Experience Using Systematic Mapping Studies to Foster Knowledge Discovery in Emerging Technology Fields

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Abstract: Emergent technology requires fast changes in educational content and more student engagement beyond the classroom. Therefore, this paper proposes a learning methodology to foster knowledge discovery in these fields using a research-based approach. In particular, we promote active learning with the use of Systematic Mapping Studies (SMS), which bring students closer to in-demand topics in emerging technologies. We test our methodology by using it in the project module of a cloud computing course. We also evaluate the methodology in terms of student outcomes, i.e., work products and their opinions. From the analysis of this evaluation, we describe advantages and possible lines of action for future improvements.

1 INTRODUCTION

Emerging technologies present a radical novelty, fast growth, and prominent impact (Rotolo et al., 2015). Their evolution is so fast that educational content often lags behind (van der Lubbe et al., 2023). In addition, such technologies often span multiple disciplines, e.g., fields like machine learning, which combines knowledge from computer science, mathematics, and domain-specific expertise. This knowledge diversity represents unique challenges for students trying to learn them (Woelmer et al., 2021). We could consider some personalizing teaching for the students. However, at scale, such teaching is particularly challenging (Siddiqui et al., 2022)

In information technology fields, for example, the industry also emphasizes that engineers should gain hands-on experience by actively learning the fundamentals of new technologies while solving real-world problems (Nakayama et al., 2012). This means that, as future practitioners, students have to learn how to base important software engineering decisions on the systematic and critical evaluation of the best available evidence (Jorgensen et al., 2005) by creating a closer link between research and practice (Dyba et al., 2005). Thus, there is a need for teaching and learning methodologies that engage students in understanding, synthesizing, and learning relevant knowledge from fast-evolving technology domains by themselves.

In this paper, we propose a research-based learning methodology, as they are widely regarded as a cornerstone of effective education (Elmgren and Henriksson, 2021), to foster knowledge discovery in emerging technologies. In particular, we promote active learning (Bonwell and Eison, 1991) with the use of Systematic Mapping Studies (SMS) (Petersen et al., 2008). SMS offers a structured approach to dive into academic literature and industry reports, helping students discover trends, gaps, and challenges within a study area, a skill applicable in both academia and industry (Kitchenham et al., 2010). Students are active in their learning process by critically organizing and assessing information. It also cultivates teamwork, as SMS projects require students to agree on various aspects. We apply our methodology to a cloud computing course, which, as reported in (Anglano et al., 2020), is a subject of growing relevance but difficult to teach due to the lack of open and collaborative educational materials. We also evaluated the methodology in terms of student outcomes, i.e., work products and their opinions, to search, as suggested by (Edström, 2008), for advantages and possible lines of action for future improvements.

The rest of the paper is organized as follows. Section 2 presents background. Section 3 presents our proposed methodology. Section 4 presents the results of the methodology application and evaluation. Section 5 presents a discussion of the findings. Finally, Section 6 presents conclusions and future work.

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2 BACKGROUND

This section introduces the essential background information used in the rest of the paper.

2.1 Active Learning

Active learning (Bonwell and Eison, 1991) is an approach that involves students in high-order thinking tasks, i.e., analysis, synthesis, and evaluation, facilitating their participation in the learning process. This approach focuses on developing students' skills rather than transmitting information by encouraging them to engage with the course material (Brame, 2016). It aims to promote deeper understanding, critical thinking, and retention of information by moving away from traditional lecture-based instruction and toward student-centered methods. As recalled in (Carr et al., 2015), active learning is associated with experiential learning (e.g., project work and role-playing), activities involving technology (e.g., simulators and games), interpersonal interaction between students (e.g., peer review, discussions) and student control, autonomy, and self-regulation. The use of active learning is reported to significantly improve exam performance in STEM education, i.e., an approach that combines science, technology, engineering, and math (Freeman et al., 2014).

2.2 Systematic Mapping Studies

A systematic mapping study (SMS) (Petersen et al., 2008) is a particular type of literature review that focuses on categorizing the results published in a research field. In particular, an SMS approach provides a well-defined and accepted process, which, once applied, provides a visual summary of the existing literature in a field. Such a summary permits the identification of research trends, gaps, and opportunities, making them valuable in educational contexts. According to (Kitchenham et al., 2010), mapping studies can teach students how to search the literature and organize the results of such search methodologically. It also provides students with transferable skills, i.e., qualities that can be used in different jobs and career paths. One of those skills is critical thinking, which is the ability to synthesize, analyze, and objectively evaluate information to produce an original insight or judgment. Students also consider that the results of an SMS are valuable means of initiating research activities (Kitchenham et al., 2010). In particular, students in the final stages of their education find the results of an SMS a helpful asset that permits them to find research ideas for their bachelor's or master's thesis.

2.3 Course DVA 500

DVA 500 - Industrial Systems in Cloud Computing[1] is a 7.5-credit course at Mälardalen University that introduces students to principles for cloud computing technologies applied to industrial challenges. This is a second-cycle course in the area of computer science, which does not require preliminary knowledge of cloud computing. One of the goals of the course is that students will be able to elicit, summarize, report, and present relevant information (relate to cloud computing). To fulfill this goal, an intended learning outcome (ILO) has been considered (see Table 1).

Table 1: Intended Learning Outcome (ILO).

The students will select topics within the cloud computing areas and analyze them using formal review method and present their analysis results.

2.4 Course Evaluation

Course evaluations are considered a tool for course analysis and course improvement (Edström, 2008). One of the elements to be evaluated is the student's views of the course, which shall be appropriately documented by using, e.g., personal opinion surveys (Handbook, nd). This kind of survey is a comprehensive research method for collecting information using a questionnaire completed by subjects (Kitchenham and Pfleeger, 2008). When creating a survey, the first step is to define the expected outcomes. Then, the survey should be designed in a specified way, e.g., cross-sectional (participants are asked for information at one fixed point in time). It is also essential to define options related to how the survey would be administered. Once designed, the survey instrument should be developed, evaluated, and applied to a sample population from which the obtained data is analyzed.

In creating surveys, Likert Scales (Bertram, 2006) are widely used. Likert Scales are psychometric response scales, e.g., a five-point scale ranging from "Strongly Disagree" to "Strongly Agree," used to ask respondents to indicate their level of agreement with a given statement. On a Likert scale, each specific question can have its response analyzed separately or summed with other related items to create a score for a group of statements. Individual responses are generally treated as ordinal data because although the response levels are relative, we cannot presume that participants perceive the difference between adjacent levels as equal.

[1] See http://bit.ly/3UO6vbB

3 METHODOLOGY

Technology's fast-paced nature demands that practitioners continuously learn new knowledge and adapt it to societal demands throughout their careers. Thus, they need to address their knowledge gap as soon as required by building a self-directed learning approach during their education. In particular, active learning approaches (see Section 2.1) engage students in their learning process through tasks that require them to analyze, synthesize, and apply knowledge. The SMS approach (see Section 2.2) can support active learning since it encourages students to actively understand a field's research landscape, develop critical thinking, and refine information synthesis skills. It also enhances learners' engagement with large volumes of evolving research. Figure 1 presents our proposed research-based learning methodology. As the figure depicts, there are two main processes in the methodology, i.e., the active learning process (at the top) and the supporting process (at the bottom). The latter process is expected to disappear (or the role of the teacher replace by peers) once the student becomes an independent researcher by learning the basis of the former.

3.1 Active Learning Process

The active learning process is designed for the student. In the first activity, the student **built foundational knowledge**, including a basic understanding of cloud computing and the SMS methodology. In the second activity, the students **select a topic based on group interest**. At this stage, group discussion fosters idea generation by bringing individuals with different perspectives, backgrounds, and expertise. In the third activity, the students **perform a preliminary study**, a small-scale study conducted to test and refine the research questions. In the fourth activity, the students **conduct and report the mapping study** by considering the previous activities and also the feedback from the teacher. This is the project's main activity and, therefore, the longest. Students are free to do it by themselves without supervision. However, they can ask for support from the teachers if needed. In the fifth activity, the students **prepare the opposition**. This activity is common in research environments and permits students to read and analyze the work of others. For this, the students receive the SMS report from another group, read it, and prepare questions to be asked during the presentation day. Finally, in the last activity, the students **present the findings and opposition**. For this activity, the students prepare a presentation in which they report the result of their work and defend it from the opposite group.

3.2 Supporting Process

This process, which is done by the teacher, starts with a task called **provide foundational knowledge**, where the teacher introduces the course concepts and the research methodology by selecting material and providing lectures. Then, the teacher **review the topic selected** by the students. The comments from this activity can help the students scope their SMS to the time given in the course. After that, the teacher **review the pilot study** focusing on comment to develop students' research skills, i.e., research question design and the selection process of the studies. Then, the teacher **review the SMS report**, where the transparent application of the methodology, the comprehensiveness of the data extraction and classification, and the interpretation and relevance of the findings are the main focus. The student can use the comments to improve the SMS report, which can be reiteratively sub-

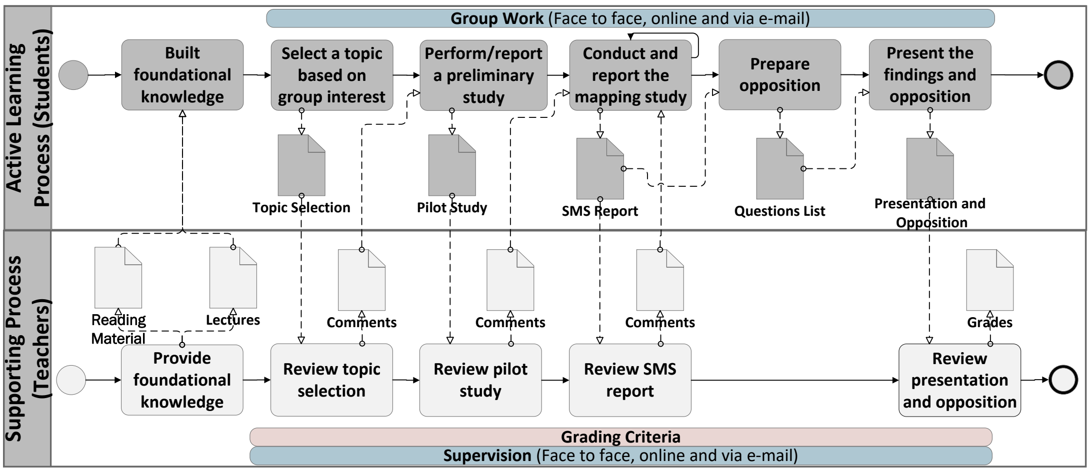

Figure 1: Learning Methodology to Foster Knowledge Discovery in Emerging Technology Fields.

mitted. Finally, the teacher **review the presentation and opposition** during the presentation day. While presentation skills are considered important, the crucial aspect reviewed is the involvement of the students in the project and their general learning experience.

3.3 Motivational Approach

Motivation in active learning refers to the internal and external factors that stimulate students to participate, engage, and take responsibility for their learning. It encompasses the desire to learn, the enthusiasm for participation in activities, and the commitment to the learning process. Motivation can be categorized as intrinsic and extrinsic. The former is the drive to engage in learning activities for their own sake (e.g., personal satisfaction). The latter is the drive to engage in learning due to external rewards (e.g., earning participation points). We promote internal motivation by giving students control over the decision of the topic to investigate and the partners to work with. Extrinsic motivation is also promoted by dividing the project into manageable deliverables that build upon each other and accumulate points. Students can always earn the total of points to form the final grade by doing and redoing project activities.

4 RESULTS

This section presents the results of the application of our research-based learning methodology.

4.1 Participants

We apply the methodology (see Section 3) to a course called Industrial Systems in Cloud Computing (see Section 2.3) to fulfill the ILO described in Table 1. The course started with 22 students, who formed groups freely, i.e., six groups with three members and two groups with two members. One 2-member group left the course after the second activity, and one person from the remaining 2-member group also left after the third activity. The remaining six groups finished the SMS and evaluate the methodology. The student working alone refuses to be part of another group and it is still pending for grading at the moment of writing this paper.

4.2 Project Material

Teachers introduce essential cloud computing concepts through traditional and guest lectures. One laboratory, where students practiced theoretical concepts, was also executed. The reading material was provided in the form of a book. Students also got in touch with the SMS process during one lecture and reading material. Evaluation criteria in the form of rubrics were also provided and socialized. Rubrics are structured frameworks used to evaluate work quality, especially in educational settings. Our rubrics were also created to provide students with guidelines, i.e., expected document parts, point-by-point (see, for example, Table 2). Strict deadlines were also communicated to the students so they could plan the work accordingly. Lectures, reading materials, evaluation criteria, and deadlines were available in the learning management system used in the course (i.e., Canvas).

Table 2: Evaluation Criteria for the Pilot Study.

Criteria	**Points**
The report is written according to the IEEE template.	1
The introduction for performing the SMS contains: 1. A short introduction of the topic selected, 2. The motivation and goal for performing the SMS in the selected topic.	1
The three research questions that address the main interests are presented. Consider: 1. The focus areas of the topic selected, 2. The types of research and contributions of the topics selected, 3. Publication sources of the selected primary studies.	3
The search string is well-defined. Well-defined means: 1. The terms used are related to a set of keywords that cover the intended research. 2. The terms in the search string shall be correctly associated with logical connectors.	1
There are inclusion and exclusion criteria. Also, there is a list of selected databases (min. 2)	1
The process of selection of the studies is presented. In this section, you should include: 1. The initial number of studies obtained after the database search. 2. The number of studies selected after doing the title screening. 3. The number of studies selected after doing the abstract screening. 4. A short text explaining whether the number of studies selected match the investigation intended.	3

4.3 Project Development

In this section, we report the project development in terms of the students deliverables.

4.3.1 Topic Selection

The students selected interesting topics based on an initial list of options provided by the teacher. As depicted in Figure 2, topics on the left side are related to properties of cloud computing, while topics on the right side focus on its relationship with other technologies. In general, the selected topics had a vast scope and the students motivations superfluous due to a lack of topic understanding. Some groups were very enthusiastic, demonstrating learning interest.

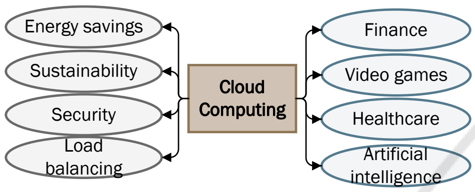

Figure 2: Selected Course Topics.

4.3.2 Pilot Study

Students refined the scope of the SMS based on the teacher's feedback. Then, they performed the pilot study based on the grading criteria presented in Table 2. Four groups received minor comments during this phase (including one group that asked questions via email), mostly related to grammar, spelling, punctuation, or word choice. One group has more important problems to solve besides grammatical ones, such as minor methodological errors, e.g., a bad definition of one of the research questions (out of three mandatory ones). The remaining two groups, including the one with two students, performed their study deficiently, presenting non-sense information that included grammatical, methodological, and template misalignments (even when an example of the report template was given). We could observe that members of these groups did not participate in the SMS lecture, which could be the reason for their poor performance.

4.3.3 SMS Report

Six groups worked on the SMS report. During this period, which lasted five weeks, only two groups asked for and received support from the teacher through face-to-face supervision. One of the groups asked questions via email on several occasions. The six groups submitted their work on time and received comments. The exact number of groups submitted their work again, with remarkable improvements.

4.3.4 Presentation and Opposition

Six groups presented their findings and opposed the assigned groups. The quality of the presentation varied from group to group. Many students were not used to presenting in public. However, the students took the opposition role very seriously, preparing relevant questions. In most of the cases, the students in charge of responding were also coherent with their work.

4.4 Students Evaluation

We evaluate the course by using a personal opinion survey with Likert scales (see Section 2.4). We also included one open question related to suggestions for improving the course. The survey, which was done at the end of the presentations day, had a average of 89% participation rate. We collected their opinions through a web-based application called Mentimeter[2]. Figures 3, 4 and 5 present a set of statements related to the project material, project development, and project goals, respectively, to which we ask students to rate them from strongly disagree to strongly agree. In general, the results show that students did not disagree with any of those statements. For example, Figure 3 presents statements referring to the project material, when the students provided their opinions between 3-neutral to 5-strongly agree, as presented below.

- The statement: "The content of the lecture was easy to understand" was evaluated in average 3,6.
- The statement: "The evaluation criteria for the project assignments were clear" was evaluated in average 3,6.
- The statement: "The recommended readings were helpful" was evaluated in average in average 4,1.

Similar behavior can be seen in the responses for the project development (see Figure 4). In particular:

- The statement: "The project instructions were clear" was evaluated in average 3,4.
- The statement: "The due dates for project assignments were clearly communicated", the average answer was 4,8.
- The statement: "Feedback was provided in a timely fashion", the average was 4,6.

Finally, in Figure 5, the statements refer to the project goal, which students provided opinions in similar rankings, as follows:

[2]https://www.mentimeter.com/auth/logout

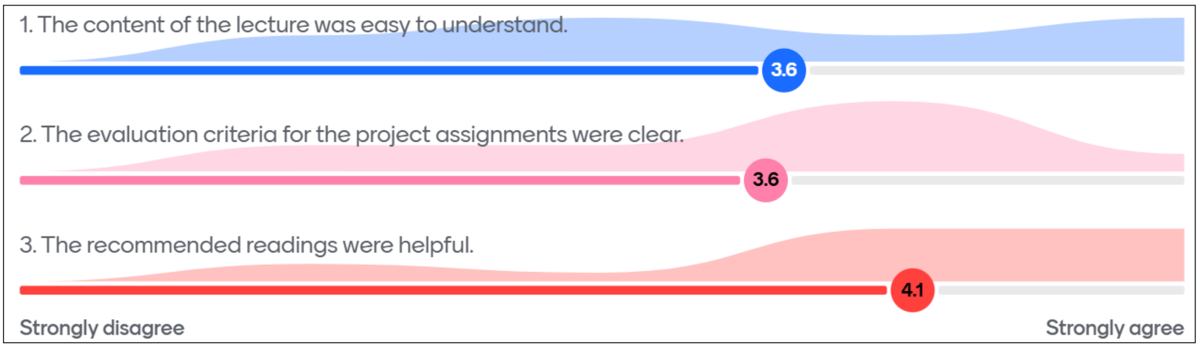

Figure 3: Evaluation of the Project Material.

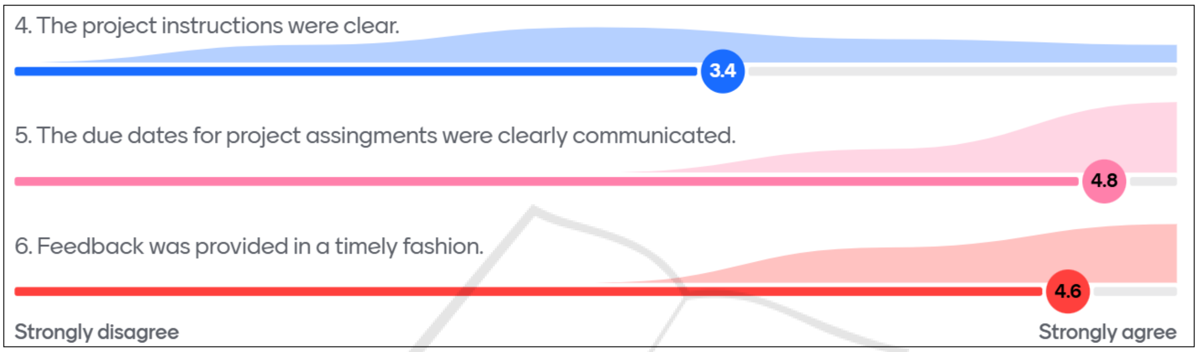

Figure 4: Evaluation of the Project Development.

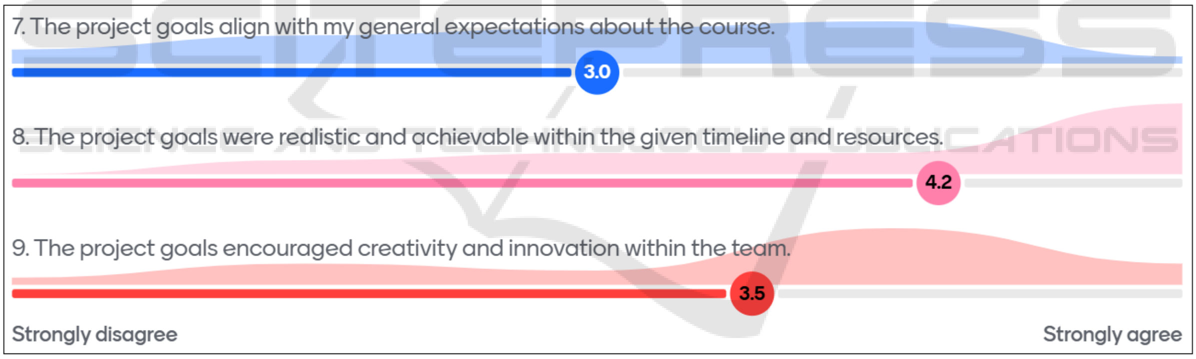

Figure 5: Evaluation of the Project Goal.

- The statement: “The project goals align with my general expectations about the course.” was evaluated in average 3,0.
- The statement: “The project goals were realistic and achievable within the given timeline and resources.”, the average answer was 4,2.
- The statement: “The project goals encouraged creativity and innovation within the team”, the average was 3,5.

Students provided 16 comments (see Figure 6) in response to an open question we proposed regarding project improvements. In general, the comments were positive with expression towards the teachers (e.g., they were great teachers) and towards the course (e.g., the course was helpful, useful, good, and beneficial). Some students were interested in more clear explanations about some SMS terminology such as contribution and research types, and the plots used to create the map. Other clarify the need for more material (beyond the SMS guidelines (Petersen et al., 2008)). Two students would like to have a more practical course in general and less theoretical. One talk about the template used as something limiting and one more about her/his difficulties in presentation.

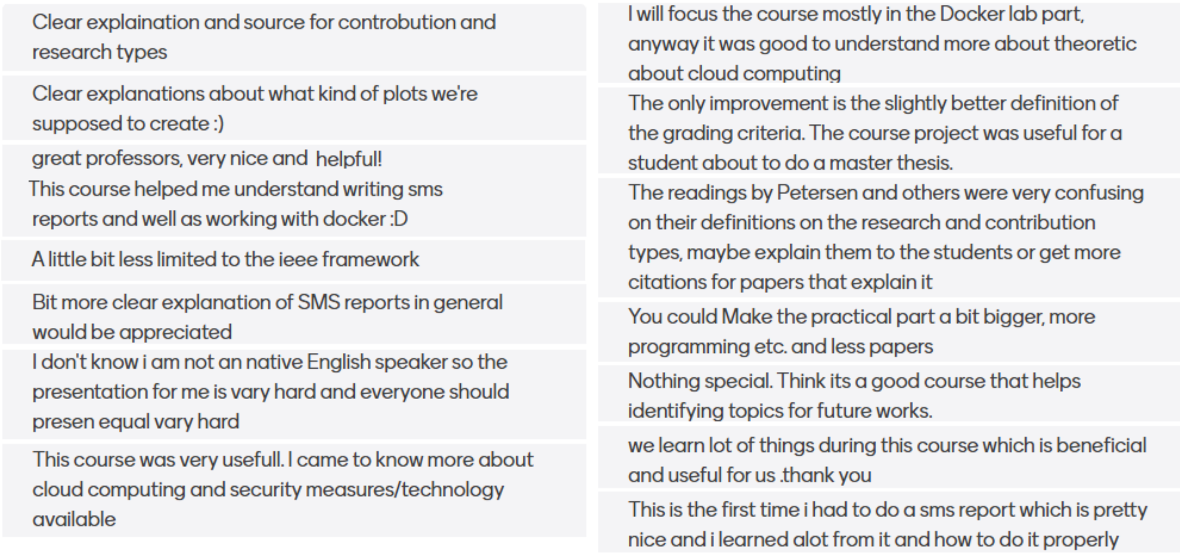

Figure 6: Suggestions for future project instances.

5 DISCUSSION

The SMS approach naturally complements active learning. First, it permits knowledge acquisition beyond the classroom (see the topics addressed in Figure 2). Second, it promotes analytical skills since SMS tasks require students to evaluate the quality and relevance of research papers. Third, it facilitates peer-to-peer learning as students work collaboratively. Finally, it promotes individual reflections as students need to be prepare for working with their peers. In the following subsections, we present insights gathered from the application of the methodology.

5.1 Students Participation

As presented in Section 4.1, 3 out of 22 students abandoned the project. We did not investigate the reasons for this situation. To be sure, we can try to contact students to understand the reasons for their decision (which could be merely personal). However, we may also need to provide a stronger initial motivation for the project to create a more robust link with the course syllabus to match the course expectations better. In addition, a project like the one considered in this methodology (i.e., the SMS) may also be seen by some students as overwhelming. Thus, it may also be necessary to help the students scope their project by providing them with literature in that respect. We could also provide examples of course project studies done in previous instances (we did not do this before since the previous reports were based on slightly different criteria). For example, we can provide students with two kinds of previous SMS projects, one with high quality and the other with deficient outcomes. In that way, students can easily understand what is expected from their reports and what can be avoided.

5.2 Material Suitability and Project Development

For some students, (see Figure 3), the provided material still lacks appropriateness, However, for the majority, the project development strategy was good (see Figure 4) We also consider that some actions can be done in such respect. First, we could include a written but brief text at the beginning of the project to guide students in the steps of the SMS process. The evaluation criteria shall be slightly revised to be less specific and open room for creativity. Finally, we could implement a flipped classroom strategy where students prepare the material in advance. Teachers, in turn, can address misconceptions in real-time and work closely with students who need additional help.

5.3 Project Goal and Deliverables

Students strongly agree with the timeline proposed for the project (see Figure 5). However, they were neutral regarding the statement “the project goals align with my general expectations about the course.” This may mean that some students expect different things from this kind of courses. For example, 2 comments (out of 14) in Figure 6) mention that students would like a more practical approach. However, the course syllabus is very clear in its focus, i.e., "the students will be trained to be able to apply critical thinking to elicit relevant information, summarize, report, and present information" (see Section 2.3). We may need to clarify this focus at the beginning of the course to mitigate some students' personal goal misalignments and negative feelings. However, generally speaking, it was a reasonable success rate for the course project since 6 groups out of eight (i.e., 75%) approved the project in due time. Moreover, students' comments were generally favorable regarding the project. In addition, we experienced only a few interactions for the deliverables, i.e., only two interactions were enough for the students to improve the SMS report.

6 CONCLUSIONS AND FUTURE WORK

This paper proposes a learning methodology to foster knowledge discovery in emergent fields using a research-based approach. In particular, we promote active learning with the use of Systematic Mapping Studies (SMS), which bring students closer to in-demand topics in emerging technologies. We applied our methodology to a cloud computing course and evaluated it in terms of students' work products and their opinions. From this evaluation, we identify strengths that make this methodology suitable, i.e., it permits knowledge acquisition not just by reading but by interacting with the research material and peers.

Possible lines of action for future improvements were also identified. In particular, there is a need for more activities that include work done by the students in the classroom. We could include at least one mandatory supervision where students need to consider a set of relevant questions to be asked to the teacher. Revision of current materials (specially the evaluations criteria and project guidelines) is also required. Finally, a more formal evaluation that comprises multiple course instances will also be applied.

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