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Pilot 2 report

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Pilot 2 report

1. Introduction

In this Pilot 2 report, we describe the evaluation of the curriculum of pilot 2. The aim of this evaluation is to investigate both teachers' and students' satisfaction with the teaching and learning process and perceived student outcomes in the curriculum of pilot 2. Background information (e.g. course settings) will also be explored to reach the research aim. Therefore, the evaluation data have been collected via individual interviews with both teachers and students from the projects of Smart Display, Smart Bin, and Smart Wheelchair and the courses of Machine Learning and Electronic Embedded System. In the following sections, the method, results, discussions and suggestions of the evaluation will be presented.

2. Method

The evaluation data for pilot 2 was collected by individual interviews with both teachers/coordinators and students. All interviewees agreed to participate in the interview either with a consent letter or email agreement. Table 1 shows the overall information of the data collection.

Table 1
Overall information about the data collection for pilot 2

Interviewee		Data collection method	
		Semi-structured interviews (40-50 minutes via Skype)	Written interviews (Via Qualtrics)
Smart Wheelchair	Coordinator	√	
	Teacher 1	√	
	Student 1	√	
	Student 2	√	
Machine Learning	Coordinator	√	
Smart Display	Teacher 1	√	
	Student 1		√
	Student 2		√
	Student 3		√
	Student 4		√
Smart Bin	Teacher 1	√	
Electronic Embedded System	Techer 1	√	
	Student 1	√	

Note: One researcher from LU conducted all interviews.

The interview was designed based on the seven fundamental elements of project-based learning curriculum in the study of Kolmos, de Graaff, and Du (2009). This was in line with the pilot 1 report (Guo, Saab, & Admiraal, 2019). Moreover, questions about teachers' and students' satisfaction with the curriculum were adopted: a) overall, what were you satisfied with this course, and why?; b) overall, what were you unsatisfied with this course and how to improve that? In short, the interviews focused on the following aspects of the courses/projects: 1) course settings; 2) course objectives; 3) final products; 4) teaching process (i.e. the role of teachers); 5) learning process (i.e. group work); 6) perceived learning outcomes; 7) difficulties during the teaching and learning; 8) satisfaction and dissatisfaction with the course.

Based on the content of the interviews, we have set up a matrix that involved all the information from the interview (e.g. Miles, Huberman, & Saldaña, 2014). Based on this matrix

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and the above-mentioned eight aspects, we summarized the similarities and differences in the main findings from the interviews. The main results are presented in the next section.

3 Results

3.1 Course settings

All courses were designed and implemented in a way of combining lectures/workshops and hands-on practices of prototyping. The lectures/workshops were adopted mainly to introduce theoretical knowledge and new assignments and discuss the assignments of previous weeks and answer students' questions. Hands-on practices were adopted to let the students implement the ideas of their prototyping. Students normally worked in groups of three to six people.

While teachers and researchers believe that educational technology is an important element of project-based learning (Krajcik & Shin, 2014), most teachings were done in a traditional way (e.g. Machine Learning). Smart Wheelchair and Smart Bin, for example, used a learning management system (Moodle and the system provided by the university). However, these systems were mainly used as a repository where teachers delivered course materials and distributed some information and students submitted their assignments. For the communication between teachers and students, in one course (i.e. Smart Wheelchair), Slack was used as a real-time communication medium to support teacher-student in-time interactions. In other courses, however, discussions between teachers and students were mainly achieved by face to face. Overall, educational technology was not integrated into teaching and learning.

3.2 Course objectives

The objectives of all courses/projects (see Table 2) can be categorized into cognitive objectives (e.g. knowledge) and behavioral objectives (e.g. skills). Regarding cognitive ones, students were expected to learn and understand the content knowledge of the course. Moreover, they were expected to understand how IoT products work and tell the differences between diverse technologies and explain the reason. In addition, they were expected to master the way of using prototyping tools and techniques. As for behavioral objectives, students were expected to develop in four aspects: 1) to acquire practical skills in developing products; 2) to be able to use and apply different methodologies (e.g. system modeling); 3) to learn how to work in teams and collaborate with peers. This included, for example, learning how to divide labors, how to work with unknown technologies, and how to solve problems together; 4) to learn how to work with clients, such as politely communicate with clients, understand the needs of clients, define the goals of clients, present the results to clients, and improve the products based on the feedback of clients and so on.

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Table 2
Main course objectives of each course/project

Courses/projects	Objectives
Smart Display	1. Learning to work in a software project and build software in a team with unknown technologies. 2. Working in a team and solving problems in teams. 3. Learning to work with clients.
Smart Bin	1. Leaning to use innovation methodologies and produce prototypes. 2. Learning to use prototyping tools and techniques.
Smart Wheelchair	1. Students acquire practical skills in prototyping and developing a connected product. 2. Learning the competence of working as a team when it comes to software development. 3. Students are able to explain course concepts. 4. Students are able to make a working prototype and explain it to others.
Machine Learning	1. An introduction to machine learning and modeling of smart systems. 2. The application of different methods of modeling intelligent systems and system modeling to the case studies.
Electronic Embedded System	1. Practicing the theory and proving that a similar structure would be feasible. 2. Teaching students the way to design a program electronic device. 3. Students are able to solve problems and challenges and decide which technology is better and also demonstrate why it is better than another.

3.3 Final products

Overall, the performance of the final products that students created was not as ideal as expected. This was confirmed by both teachers and students. The prototype created in Smart Display was assessed as not working well and "not even close in many ways", which was more like a semi-finished coding product. Two third of the smart bin developed was evaluated as not ideal. A student from Smart Wheelchair also admitted the prototype did not work well and should be improved in many ways.

The evaluation of the quality of final products was mainly through the assessment of students' reports and course essays via grading rubrics made by teachers. In Smart Bin, there was a group outperformed other groups because this group performed well in the aspect of comping up with many new perspectives and ideas. However, there was a problem with this evaluation method mentioned by a teacher from Machine Learning, namely the grading can be fuzzy because it was difficult to confirm from reports what knowledge and skills were applied by students to the products.

3.4 The role of teachers

Apart from taking a traditional role, such as introducing course objectives, giving lectures, and presenting assignments to students, teachers also had diverse roles during the teaching. These included five aspects:

1. Creating suitable course materials. For example, at the beginning of Machine Learning, the teacher discussed with clients about how the project would be going. In so doing, all the relevant content knowledge was designed and presented in an easy way that makes sense to the students.

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2. Finding students learning resources. For example, in Smart Bin teachers provided students with external resources like ready posters that students can use directly for their assignments.
3. Making up students' knowledge. For example, in Electronic Embedded System students joined in the course with different educational backgrounds. In order to help these students to compensate for the lack of their background knowledge, teachers provided them with relevant resources, such as online courses, books, and slides.
4. Inspiring students to reflect. For example, teachers from Smart Wheelchair encouraged students to propose their own ideas and discussed and extended these ideas in a more open direction. In so doing, students perceived not only the coding itself, but higher things, such as rationales and theories, related to it.
5. Providing help for students' collaboration. Students often get stuck when they collaborated with peers during hands-on activities. They needed teachers' suggestions and feedback to go forward. For example, during a hands-on programming activity in Electronic Embedded System, the teacher was available for explaining and repeating the code that students did not understand. Sometimes, however, teachers did not bother the practices. For example, the teacher from Smart Bin did not step into students' problems but observed how would students do and end up the conflicts by themselves.

3.5 Group work of students

Several procedures of learning were adopted by students, particularly during hands-on activities. Generally speaking, at the beginning of the project, students searched the internet for the materials needed and the things that they did not understand. Afterwards, they had brainstorm sessions to discuss what problems they wanted to solve and which technologies could be used. Before dividing the labor, students tried to understand different skills and competences of each group member. In so doing, each member could take responsibility for different parts, which could lead to a shared responsibility to the development of the project. Basically, plans were discussed and decisions were made together by all group members. Sometimes students also gave and received advice from other groups. As for the implementation of the project, there was a lot of trial and error. Students needed to do a lot of testing to find out whether their ideas and prototype could work out. Therefore, much improvement was done based on the data that students got from the testing.

3.6 Perceived learning outcomes

Students' perceived learning outcomes (see Table 3) were categorized as cognitive, behavioral, and affective outcomes (e.g. Guo, Saab, Post, & Admiraal, 2020; Post, Guo, Saab, & Admiraal, 2019). Regrading cognitive outcomes, students learned theoretical content knowledge by taking the lectures, reading books, and writing the final reports and essays. In so doing, students got the insights into the whole picture of IoT products and had a deeper understanding of what IoT is. For the students who major in design, the projects opened their horizons and allowed them to understand how to connect design to a digital project. As for behavioral outcomes, students gained some skills, including teamwork skills, problem-solving skills, and the skills of leadership. They also improved specific technical skills through hands-on practices, such as embedded programming, physical debuggers, and Python. For example, students from Smart Display noticed the difficulties with communicating between smaller groups and improved during the project. The student from Electronic Embedded System mentioned that he developed the right way of approaching problems. That is, however, not something that students can get from only one course or project. For the student who was better at coding than other group members, she learned how to help and manage other people while not hurting their feelings during the Smart Wheelchair project. In terms of affective outcomes, students from Smart Display and Electronic Embedded System felt they were more independent in solving problems

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and more interested in group work. However, some students from Smart Bin were not actively involved in group work.

Table 3
Main students' perceived learning outcomes of each course/project

Courses/projects	Perceived learning outcomes		
	Cognitive	Behavioral	Affective
Smart Display	• Content knowledge	• Skills of communicating with group members • Skills of using certain tools	• Being independent on problem solving as an individual
Smart Bin	• Content knowledge	• Skills of dealing with clients • Skills of presenting ideas	• Different levels of motivation for group work
Smart Wheelchair	• Content knowledge • The understating of how IoT system works. • Expanded horizons for designers	• Leadership skills • Skills of using certain tools	
Machine Learning	• Content knowledge • Personal insights into course concepts	• Skills of applying knowledge in a project	
Electronic Embedded System	• Content knowledge	• Skills of approaching to problems • Skills of working with different people	• Interests in collaborative learning

3.7 Difficulties of the courses

Several difficulties that teachers and students encountered during the teaching and learning are presented as follows:

1. Although there are innovative pedagogies that focus more on student-centered learning (e.g. flipped classroom), it is hard to adopt these methods as students need to learn fundamental content knowledge in detail.
2. As many of the projects are about new technology, the biggest difficulty for students was the lack of information. Although most of them searched the internet, they could not find a useful frame or references. Even when students found something that might help they could not understand because the knowledge was above their current level.
3. The background and the level of understanding of students are diverse. This makes it difficult for teachers to give guidance to the students who have knowledge gaps. It is also not easy for students to collaborate with team members with different knowledge.

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4. Some group members (e.g. Electronic Embedded System) did not care about the project and presented details of life out of class. Some students (e.g. Smart Display) were not willing to collaborate with others.

3.8 Course satisfaction

In general, students were satisfied that they learned and understood many things related to IoT in a short period. They were also satisfied that the courses were designed in a way that is different from many theoretical courses they had. Moreover, although courses were not easy to follow, it constantly kept students growing and pushing them toward the next step. Students were also satisfied with the teaching. Overall, teachers gave lectures, tutorials, and suggestions about students' plans and presentations in an interesting and clear way. More importantly, teachers often encouraged students to explore their own ideas. As for the feelings of group work, students enjoyed the collaboration with others. This is a good way of exchanging knowledge with others and you can improve faster.

4. Discussion and suggestions

The courses/projects implemented in pilot 2 were evaluated by research interviews that were designed based on the key elements of project-based learning (Kolmos et al., 2009). The results showed that students were generally satisfied with the course. The course settings and objectives were reasonable. Teachers fulfilled their roles and students actively engaged in group work. Three types of learning outcomes (i.e. cognitive, behavioral, and affective) were perceived by both students and teachers, in which, however, the performance of final products was not ideal as expected. Moreover, several challenges during the courses were reported by both students and teachers.

In order to improve future courses, several suggestions are presented:

1. The most important thing for future courses might be the choice of a suitable project for the background of both teachers and students.
2. Before the project starts, an introductory course with a couple of sessions should be provided.
3. More tutorials are needed, particularly the tutorials that focus on specific topics (e.g. programming). For the coding that students do not understand, it is better to provide them with individual worked examples as reference.
4. A clear weekly schedule of assignments that are not complex should be provided to students. By finishing these assignments students are able to make progress step by step.
5. To improve group work, a group leader should be designated to keep group members focused and motivated.

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Glossary for technical terms

IoT: The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines (see https://en.wikipedia.org/wiki/Internet_of_things)

Moodle: Moodle is a free and open-source learning management system (LMS) (see https://en.wikipedia.org/wiki/Moodle)

Slack: Slack is a proprietary business communication platform developed by American software company Slack Technologies (see https://en.wikipedia.org/wiki/Slack_(software))

Python: Python is an interpreted, high-level, general-purpose programming language (see https://en.wikipedia.org/wiki/Python_(programming_language))

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