Engagement contexts of software engineering education projects

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Engagement Contexts of Software Engineering Education Projects

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Abstract—The inclusion of a capstone project has become a core component of many software engineering and computing related courses. There is general agreement that a substantial final year project provides an opportunity for students to demonstrate breadth and depth of acquired knowledge alongside industry-oriented skills and independent working. Traditionally, capstone projects are academic-proposed individual projects, in which students work from a project outline with one or more academic supervisors. Although useful to demonstrate the application of knowledge, such projects lack key activities that have been cited as beneficial to student experience and career-readiness, specifically working with others in a team and with external clients. In our study we provided a range of projects for students in a final year, compulsory capstone Software Engineering project module which forms a major requirement of the overall degree. The students were required to select a project which could be individual or team-based and where the origin of the project could be academic-proposed, student-proposed, community-based or industry-supported. Students then completed these projects with a mixture of academic supervision and, where appropriate, input from the community group or industrial partner who had proposed it. After completion, a mixed-method approach was used to evaluate student experience and satisfaction. The initial findings indicate that students who chose a team-based project and specifically those who took projects proposed for a real-world user (community or industry) were more satisfied with their experience and agreed to a greater extent that they had developed new skills. Within this group, those who chose the community projects expressed the highest levels of satisfaction, feeling rewarded that their contribution was to a project for social good. These initial findings validate the beneficial approach of involving external partners such as community groups in team-based capstone projects.

Keywords—software engineering education, collaborative learning, project-based learning, capstone course, community engagement

I. INTRODUCTION

The primary aim of any software engineering (SE) degree programme is to prepare the students with the skills and knowledge to enter and thrive in the SE industry. Accordingly curriculum guidelines have been developed along these lines with the aim of ensuring that SE programmes provide an effective passage into the industry [1]. However, research into the preparedness of the students for industry has frequently reported a skills gap between industry’s needs and expectations and graduate acquisition [2]. As a means of tackling this disparity the ACM/IEEE joint task force in SE2004 [1] recommended software engineering projects to be included as a component of a SE programme. This was further reinforced by the recommendations made by the follow-up joint task force in SE2014 [3]. While software engineering programmes vary in emphasis and content, many programmes now include a significant project in the final year of the programme often referred to as a capstone project [4]. The aim of this type of project is to develop a software solution to a specific problem using effective software engineering practices. The project will often provide the opportunity for the student to demonstrate many of the skills developed throughout their studies as well as developing new skills, as required, to successfully deliver on the project.

The final year projects that are provided in programmes vary considerably [5] from projects proposed by academics within their specific research area to industry-proposed projects partially supervised or mentored by industry as well as academic staff. Other projects may be sourced from a community-engagement initiative or other social call for proposals. Projects may initially be ill-defined problems, and require a substantial effort in the early stages of requirements elicitation to fully define their purpose and scope. Others may have requirements more clearly defined at the outset but provide added challenges with, for example, the integration of new and unfamiliar technologies or the further evolution of initial requirements.

There are significant challenges to designing a final year software engineering project module to ensure that opportunities for learning and assessment are appropriately and consistently embedded even within a wide variety of project contexts. In addition to the technical software engineering skills, a final year project usually provides the opportunity to develop project management skills; agile development approaches; and communication skills, for example when working with peers, mentors, supervisors, industrial partners. These aspects need to be considered within the project module design and assessment.

In order to design a fully student-centred programme of study it is important that the students’ needs, and experience are considered in addition to the curriculum content. Student satisfaction is often captured through module and programme evaluation processes but often does not provide the detail that might usefully be considered in an effective module review centred on student experience. In this paper we explore a specific student cohort’s opinion of their final year projects, focusing on their perception of how effectively the module has delivered the skills they need. We capture and evaluate their response to the following research question:

RQ: What is the most effective software engineering project context?

Sub-Research Questions:

• Is there a difference between industry and community group projects in terms of effectiveness?
• Is there a significant difference in student opinion of skills learned during the project depending on context?

In section II we look at related work and include details of the final year SE module in our programme, section III covers the methodology of our study with results presented in section IV and finally a discussion and conclusion in section V.

II. BACKGROUND

A. Related Work

It has been widely published that there is often a gap between the skillset requirement to enter and work effectively in the software engineering industry and the skills that recent graduates have acquired during the course of their studies on a software engineering programme [2, 6, 7, 8, 9]. Results from one empirical study into this gap noted that the “lack of project experience and problem solving abilities are the most commonly cited issues” [2]. Following the 2004 Joint Task Force in Computing Curricula [1] a recommendation was made that a significant project should be a component in any software engineering curriculum in higher education. In order to address this, one approach is to include what is known as a capstone project in which students aim to develop a software solution to a “real-world” problem. There are a number of challenges associated with this approach. For example, it may be difficult to source a project which is or bears some similarity to a “real-world” project. If these projects are proposed by an external source, there needs to be a mutual understanding about what contribution the external partner will make and there can be tensions between the aim of the external and academic stakeholders. For academic-proposed projects there is often an understanding that the project supervisor will guide the students through the learning and assessment but will also provide a customer view, i.e., act as the customer when end user feedback is needed. This can be challenging and involve an element of conflict. As noted by Bruegge [10] “project courses with simulated clients such as colleagues from the university are not unusual” but there remains a question about the effectiveness of this approach. Some institutions use a single-project course approach in which all students work in teams on the same project [11, 12, 13].

1) Industrial Partners

Links with industry are an important component in maintaining alignment between higher education curriculum and industry’s needs for graduate skills. Additionally the provision of real-world projects directly from industry has been shown to be particularly effective in helping students to practice the skills they have learned as well as identify skill gaps and encourage self-directed learning [6]. To provide such projects, our school sends out requests for final year projects for our Computer Science and Software Engineering students to known and established industry partners in the summer preceding the academic year start. The number of projects returned varies from year to year and the companies proposing them may be large multi-national companies to smaller local organisations working in the Software engineering space.

2) Queen’s University Belfast Science Shop

The Science Shop is a community-engaged research initiative which creates links between community-based organisations in Northern Ireland jointly with Queen’s University Belfast and Ulster University. Their mission is to “support students and community-based organisations to create innovative solutions to societal problems through curriculum-based engaged research projects in response to community needs” [14]. Community groups who don’t have the necessary resources or funding to fulfil a vision or goal are invited to propose projects to the Science shop for consideration. There is a diverse range of projects with a growing number of projects that require a software engineered solution to meet their requirements.

3) Teamwork

The importance of acquiring “soft skills” (often also referred to as “transferrable skills”) in addition to technical skills has been identified within the industry [15]. Additionally, this has prompted significant discussion within the research community with teamwork and communication appearing most frequently in papers on software engineering [16]. The inclusion of group work in the curriculum is now an essential component of most software engineering programmes as it is well recognised that teamwork develops a wide range of skills such as collaboration, negotiation, leadership and additionally, promotes a more realistic experience of project management.

B. Software Engineering Project Module

The Software Engineering Project module has been a key component in the Bachelor of Engineering in Software Engineering with placement programme at Queen’s University Belfast for many years. In this paper we look specifically at the Software Engineering Project module as it was run during the academic year 2020-21. We describe the format of the module specifically in relation to the project contexts and the relevant stakeholders. The module was double weighted and extended over both semesters in the final academic year worth one third of the total marks in the final year. Successful completion of the project was required for the award of the degree. The module was designed and managed by a module convener who provided general guidance, supplementary lectures, and mentoring for projects, with additional supervision for some projects.

In 2020-21 there were 72 students enrolled in the module, many of whom were returning to the university from a year on placement in industry to complete the fourth and final year of their degree.

In the summer prior to the academic year, the School put out a call for projects for the Software Engineering students to known industry partners. 9 projects were proposed by the industrial partners, 8 of which were deemed suitable only as individual projects. Additionally, the Queen’s University Belfast Science Shop proposed 3 projects, all of which could be adapted to individual or team projects. A selection of other projects was provided by academic staff.

At the start of the module the students were provided with a selection of project titles and short abstracts from this diverse range of sources or contexts. The majority of these projects were specified as team or group projects. Additionally, the option for a student to propose their own projects was provided. They took the form of the contexts in Table I. Although flexibility and diversity were provided in the project formats, the students were encouraged to get into teams of four students and to select team-based projects. Students with specific or exceptional circumstances were provided with a smaller selection of individual projects.
TABLE I. PROJECT SELECTION OPTIONS WITH CONTEXT

<table>
<thead>
<tr>
<th>Team/Individual</th>
<th>Project Context</th>
<th>Number of Projects selected</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>Science Shop</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Team</td>
<td>Industry</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Team</td>
<td>Academic</td>
<td>15</td>
<td>49</td>
</tr>
<tr>
<td>Team</td>
<td>Self</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Individual</td>
<td>Science Shop</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Individual</td>
<td>Industry</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Individual</td>
<td>Academic</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Individual</td>
<td>Self</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Thirteen out of the total projects were indicated as suitable only for an individual. Students with a novel project of their own were invited to propose the project to the convenor who would review their proposal and if approved provide supervision of the project.

Students, either as a team, or as an individual, submitted their top three project choices along with reasons on why they had made those particular selections. The module coordinator allocated projects to the students with all teams successfully being awarded at least one of their top three choices. Table II outlines the final selection by the students.

As can be seen, 82% of the student cohort formed into groups and selected team projects. All of the individual projects provided were chosen.

The students then contacted their project sponsor or supervisor to kick-off the project and start the discovery phase. The project involved phases of discovery, requirements elicitation, design, development, testing, documentation and evaluation in the production of a software engineered solution to a problem. These phases were supported and mentored by the academic supervisor, project sponsor and/or module convenor. The module had three submission milestones: a project description and plan (first semester); progress review and demonstration of an early prototype (first semester); and finally, in the second semester, a dissertation, demonstration of the developed solution, codebase and individual development journal. For students working as individuals the scope was scaled back accordingly from that expected by a team submission. Throughout the whole project lifecycle the students were encouraged to use an agile approach.

TABLE II. PROJECT SELECTION OPTIONS WITH CONTEXT

The first two assessment points had taken place with formative feedback and marks returned to students. However, this early assessment contributed only 10% to the overall module mark and is focussed mainly on providing detailed formative feedback to guide the students with the later stages of their project and final submission components. Formative feedback was provided throughout both semesters during supervision or short stand-ups with the module convenor, supervisors and external project partners.

A. Data Collection

The relative merits and drawbacks of quantitative and qualitative strategies for research has been debated over many years, particularly within the field of social sciences. Quantitative data research involves the collection and analysis of data often involving gathering large data sets. Conversely, qualitative data research often involves the collection of data in a range of different forms but mainly non-numeric. While quantitative data will often gather data across a wide group or large cohort, qualitative data tends to focus more deeply on specific insightful cases. In this study a mixed method approach was used to collect both quantitative and qualitative data. A survey was prepared which was sent out to all the students in the module asking them to agree to participate in a short questionnaire which aimed to elicit feedback on the student experience across all the different project contexts. The questionnaire was anonymous.

The survey consisted of 9 questions (Table III) which focussed on exploring how the students perceived their learning experience during the project. The answers given were in the form of a 5-point Likert scale: Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree. We also collected the type of project that the participant was involved in at the outset of the questionnaire in order to categorise responses. The survey concluded with two open-ended questions (Table III).

Following the last question in the survey the students were invited to consent to take participate in a focus group to discuss their experience with the module. Consenting participants were directed separately to a form to provide contact details. Once the questionnaire was closed the students elected to join the focus group were invited to a guided discussion, unrecorded but with notes taken.

B. Data Analysis

From a total of 72 students invited to take part in the survey 10 students completed the survey resulting in a response rate of 14%. It should be noted that students had completed several module evaluation questionnaires prior to this study in addition to the annual NSS survey and may have been experiencing survey fatigue [16]. Throughout the course
of the year, students are asked to participate in up to 32 questionnaires to evaluate modules.

The response rate, while low, was not unusual for a module survey. Cronbach’s alpha measure of internal reliability was 0.89 which is considered “Good”. The quantitative data from the survey was analysed and visualised using the Likert Scale. Negative responses (“Strongly Disagree” and “Disagree”) were quantified negatively; Neutral was unsigned and “Agree” and “Strongly Agree” were regarded as positive values) the length of the horizontal bar indicates the % selection for that value. There were 7 students who indicated a willingness to take part in the focus group of which 6 participated. The qualitative data gathered from both the survey and the focus groups are also discussed in IV.

IV. RESULTS

A. Quantitative Data

In this section we visualise and analyse the results based on the context of the project context, namely: Industry, Science Shop, and Academic. We analyse the qualitative feedback gathered from both the open-ended questions in the survey and the focus group discussion to gather insights.

The questionnaire results were disaggregated between Individual versus Team project. There was only one respondent identifying their project as an individual project therefore, for the purposes of analysis, there was little insight to be gleaned from a comparative study for such a small sample. The individual student had selected an academic-proposed project and responded positively to most questions with the notable exception of “Neutral” to “developing skills in working with others”.

Across the cohort of team members the majority of the participants demonstrated a positive experience across all categories of project. In particular, the students rated the project as particularly effective in helping them to understand the users’ perspective and to develop team-working skills. They also cited a strong sense of ownership and buy-in with their project. When the data was disaggregated according to project source we see in Fig. 1 that the community-based projects (Science Shop) evoked a consistently positive response across the survey questions. Projects sourced from industry were mainly positive but there was a notable split in respondents’ sense of ownership and overall enjoyment of the project. For the projects proposed by academics there was an overall positive response towards a sense of ownership of their project and that the project helped with understanding the user’s perspective with the exception of one respondent who provided a largely negative response across most categories except for “ownership”. This would indicate that the student had a less than positive experience with their team, and this was further confirmed with provided qualitative feedback. Unsurprisingly, all the students in team projects noted that they gained skills working with others.

B. Qualitative Data

At the end of the survey two open-ended questions were posed (Table III). In the student responses there was particular emphasis on team-working and communication skills. Students also felt that they gained valuable experience in project management within the context of software engineering:

- “It’s good to work with sprint boards when working with a team and to meet every day so all team members are held accountable for their own work” (Student Team Academic Project);
- “Remember that you can’t always get all the requirements done so prioritise early on” (Student Team Academic Project);
- “I also learned to work as part of a small team in a cohesive unit to complete work and meet deadlines”. (Student from Team Science Shop project);
- “It allowed me to gain experience with working in a team in an uncertain time (remote learning and Covid)”. (Student from Team Science Shop project);
- “Skills such as, project management, independent researching and working in an agile environment”. (Team Industry Project).

Furthermore, respondents identified the benefits in working with an external partner:

- “Working with an external contact in the industry also provided my team with the experience of working alongside a client, whereby we had regular meetings and rapid feedback loops, to ensure that the project fits their requirements” (Student Team Industry Project).

The focus group consisted of students who had completed their projects as part of a team, so no further feedback was provided by students working on an individual project. During the discussion the students indicated that the greatest gains in the projects were in communication skills, with their teammates, supervisors, and acting customer. All the students in the focus group felt that the benefits of working in a team outweighed any challenges. The following benefits were noted:

- “...in industry they would be working in teams so these were important skills to acquire” (Student from Team Industry Project);
- “…the project could have bigger scope as there were more people working on it” (Student from Team Science Shop project);
• "...team members were able to share knowledge and bring their own area of expertise to the project" (Student from Team Industry project).

The focus group also identified that a significant challenge of the project was the requirements elicitation phase:
• "...the main challenge was finding out what the customer really wanted as they often didn't know. Requirements were not that clear. Ideas were not always feasible." (Student Team Science Shop project).

This last comment referred to a community-based project in which the technical knowledge of the sponsoring external partner was low. However, learning how to elicit requirements from a real-world customer was also indicated as one of the main benefits to a project with an external source.

V. DISCUSSION AND CONCLUSION

This paper reports the outcome of a study into students’ perception of different software engineering (SE) project contexts in a software engineering capstone project module. The student cohort in this module worked on projects for both semesters of their final academic year in a variety of contexts. A survey was used to capture the students’ perception of the effectiveness of the SE project in different contexts. Following the survey, students were invited to take part in a focus group to investigate further. Qualitative and quantitative data was captured and analysed for key patterns and insights.

The number of respondents was low which raises some concern around the validity of the results of the study. Furthermore, the students choosing to complete this voluntary study may have also introduced an element of self-selection bias. However internal reliability was measured as a high “good” response.

Our study indicated that, from the students’ perspectives, academic, industry or community-based had provided opportunities to develop skills in gathering requirements, understanding the user perspective and exploring new ideas.

Fig. 1. Contextual Response to Likert Scale Questions
On the whole, there was a strong positive response from the student respondents in the study in how the projects had helped to deliver opportunities to practice project management and team-working skills. When the data was disaggregated into project contexts the student respondents were most satisfied when taking part in a community-based or industry project. Projects proposed by academics received a largely positive response with one exception. The community-based projects scored particularly positively in terms of requirements gathering, understanding the user’s perspective and exploring new ideas. Students taking the industry project responded very positively to the opportunity to develop project management skills. Overall the students’ indicated a preference for a project proposed and supported in industry or a community-based project supported by QUB Science Shop.

We argue that students completing a project in industry or in a community-based setting provides the best opportunity to learn non-technical skills (project management, team-working skills) for a career in the Software Engineering industry. Specifically, the industry projects appeared to best develop project management skills. This may be because the students were reporting back to their industry project proposer who would be using SE project management approaches in their daily work. Project proposals sourced in the community or charitable sector are frequently accompanied by an unclear vision (more an aspiration to solve a problem) and rarely have any well-defined requirements. Projects of this type are seen as particularly challenging around the discovery and analysis phase, however students taking these projects felt that this created a very good opportunity to develop the skills around requirements elicitation.

One of the issues which influenced the validity of the results was the fact that a small number of the cohort taking this module were given the opportunity to complete an individual project, as these were offered only as an exception. All of the individual projects provided were selected which would indicate that there was a strong preference among eligible students for working on their own. However, the students choosing to join the focus group had all completed a team project and reported positively about their experience. Without exception, they strongly recommended team projects to help develop the skills needed to work in teams in industry.

From the discussions within the focus group and the results in the survey, students working on a community-based project expressed high levels of enjoyment in spite of any well-defined requirements and graduates’ readiness, “2011 IEEE Symposium on Computers & Informatics, 2011, pp. 542-547, doi: 10.1109/SCI.2011.5958974.


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