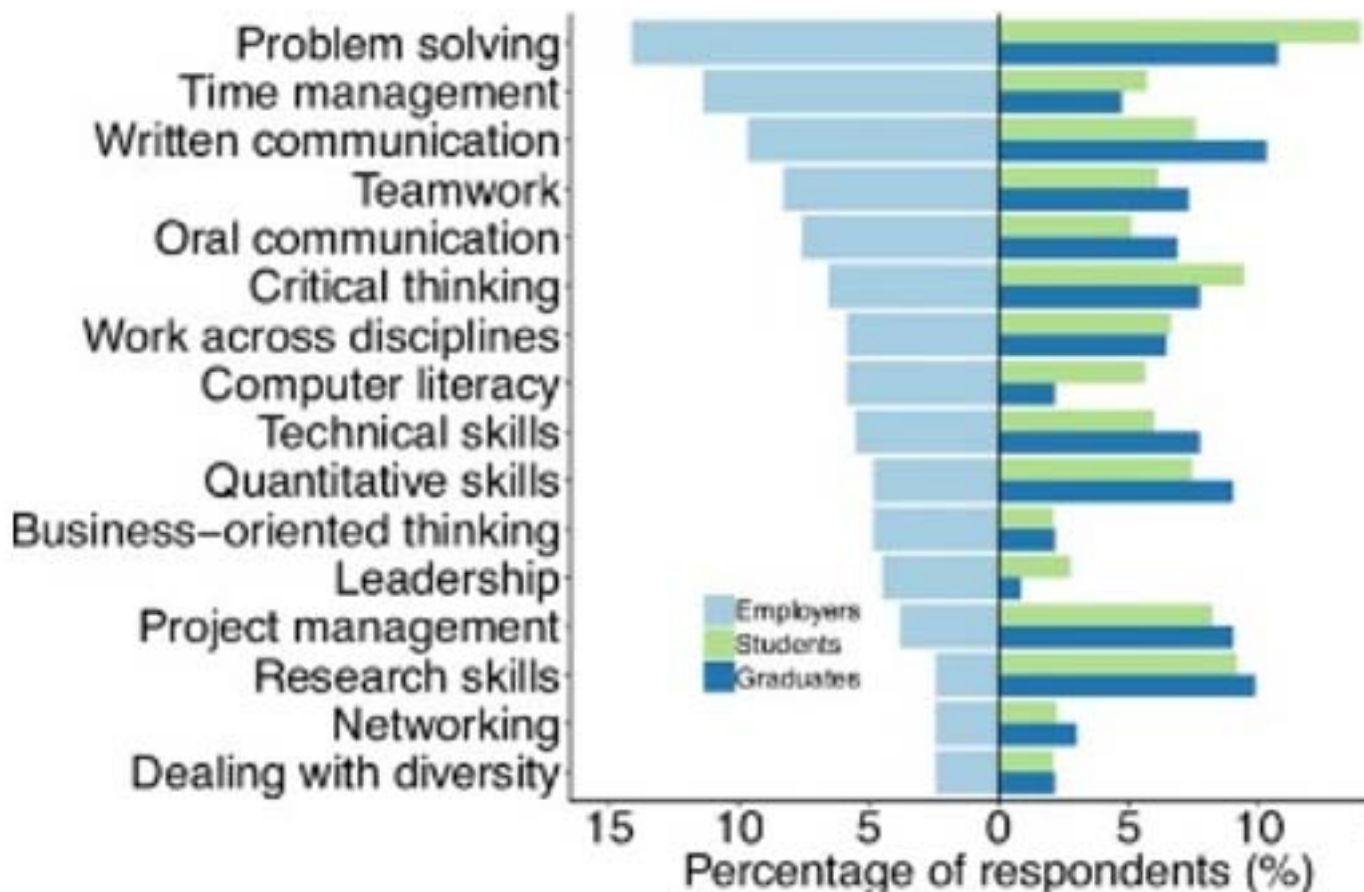

1

Figure 1: Fig. 1 :

11

| Competence Category	Transferable Skills and Competences
Career Development	- Career planning and assessment - CV writing - Interview techniques - Job application - Job searching - Skills documentation and verification - Skills gap identification and development
Cognitive	- Abstraction and creativity - Analysis and synthesis - Critical thinking - Organisation and optimisation - Problem-solving
Communication	- Academic writing - Formal correspondence - Oral presentation - Science for non-technical audiences - Science for policy making - Social media and webinar usage
Digital	- Information accessing and retrieval - Information presentation and visualisation - Information processing and exchange - Programming - Software usage and development
Enterprise	- Commercialisation - Entrepreneurship - Innovation - Intellectual Property Rights (IPR) - Knowledge transfer within and across sectors - Legal and business standardisation - Patenting
Interpersonal	- Conflict management - Discipline and perseverance - Diversity awareness - Independence and responsibility - Leadership

2

Figure 2: Fig. 2 :

3
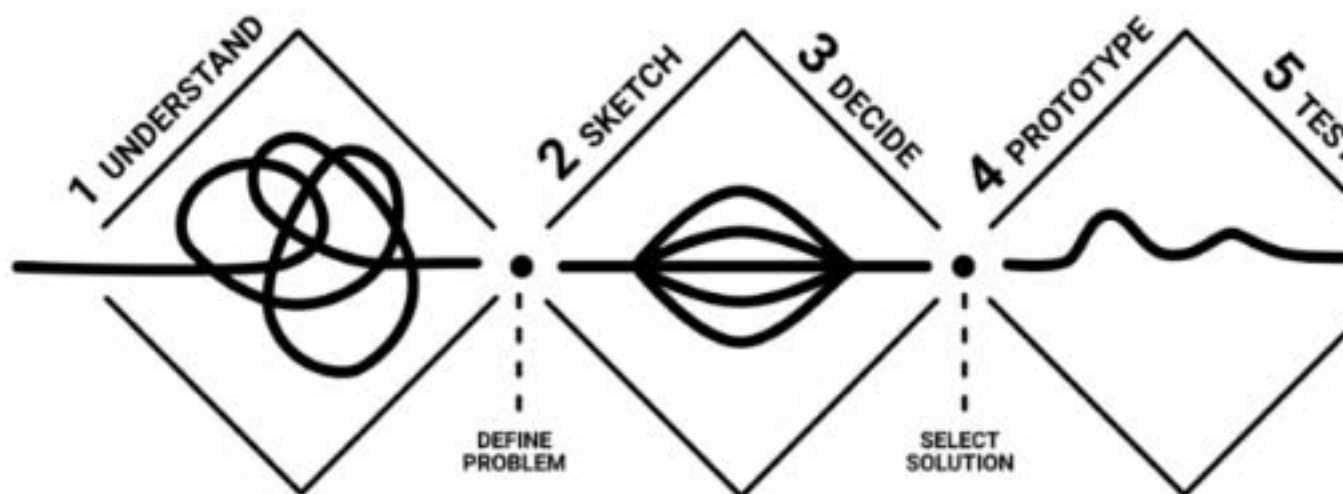
Figure 3: Fig. 3 :

d) Transferable Skills gained from PBL modules and its
importance
According to Haan (2010), Rieckmann (2012) &
Wiek, Withycombe & Redman (2011) the key
competencies searched by employers are critical
thinking, collaborative work and integrated problem
solving. Eby. J.W, Herrell. A.L, & Jordan(

Figure 4:

Retrospective studies:
II.

Figure 5:

1

Variables	Problem solving	Teamwork	Analytical skills	Communication skills	Acquiring new knowledge
	Create solution design	Task management	Decision making	Interpersonal communication	Use of new working methods
	Meet requirements of users	Schedule compliance	Creativity	Responsive to feedback and criticism	Development of professional competencies
Performance indicators		Delegating tasks and work without dominating		Handling disputes	

Figure 6: Table 1 :

2

Inductive categories (Codes)	Subcategories
	Coming up with solutions
	Understanding user requirement
Problem solving	Synthesizing information
	PBL module assessment marks
	Active participation
	Contribution of work
Teamwork	Planning and organizing
	Ability to work with others
	Pick viable solutions amidst
Analytical skills	options Presenting analyzed information
	Decision making
Communication skills	Group communication Conflict resolving Idea expression
Acquire new knowledge	Self-study
	Transferable skills
	Soft skill development

Figure 7: Table 2 :

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[Granado-Alcón] , Granado-Alcón .

[Alonso-Martín et al.] , M C P Alonso-Martín , M Vélez-Toral , D Gómez-Baya , . E Herrera-Gutiérrez , Martínez-Frutos .

[Ferreira and Canedo ()] *A Design Sprint based model for User Experience concern in project-based learning software development*, V G Ferreira , E Canedo . 2020. Uppsala.

[Wright and Livera ()] *A repeated cross-sectional and longitudinal study of mental health and wellbeing during COVID-19 lockdowns in Victoria*, De A Wright , Lee A K H Livera . 10.1186/s12889-022-14836-9. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-022-14836-9 2022. Australia. BMC Public Health. 22.

[Guo et al. ()] 'A review of project-based learning in higher education: Student outcomes and measures'. P Guo , N Saab , . L Post , W Admiraal . https://reader.elsevier.com/reader/sd/pii/S0883035519325704 *International Journal of Educational Research* 2020. 102. (token=E90BDC796FAC0E3C86E5571A6EBC6661342C7D7B3134F3C317 9183C4A2629C0A0FC4FB3124CEA36B2F8ABEE91 087244F&originRegion=eu-west-1&originCreation= 20230201105457)

[Hazreen and Su ()] 'An exploratory study on risk factors for chronic noncommunicable diseases among adolescents in Malaysia: overview of the Malaysian Health and Adolescents Longitudinal Research Team study (The MyHeART study)'. M A Hazreen , Jalaludin T T M Y Su . 10.1186/1471-2458-14-S3-S6#citeas. https://bmcpublichealth.Biomedcentral.com/articles/10.1186/1471-2458-14-S3-S6#citeas *International research symposium on population health* 2014. 14 (3) .

[Newman ()] 'An overview of the design, implementation, and analysis of Longitudinal studies on aging'. A Newman . 10.1111/j.1532-5415.2010.02916.x. https://agsjournals.onlinelibrary.wiley.com/doi/abs/10.1111/j.1532-5415.2010.02916.x *Journal of the American Geriatrics Society* 2010. 58 (2) .

[Devlin ()] *Assessing group work*, M Devlin . https://www.researchgate.net/publication/304582428_Assessing_Group_Work 2004.

[Van Belle et al. ()] *Biostatistics: a methodology for the health sciences*, G Van Belle , . L Fisher , . P Heagerty , T Lumley . https://books.google.lk/books 2004. John Wiley & Sons. (hl=en&lr=&id=KSh 8IOrLPzwC&oi=fnd&pg=PR7&dq=Van+Belle+G, +Fisher+L,+Heagerty+PJ,+et+al.+Biostatistics: +A+Methodology+for+the+Health+Sciences.+L ongitudinal+Data+Analysis.+New+York,+NY:+Jo hn+Wiley+and+Sons,+2004.+&ots=K6beJGi2JL &sig=lsWUgXOydD7UXWeUqJSK7f8JS38&redir_es c=y#v=onepage&q&f=false)

[Warr and West ()] 'Bridging Academic Disciplines with Interdisciplinary Project-based Learning: Challenges and Opportunities'. M Warr , West . https://eric.ed.gov/?id=EJ1257972 *Interdisciplinary Journal of Problem-based Learning* 2020. 14 p. .

[Caruana et al. ()] Roman E J M Caruana , Hernández-Sánchez , P Solli . https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4669300/#r1 *Longitudinal studies*, 2015. 7.

[Rashid et al. ()] 'Case study method: A step by step guide for business researhes'. Y Rashid , A Rashid , M A Warraich , S Sabir , A Waseem . 10.1177/1609406919862424. https://journals.sagepub.com/doi/pdf/10.1177/1609406919862424 *International journal of qualitative methods* 2019. 18 p. .

[Nägele and Stalder ()] 'Competence and the Need for Transferable Skills'. C Nägele , B E Stalder . *Competence-based Vocational and Professional Education. s.l* 2017. Springer International Publishing Switzerland.

[Ferreira and Canedo ()] 'Design sprint in classroom: exploring new active learning tools for project-based learning approach'. V G Ferreira , E D Canedo . *Journal of Ambient Intelligence and Humanized Computing* 2020. 11 p. .

[Winfield et al. ()] *DESIGN SPRINT METHODOLOGIES TRANSFORMED*, K Winfield , N D Sizer , F L Siena . 2022. London.

[Sumual et al. ()] *Design Sprint Methods for Developing Mobile Learning Application*, H Sumual , J R Batmetan , M Kambey . 2018. p. .

[Arce et al. ()] 'Design Sprint: Enhancing STEAM and engineering education through agile prototyping and testing ideas'. E Arce , A Suárez-García , J A López-Vázquez , M I Fernández-Ibáñez . *Thinking Skills and Creativity* 2022. 44 (1) .

[Andrés et al. ()] *Design Sprint: Enhancing STEAM and engineering education through agile prototyping and testing ideas, Thinking Skills and Creativity*, Elena A S Andrés , López-Vázquez , M Fernández-Ibáñez . https://reader.elsevier.com/reader/sd/pii/S1871187122000426 2022. 44. (token=9ECC5F4E8DD6CA807DE56919A1A1901E9EF3590C5 E36D99778DBCE3A5663824FC620E87F084E7C9C 146864C69897EA2A&originRegion=eu-west-& originCreation=20230131094358)

[Murgu et al. ()] *Design Sprints and Direct Experimentation: Digital Humanities + Music Pedagogy at A Small Liberal Arts College*, C Murgu , M Dancigers , E Solloway . 2021.

[Beyer and Pfister ()] *Design Sprints for Online and On-Campus Visualization Courses*, J Beyer , H Pfister . 2021. Salt Lake City: IEEE.

[Eby and Herrell ()] J W Eby , Jordan A M L Herrell . *Teaching in the Elementary School: A Reflective Action Approach, 5*, (Pearson; London, UK) 2009. (th ed)

[Soyupak ()] 'Embedding Design Sprint into Industrial Design'. O Soyupak . *Design Technology Educations: An International Journel* 2021. 26 (2) p. .

[Gurcan and ?evik ()] *Expertise Roles and Skills Required by the Software Development Industry*, F Gurcan , S ?evik . 2020.

[Klynhout ()] *Fostering Students' Entrepreneurial Competencies in Higher Education with Design Sprints*, M Klynhout . 2022.

[RieckmannM ()] 'Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?'. RieckmannM . https://www.researchgate.net/publication/232364850_Future-oriented_higher_education_Which_key_competencies_should_be_fostered_through_university_teaching_and_learning *Futures* 2012. 44 p. .

[Weber et al. ()] 'Identifying Transferable Skills and Competences to Enhance Early Career Researchers Employability and Competitiveness'. C T Weber , Canolle M F Borit , O' E Hnatkova , Pacitti G Neill , F Parada . https://www.semanticscholar.org/paper/ *Identifying-Transferable-Skills-and-Competences-to-Weber-Borit/9*, 2018. (e824fd2 b7d9bd10f6cfa47a162ec3c1893eacf5)

[Van Oostveen and De Lange ()] 'Imaging Techniques in Alzheimer's Disease: A Review of Applications in Early Diagnosis and Longitudinal Monitoring'. . W Van Oostveen , E C M De Lange . https://www.mdpi.com/1422-0067/22/4/2110 *International Journal of Molecular Sciences* 2021. 22 (4) .

[Mackeracher et al. ()] *Improving Australia's marine science postgraduate training system to meet the needs of the 'Blue Economy*, T Mackeracher , Marsh , Helene . https://www.researchgate.net/publication/339366990_Improving_Australia%27s_marine_science_postgraduate_training_system_to_meet_the_needs_of_the_%27Blue_Economy%27 2020.

[Cook et al. ()] 'Improving Teacher Education Through Longitudinal Research: How studying our graduates led us to give priority to program planning and vision for teaching'. Andriole D D Cook , S J Durning , N Roberts , M M Triola . 10.1080/17425960903306880. https://www.tandfonline.com/doi/abs/10.1080/17425960903306880 *Studying Teacher Education* C , CliveB , Cleovoulou T Fletcher (eds.) 2010. 2009. 85 (8) p. . (Academic Medicine)

[Jaime ()] 'Improving Teamwork with University Engineering Students. The Effect'. Marin-Garcia1 , J A Jaime , L . *WSEAS TRANSACTIONS on ADVANCES in ENGINEERING EDUCATION* 2008. 5 (1) p. .

[Holley ()] *Interdisciplinary curriculum and learning in Higher education, Oxford research encyclopedia of education*, K A Holley . 10.1093/acrefore/9780190264093. 001.0001/acrefore-97801902 64093-e-138;jsessionid=4F2E65E4227FEC72BC21 CA2CAD098AE0. https://oxfordre.com/education/display/10.1093/acrefore/9780190264093 2017.

[Wateridge ()] 'IT project: a basis for success'. J Wateridge . *International Journal of Project Management* 1995. 13 (3) p. .

[Wiek and Redman ()] 'Key competencies in sustainability: A reference framework for academic program development'. Withycombe A Wiek , C L Redman . 11625- 011-0132-6. https://link.springer.com/article/10.1007/s *Sustainability Science* 2011. 6 p. .

[Thomas ()] *Longitudinal study definition, approaches and examples, Scribber*, L Thomas . https://www.scribbr.com/methodology/longitudinal-study/ 2022. (text=Prospective%20longitudinal%20studies%20eliminate%20the,carb%20diets%20on%20w eight%20loss)

[Khamis and Sulong ()] 'Measurement of Students' Performance Level in a Group Project by using'. N K Khamis , A B Sulong . *Peer Review and Lecturer Assessment. Social and Behavioral Sciences* 2011. 60 (1) p. .

[Duffrin ()] 'Project based learning in a food science course: benefits and opportunities of collaborative work between students of Bachelor of Nutrition and Biotechnology Engineer'. Willard M W Duffrin . https://www.researchgate.net/publication/303704652_Interdisciplinary_Problem-Based_Learning-A_Student-Centered_

704 Pedagogy_to_Teach_Social_Sustainable_Development_in_Higher_Education
705 *357201227_Project-based_learning_in_a_food_science_course_Benefits_and_opportunities*
706 *_of_collaborative_work_between_students_of_Bach elor_of_Nutrition_and_Biotechnology_Engineer/citati*
707 *ons 12. Braßler.M*, 2021. 2016. 2 p. . Teaching Education for Sustainable Development at University Level
708 (Interdisciplinary Problem-Based Learning-A Student-Centered Pedagogy to Teach Social Sustainable
709 Development in Higher Education)

710 [MT ()] 'Project Based Learning in higher education: Student's perception of transforming traditional learning
711 into an active and constructivist experience'. MT . `https://www.researchgate.net/publication/`
712 `329225551_PROJECT_BASED_LEARNING_IN_HIGHER_EDUCATION_STUDENT'S_PERCEPTION_OF_`
713 `TRANSFORMING_TRADITIONAL_LEARNING_INTO_AN_ACTIVE_AND_CONSTRUCTIVIST_EXPERIENCE`
714 *Proceedings of the ICERI2018 Conference*, (the ICERI2018 ConferenceSeville, Spain) 2018. p. .

715 [Gary ()] 'Project-Based Learning'. K Gary . `https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=`
716 `&arnumber=7274311` *Computer* 2015. 48 p. .

717 [Granado-Alcón et al. ()] 'Project-Based Learning and the Acquisition of Competencies and Knowledge Transfer
718 in Higher Education'. M Granado-Alcón , D Gómez-Baya , E Herrera-Gutiérrez , M Vélez-Toral , Alonso-
719 Martín , M Martínez-Frutos . `https://www.mdpi.com/2071-1050/12/23/10062` *Sustainability* 2020.
720 12 (23) .

721 [Granado-Alcón et al. ()] *Project-Based Learning and the Acquisition of Competencies and Knowledge Transfer*
722 *in Higher Education, Sustainability, 12, 10062*, M Granado-Alcón , D Gómez-Baya , E Herrera-Gutiérrez , M
723 Vélez-Toral , Alonso-Martín , M Martínez-Frutos . `https://www.mdpi.com/2071-1050/12/23/10062`
724 2020.

725 [Flores-Fuentes and Juárez-Ruiz ()] *Project-Based Learning for the Development of Mathematical Competencies*
726 *in High School*, Flores-Fuentes , E Juárez-Ruiz . `https://www.scielo.org.mx/pdf/redie/v19n3/`
727 `1607-4041-redie-19-03-00071.pdf` 2017. 19 p. .

728 [Humphrey ()] *PSP: A Self-Improvement Process for Software Engineers*, W S Humphrey . 2005. Addison-Wesley
729 Professional.

730 [Santana ()] 'Scrum as a Platform to Manage Students in Projects of Technological Development and Scientific
731 Initiation: A Study Case Realized at UNIT/SE'. L F Santana . *Journal of Information Systems Engineering*
732 *& Management* 2017. 2 (2) p. .

733 [Dias and Brentley-Dias ()] 'Setting the Standard for Project Based Learning: A Proven Approach to Rigorous
734 Classroom Instruction'. Dias , L Brentley-Dias . `https://www.researchgate.net/publication/`
735 `318822669_Setting_the_Standard_for_Project_Based_Learning_A_Proven_Approach_to_`
736 `Rigorous_Classroom_Instruction` *Interdisciplinary Journal of Problem-Based Learning* 2015. 11.

737 [Sheppard and William ()] Kelly S D M Sheppard , Colby S William . `https://eric.ed.gov/?id=ED504076`
738 *Educating Engineers: Designing for the Future of the Field. Book highlights, Jossey-Bass*, 2008.

739 [Matturro ()] *Soft skills in software engineering -A Study of Its Demand by Software Companies in Uruguay*, G
740 Matturro . 2013. San Francisco: IEEE.

741 [Sprint ()] Design Sprint , SA . `https://design-sprint.com/google-ventures-design-sprint/`
742 *Google Ventures Design Sprint*, 2023.

743 [Knapp et al. ()] *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days*, J Knapp , J Zeratsky
744 , B Kowitz . 2016. New York: Simon and Schuster. (1 ed.)

745 [Mioduser and Betzer ()] 'The contribution of project-based learning to high achievers' acquisition of technolog-
746 ical knowledge and skills'. Mioduser , N Betzer . 10.1007/s10798-006-9010-4. `https://link.springer.`
747 `com/article/10.1007/s10798-006-9010-4` *International journal of technology and design education*
748 2007. 18 p. .

749 [Haan ()] 'The development of ESD-related competencies in supportive institutional frameworks'. H
750 Haan . `https://www.researchgate.net/publication/225773272_The_development_of_`
751 `ESD-related_competencies_in_supportive_institutional_frameworks` *International Review*
752 *of Education* 2010. 56 p. .

753 [Holmes ()] *The effects of project-based learning on 21st century skills and No Child Left Behind ac-*
754 *countability standards*, L Holmes . `https://www.proquest.com/openview/36` 2012. (f811030b31
755 abfa63690c7a6771a0ae/1?pq-origsite=gscholar&cbl=18750)

756 [Vogler et al. ()] 'The hard work of soft skills: Augmenting the project-based learning experience with in-
757 terdisciplinary teamwork'. J Vogler , Davis P D W Thompson , Finley B E P Mayfield , D Yasseri .
758 10.1007/s11251-017-9438-9. `https://link.springer.com/article/10.1007/s11251-017-9438-9`
759 *Instructional Science* 2018. 46 (3) p. .

760 [Adamopoulos ()] 'Universities should be about transferable skills and continuing education'. A
761 Adamopoulos . `https://www.forbes.com/sites/forbesbostoncouncil/2019/01/03/`
762 `universities-should-be-about-transferable-skills-` *Forbes* 2019. p. 7432.

29 CONCLUSION

763 [Ferreira and Canedo ()] *Using design sprint as a facilitator in active learning for students in the requirements*
764   *engineering course: an experience report*, V G Ferreira , E Canedo . 2019. Limassol: ACM.

765 [Collier and Thomas ()] 'Validating   the   Power   of   Bilingual   Schooling: Thirty-Two   Years
766   of   Large-Scale,   Longitudinal   Research'.   V   Collier   ,   Q   P   Thomas   . `https://www.`
767   `cambridge.org/core/journals/annual-review-of-applied-linguistics/article/abs/`
768   `validating-the-power-of-bilingual-schooling-thirtytwo-years-of-largescale-longitudinal-resear`
769   `909F284BFF9C327124AD08987143E677` *Annual Review of Applied Linguistics* 2017. 37 p. .