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Integrating Problem-Based Learning and Project Management: On-the-Job Innovation in Software Engineering Training

Ton Nu My Nhat[1*], Thai Ly Anh Khue[2], and Hoang Thi Thu Hien[3]
[1]Ho Chi Minh University of Food Industry, Vietnam
[2]FPT Software, Vietnam
[3]Quy Nhon University, Vietnam

ABSTRACT

Software engineering education, which is typically linked with pressing global practical issues and challenges, has witnessed increasing efforts to prepare the undergraduates and graduates with the right set of knowledge and skills relevant to the rapidly-changing industry. One of the attempts to align academic curricula with businesses' expectations has been the inclusion of some problem-based learning (PBL) units in various engineering degree programs, which has been advocated as effective in developing the learners' technical knowledge, hard and soft skills and attitudes. However, with the high demand for professionals skilled in many different computing-related areas, the gap between industry expectations and engineering education is still widely recognized. This paper presents an initiative to develop the new staff's professional performance in a globally-recognized software company in Vietnam. It concerns an on-the-job program which integrated PBL principles and real-world project management. The initiation involved 01 Senior Project Manager, 02 Associate Project Managers and 05 Senior Software Engineers as trainers and 23 novice employees as trainees. Targeted to serve GenZ software human resources, this training program was based on real business-requested projects which introduced top-hiring technologies, covering business-requested technical stacks and simulating teamwork-focus development process. The qualitative and quantitative data revealed positive effects regarding the goals targeted, namely retaining talent employees and supporting the new staff's development of professional skills. The program holds implications for increasing and diversifying the collaboration between universities and IT industry in tandem with the well-researched and long-established PBL modules in degree software engineering programs.

Keywords: problem-based learning (PBL), generation Z (GenZ), software engineering education, professional development

INTRODUCTION

The shortage of IT personnel all over the world has been around for more than half a decade and emerged as one of the most difficult problems for the IT market. In Vietnam, the disproportion between software engineers (SE)' qualifications and business requirements is predicted to create a very high demand-supply gap in software industry until the second half of this decade. Despite this unemployment rate, the Great Resignation recently led to a paradox where the turnover rate is also extremely high, with around 60% of engineers looking for a new job. Also, at present, engineers aged from 20 to 35 start dominating the IT market; an overwhelming majority belong to Generation Z, who have grown up alongside the omnipresent social media and entered the workplace during a global pandemic. They tend to fight back against traditional educational and working style.

This human resource issue has emerged as one of the most critical challenges faced by FPT Software in recent years, especially after the pandemic. FPT Software, a part of FPT Corporation, is a globally leading technology and IT services & solutions provider

* Corresponding Author (Email: nhattnm@hufi.edu.vn)

headquartered in Vietnam, with approximately 54,000 employees in 28 countries. FPT delivers multiple world-class services in Smart factories, Digital platforms, Digital Product Development, Cloud, RPA, AI, Enterprise Mobility, Application Services, Managed Services, Business Applications, and so on. It serves 1,000+ customers worldwide in the industries of Manufacturing & Automotive, Banking, Aerospace & Aviation, Finance & Insurance, Healthcare & Life Sciences, Logistics & Transportation, Retail, Utilities & Energy, and others.

This paper reports an initiative, namely Software Engineers Training & Upskill Program, or SETUP, to cope with this problem in a strategic unit of FPT Software. It was targeted to serve GenZ software human resources. The program integrated PBL principles and real-world project management. It involved 03 Project Managers and 05 Senior Software Engineers as trainers and 23 novice employees as trainees. Through this training program, the novice staff was immersed in real business-requested projects which introduced top-hiring technologies, covering business-requested technical stacks and simulating teamwork-focus development process.

LITERATURE REVIEW

In software engineering education, PBL approach is advocated as one of the means to link the theoretical concepts to their practical applications by providing students with insights into real SE projects (Delaney & Mitchell, 2002; Fioravanti et al., 2018) and has been proven to develop a wide variety of competencies in engineering graduates. PBL increases the course success rate and improves students' learning outcomes because it motivates students' engagement (Morais, 2021). The PBL principles also support development of hard and soft skills for professional performance (Fontão et al., 2019). Some of these are self-efficacy, improved conceptual understanding, synthesis of information, ability to work in a team and reasoning skills (Guedes et al., 2017; Gavin, 2011; Souza et al., 2019). Therefore, this innovative approach effectively prepares the students as competent human resource for the working environment upon their graduation. The industries can easily find the teams they want. It also enhances the prospective utilization of projects and institutions products (Faizi & Umar, 2021).

The previous PBL-based studies in SE mostly involve pre-internship students and are aimed to improve the learning effectiveness in higher education. Some studies report the incorporation of principles of PBL along with the traditional teaching method (Abad et al., 2019; Brodie et al., 2008; Delaney & Mitchell, 2002; Faizi & Umar, 2021; Pérez & Rubio, 2020); others are concerned with integrating real projects into the curricula (Garmendia et al., 2020; Heberle et al., 2018; Yap, 2018; Yu et al., 2020). Through this innovative pedagogical methodology, which usually requires cooperating in small teams, the students are trained with real-time problem-solving techniques and gradually gain deep understanding of SE concepts. Students are also guided to think and discuss problems designed by teachers from the perspective of enterprise applications.

Another approach to align theoretical foundations with market-oriented aspects is industry-academia collaboration (Faizi & Umar, 2021; Fioravanti et al., 2018; Fontão et al., 2019). This methodology extends the PBL concept with respect to competences through real-life projects. Formal classes become environments where students are immersed in practice, solving real complex problems from real clients of software factories. The problems must be related to the actual business of the cooperated enterprises. The students consider aspects such as dealing with managers and real stakeholders while receiving guidance from the lecturer, a company expert, and support from peers. The third line of research focuses on creating an assessment framework to support teams on real-world, ill-structured problems in order to guide students' behavior on the project. These attempts facilitate supervisors' work on monitoring

and supporting teams; they enable individual contributions in a team to be identified and rewarded (Pérez & Rubio, 2020; Tubino et al., 2020).

However, there are admitted shortcomings to the effectiveness of PBL pedagogies in engineering education. The major criticism against PBL in engineering education is that it is insufficient in developing all the required professional skills of an engineer (Mills & Treagust, 2003). Mills & Treagust (2003) posit that although students educated in a PBL environment might be more motivated and demonstrate better communication and teamwork skills, they may lack a deep understanding of engineering fundamentals. These researchers call for further empirical and action research.

METHODOLOGY

Research Setting

The program reported in this paper was implemented in a strategic unit of FPT Software - Global Automotive and Manufacturing, or GAM for short. GAM is professional in Digital Transformation with 150+ manufacturing clients across domains, especially integration, development and deployment of Robotic Process Automation (RPA), Manufacturing Execution System (MES), and Data Platform for factories. Digital Factory Services (*DFS*) is a business unit of GAM. DFS targets to provide end-to-end services, leveraging strong domain knowledge and technologies strength, as well as the excellent operations to accelerate and adapt customers' needs in their digital transformation programs.

In GAM.DFS, SETUP was aimed to train and retain young key personnel in the unit. This PBL program was GAM's main mission is to provide, improve and update services that help automotive manufacturers achieve innovation and deliver next-generation vehicles. We use accumulated knowledge on digital transformation and extensive know-how on the integration, development and deployment of advanced technologies. The program consists of stages designed based on PBL principles to assist the junior staff to level up their technical knowledge and develop soft skills for professional performance while being immersed in practicing with real-world projects to be completed in DFS which covered business-requested technical stacks.

Participants

The program involved 08 trainers and 53 trainees. The trainers were 03 Scrum Masters and 05 Seniors Engineers. The criteria for the Scrum Masters to have been invited were that they achieved the Professional Scrum Master I Certification recognized by Scrum.org. One Scrum Master was Project Manager who took the role of project lead and design advisor; two others were Associate Project Managers. The Senior Engineers developed and implemented the program. As regard the trainees, in 2021, a batch of more than 100 Junior Software Engineers joined GAM.DFS, 53 of whom were assigned to customer G (*pseudonym)*'s projects. SETUP trainees included 23 out of the 53 selected engineers. The criteria for the engineers to be participants in the three-month training program were that (1) they were college graduates from FPT University and (2) they had been equipped with basic knowledge of technical stacks defined in the program through an optional course termed Fresher Engineer Training Course in FPT curriculum for software engineering. The other 30 Junior Engineers were assigned to projects following the usual, traditional process when they were guided by other senior members.

The PBL program

Planning was crucial for the success of the whole program. The trainers discussed to maximize all the positive aspects by distributing trainees into groups of similar interests and

their own choice, and balancing workloads between groups and across stages. Conceptually, SETUP was primarily based on Kolmos et al. (2020)'s framework, PBL principles in general (Larmer & Mergendoller, 2010), and PBL programs for SE in particular (Ajraoui et al., 2019; Fioravanti et al., 2018; Fontão et al., 2019). The evaluation criteria were informed by Dos Santos (2016), Pérez & Rubio (2020) and Tubino et al. (2020). Specifically,

- Overall aim: To promote novice trainees' professional performance in order to cope with real demands of the global rapid development of software industry by engaging them in practical learning and experience of principles, methods and procedures for the development of defined projects, with the key factor being the business-request matching.
- Objectives: To develop technical knowledge, including technical stacks, soft skills, modern software development processes and cloud-based collaboration tools; to develop three sets of skills - critical thinking skills, interpersonal skills, media and literacy skills; and to enhance professional attitudes.
- Stages: four major stages - starting the project, developing the project, reporting the project, and assessing the project.
- Trainers' roles: Facilitating interaction between group members and across groups; promoting discussion among members about tasks in person and in online beyond the hours of the company; gradually transferring responsibility of management to trainees.
- Trainees' roles: Being involved in real-world meaningful and functional projects that initiated questioning, making decisions within a suggested framework, designing the process for reaching a solution, accessing and managing the information they gathered and drawing their own conclusions; regularly reflecting on what they were doing.
- Working modes: Small collaborative groups and individually.
- Training activities: The activities were aimed to encourage technical knowledge to be updated and applied effectively within professional roles and to enhance the trainees' externalization of their working knowledge, so that it can be shared and learnt from, to the benefit of both the individual and the team. The activities were designed in such a way that they could be transferable, with immediate application in practice (Holgaard et al., 2020).
- Assessment: There were regular and final evaluations of the abilities to plan, manage, and accomplish a final quality-driven product required by real clients, namely the 21st Century Skills - collaboration, communication, critical thinking, and the use of technology.

Before having the employees undertake the projects, the trainers undertook three phases as follows:

- *Phase 1 - Projects Selection*: The Senior Manager identified the future needs of specific technical stacks depending on business insights and bidding information. The Senior Engineers then created a pool of completed and on-going real-world products which have the use of those technologies. These products were filtered to eliminate the ones that matched the following conditions: being outdate or deprecated version of technology, lacking team collaboration, and involving complicated data structure and algorithm. The final set of projects was small and medium modules within selected customers' products.
- *Phase 2 - Security & Compliance Evaluation:* As all the projects either came from the previous or current customer G's products, the Senior Managers and Associate Managers had to review and cross check with business contracts to make sure selected modules did not consist of information, calculations or algorithm that violated the non-disclosure agreement. A part of this job could be automated using a legal tool developed in-house by FPT.
- *Phase 3 - Projects Modification*: After selection, the Associate Managers worked with Senior Engineers to remove redundant features across projects, and input additional

functions that required research on new technologies and intensive collaboration between participants. The Managers were also responsible for simulating the execution plan for each project to make sure a small team from 3 to 5 members could deliver within one month.

Data Collection and Analysis

The impact of the 3-month training program was measured via the differences in KPI between the two groups of trainees – those who participated in the program and those who did not. In GAM.DFS, FPT Software, staff evaluation was done on a monthly basis by all direct managers. The evaluation system focused on both product and process, specified in three areas, namely *workload*, *quality*, and *attitude*, with a 5-point scale, corresponding to participants' performance specifically in that month, with 1 being the lowest and 5 the highest. These criteria together formed a final K Personal Performance (KPerf or KPI), ranging between 0.5 and 1.5. The weight for Workload, Quality and Attitude are 40%, 40% and 20%, respectively. All evaluations were made and submitted every month on FPT's JIRA platform.

- *Workload*: level of participation in group performances, engagement with appropriate project stages, contribution to product achievement;
- *Quality* (of product): project deliverables and others - Reliability, Efficiency, Integrity, Usability, Maintainability, Flexibility; end-user's satisfaction.
- *Attitude*: level of engagement with stakeholders, accountability, attendance, and communication;

The term-end checkpoint interviews were aimed to get qualitative information, basically based on monthly evaluations with the senior engineers and direct managers of the trainees in order to gain more insights and reasons underlying the obtained data.

FINDINGS AND DISCUSSION

SETUP was an on-the-spot program which aligned PBL to real-world projects. It focused on project management and collaboration among trainees as the core competencies in engineering education (Kolmos et al., 2020). The selection of participants, program design and evaluation processes were proved to be effective. Generally, compared to the non-participants group, those who were selected and joined the PBL program performed a considerable higher quality and productivity of delivery. The Paired Samples Test of KPI of two groups (Table 1) revealed statistically significant difference (sig. 2-tailed = 0.000 < α = 0.05). The results indicate that there are significant differences between two groups on a variety of factors.

Positive Outcomes

Data obtained from the monthly evaluations indicate positive performance of participants in the program. Overall, being involved in the specified projects has proved to be beneficial to young engineers' (1) technical knowledge and (2) development of soft skills.

First of all, PBL approach brought the participants advantages towards highly-required technical knowledge informed by advanced technologies. The additional benefit lay with the quality of delivery. Trainee participants were equipped with experiences and best practices from programs of common bugs and risks while developing specific functions. This gave them a better testing mindset and vision so as to identify and fix bugs before committing their codes or creating pull requests.

Then, running the real projects was perceived to help trainees improve their soft skills, such as inter-personal, negotiation, organizational, team work, leadership, initiative, decision-making, and self-regulating skills as they were put to work together in groups and forced to solve problems together.

Table 1: Paired samples test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. D	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	*Upper*			
Pair	.19245	.19771	.04123	.10695	.27795	4.668	22	.000

Participants were highly involved in Scrum Events, following all intensive Scrum Activities of teamwork, led by certificated Scrum Master, leveraged cloud-based team boards, which helped them promote communication skill, online collaboration, problem-solving skill and critical-thinking skill. Self-regulating improvement was another point praised by direct managers as their projects were beneficial from participants' ability to research and solve complex problems by themselves instead of asking senior members for guidance. This was thanks to one of the key features focused on the program being the scaffolding of the complexity of the projects based on the trainees' level of maturity and interest; individual tasks were customized to suit novice trainees' levels.

Overall, the program contributed to solving about 60% resources shortage between Q2-2020 until Q4-2021. Meanwhile, the extension in 2022 helped reduce turnover rate from 20% to only 5% after 2 quarters.

Challenges and Lessons Learned

However, there were a couple of unforeseen difficulties during the various phases.

Most trainees found online collaboration the most challenging issue. As some engineers were hard to reach through online communication tools such as Workchat or Microsoft Teams. This totally matched trainers' perceptions as many engineers tended to set Do Not Disturb status during working hours in order to 100% focus on their tasks. Scrum Masters also found it difficult to coach trainees update their tasks' progress on online Team Board Before Daily Stand-up meetings. The second challenges brought to attention was tasks' estimation. While most trainees were optimistic about the difficulties they faced during Sprint Planning, Scrum Masters shared a different point of view. They indicated that tasks were usually overestimated and trainees were lack of technical researching effort before making the estimation. Since customers were very sensitive with project planning and estimation, Scrum Master suggested senior members take extra care on guiding trainees to do more detailed technical research before coming up with an estimation. Finally, senior engineers stated that the provided solutions were not optimized and those could cause technical debts in the future. Senior technical members all agreed that the program should help participants to identify which problem they needed to consult senior members' experience.

Qualitative data confirms the findings of the previous studies concerning the strong correlation between team discussions and working effectiveness (Fioravanti et al., 2018; Kaddour, 2020; Shuto et al., 2016; Shuto et al., 2016). Some sub-groups were particularly more active during regular meetings by raising questions and initiating alternative solutions to suit the immediate market realities and clients' evaluations and requirements instead of following the predefined plans based upon their analysis of factors influencing the project at a specific stage. This proved their development in self-awareness, project management and mentoring skills. The trainees reported extra-hours spent on improving software quality and adaptability. They manifested professional skills and ability to access, identify, manage, evaluate, and use effectively different types of media and information technologies. On the contrary, lack of communication among one group, and the corresponding ineffectiveness in task accomplishment was also noticed. This was due to the initial differences in the trainees' prior knowledge and maturity. This resulted in failure to manage their own assigned tasks on the part

of a few individuals. The trainers were then overloaded with individual assistance. However, this challenge was soon overcome when some active trainees took the lead and support their partners. We did not opt for relocating these to other tasks. We learned from experience that most new employees were not motivated to change groups due to the time required to adapt to a new task.

This study agrees with positive findings of the previous studies in terms of project-manager's involvement as a vital element (Fioravant et al., 2018; Mills & Treagust, 2003), positive effects of PBL-based program on learning skills and motivation (El Ajraoui et al., 2019; Garcia & Pacheco, 2014; Pérez & Rubio, 2020), problem solving skills and social skills (Abad et al., 2019; Kaddour, 2020; Shuto et al., 2016). The proximity of trainers to trainees was a positive point to be highlighted from our training program. During the first stage, the trainer was very instructive in terms of what the problem was and what workable solutions would be, so the trainees were not frustrated and got engaged. What makes this study stand out from the other studies is that it implemented a PBL program in the training of the new staff in a company instead of bringing the real-world characteristics to preservice classes. In this way, the trained staff developed the hard and soft skills for professional performance while benefited from the latest advanced technologies of a global company. They can become a trainer resource themselves, enabling peer-to-peer mentoring in the company over consecutive years.

CONCLUSION

Different from the previous PBL studies concerning SE which integrate or simulate real-life projects in the academic environment, this research was innovative in extending these attempts to solve the business-requested contracts in a globally leading technology and IT services & solutions provider in Vietnam. This study implemented additional training for the growth of the staff which integrated PBL core principles and real-project management to address the education-enterprise gap in Gen-Z young staff. The program was reported to have enhanced advanced technical knowledge, fostered innovative attitudes and cultivated soft skills amongst the young software engineers. PBL helped them efficiently adapt to business' modern requests and development processes. The PBL program was effective in improving their projects' productivity and quality during development phases. The study has also provided more insights into PBL when it comes to on-the-job programs. It should be taken into consideration that some unexpected disadvantages occurred, causing some concerns about future technical issues.

Globalization of software engineering has increasingly intensified the urgency to develop professional and innovative engineers for diverse workplaces. These results hold implications for the continued in-depth cooperation between university and business. In addition to the usual option of lecture and business expert collaboration in PBL courses as formal classes, the PBL programs such as SETUP can be implemented when students serve their internships in companies. The companies can then give great added value when the undergraduates have hands-on experiences practice with real tasks and projects and are supported active and reflective learning activities. The key dimensions observed in SETUP can constitute principles to design fieldwork programs to support the students when they start to orient themselves in the environment outside academia, hopefully even in multinational projects as it has been implemented in other fields (Smith & Trent, 2020) in the very near future.

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