Does Learning by Doing Have a Positive Impact on Teaching Model Checking?

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ABSTRACT

The theory of education *Learning by doing* exposed by Dewey theorized that learning should be relevant and practical, not just passive and theoretical.

The aim of this study is twofold: firstly to report on the effort related to the improvement of usability of a model checker tool by master students enrolled in the Software Engineering and Distributed Systems in Internet sections in our university, and secondly to investigate if the integration of research-based assignment into teaching and learning favorably influence learning.

The results of quantitative analysis (perceptions and opinions of the students collected through surveys and an independent t-test statistical test) acknowledge the effectiveness and efficiency of learning by doing approach in teaching model checking, both concepts and tool's usability.

The results of qualitative analysis (discussions, perceptions and opinions of both students and teacher) recognize the importance of learning by doing activities (poster creating and presenting, project-based assignment, research based assignment) in teaching/learning model checking.

CCS CONCEPTS

• **Social and professional topics** → **Computer science education**; **Student assessment**; • **Software and its engineering** → **Formal software verification**; *Software safety*; *Programming teams*; • **Applied computing** → *Interactive learning environments*; *Collaborative learning*.

KEYWORDS

Learning by doing, model checking, usability of tools, research-based learning, learning factors

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1 INTRODUCTION

The theory of education *learning by doing* exposed by Dewey [10] theorized that learning should be relevant and practical, not just passive and theoretical. Thus, the focus is on the student's powers and interests and not just absorbing information. Hence, the education should consider to present the information into new forms, images and symbols such that the student will be drawn and interested in participating in the learning activity, raising his/hers intellectual curiosity.

Prior studies [7], [13] in computing education have examined facet of *learning by doing* strategy. An active learning method for the teaching of physical sciences and mathematics to engineers is described in paper [7]. The study emphasizes the factors paramount in the success of this pedagogical innovation, presenting the similarities between their experience and other well-known methods such as problem-based learning, problem solving and, more generally, the concept of *learning by doing* coined by John Dewey [10] in his philosophy of education.

Cooperative learning [13] is one example of an instructional practice based on theory validated by research. The paper provides clear definitions of cooperative, competitive, and individualistic learning. Various research studies have validated and demonstrated that cooperative learning (compared with competitive and individualistic learning) increases students' efforts to achieve, encourages positive relationships with classmates and faculty, and improves psychological health and well being.

Opposite to previous studies [11], [16], [17],[15], our investigation employed *learning by doing* activities to both lectures and practical work (i.e. laboratories) regarding model checking's concepts and tools, adding research-based assignment element with the aim to increase and improve the degree of learning, both concepts tool-based usability.

The first objective of our study is to report on students and instructor experience regarding *learning by doing* method applied in model checking lecture and practical work. The investigation aims to uncovering the improvements of the used model checking tool regarding it's usability by the students.

A second aim of our investigation is to analyze the integration of research-based activities into teaching. Another aspect of our inquiry is concerned with identifying the constellation of factors of cognitive order that favorably influence learning, allowing to investigate how efficient learning is formed. the study examines to what extend research-based assignment contributes to efficient learning.

Various teaching activities (poster, project-based learning, conducting research, team work) were performed in lectures and practical work (laboratories) regarding model checking concepts and tools. At the end of the term, students completed a survey asking them to report on their perceptions of learning by doing activities.

The survey results reveal that all the students that participated in the poster-based lecture that are among the survey respondents (64 in total) thought that this teaching activity helped their learning (34 students with 17 *Agree* and 17 students with *Strong Agree*). Furthermore, the proposed structuring of the practical work activity (project-based and research-based) was considered as helpful by the survey respondents to better understand and learn the concepts and use the model checker tool, i.e. 89% stated (*Agree* or *Strong Agree*), whereas 9% were in disagreement with it, and only 1 respondent marked as *Not Applicable* (he/she may have not submitted the assignment).

The cognitive factors that favors effective learning revealed that *systematic learning throughout the semester* constitutes actional leverage in efficient learning by students respondents. Another result of the study concluded that learning is efficient in subjects that the students like (46%), and at the same time 32% of the students consider that their learning as being efficient in lectures where they enjoy the teacher's teaching style. This compels teachers to introspect and reflect on their own teaching style.

The instructor found that applying those activities in both lectures and seminars engaged students in participating in class activities, and that preparing for those activities was more labor intensive than the standard exposure teaching method. Thus, the proposed learning activities are new regarding ***the synergy of all of them (posters creation and presentations, project-based activities, research-based assignment)***. The *union of all activities* improves the usability of the model checker tool by the students, increasing the *engagement of students*, *participation in class* and *elevating their grades*.

The rest of the paper is organized as follows. Section 2 briefly discusses learning by doing methodology. The detailed description of how *learning by doing* was adopted in the course to both lecture and practical work level, and how we collect the student experience data are presented in Section 3. The results are presented in Section 4, emphasizing both students and teacher experience, and also exposing the factors of cognitive order that favorably influence learning. Section 5 considers various concerns about applying *learning by doing* in large classes and based on reflection, expresses some suggestion for future adoption of the method.

2 BACKGROUND

Facet of *learning by doing* strategy have been examined in prior studies [11], [16], [17],[15] in computing education. Gibbs's book [11] contains the reflective learning cycle and emphasizes practical teaching and learning methods for implementing learning by doing. The four stage model of *learning by doing* is the one of Kolb [16].

Several theorists have proposed cyclical models to explain how people learn from experience, but they all share the important features of Kolb's model which is itself derived from Lewin's plan [17] for the creation of scientific knowledge by conceptualizing phenomena through formal, explicit, testable theory. More information about three models of experiential learning process may be studied in Kolb's book [15] (Lewinian Model of Action Research and Laboratory Training, Dewey's model of learning, Piaget's Model of Learning and Cognitive Development).

Regarding teaching software model checking several studies exists [3], [21], [6] articulating the role of model checking [14] in software engineering and also presenting various approaches in teaching-learning, from puzzles [20] to robot systems [19].

Several others studies [23], [22], [8] exists examining the use of model checking relating to software architecture. Current approaches to model checking in software architecture are split in two categories: to apply existing formal methods to architectural design, and to develop notations and tools for describing and analyzing software architectures using Architectural Description Languages.

Our work seeks to replicate and expand on these findings regarding student and teacher experiences on *learning by doing* activities. We investigate this method when adopted throughout lecture and practical work for teaching model checking topic, providing examples for both poster-based lecture activity and project-based and research-based practical work. We evaluate student experiences in more depth, presenting both results of the questions related to lecture and practical work, and also identifying the cognitive factors that supports efficient learning.

3 METHODOLOGY

This section describes background information about the undertaken study, i.e. specifying the study context, how we adopt the learning by doing methodology, and the survey structure and questions.

Our goal is to establish what impact had the application of Learning by Doing on the teaching results.

Firstly, we emphasize the research questions.

Research question 1: Is Learning by Doing approach effective in teaching model checking?

Research question 2: Which are the factors of cognitive order that favorably influence learning?

We performed both a quantitative and qualitative analysis to answer the above questions, thus the obtained grades of the involved practical work and final exam in our study are used, and also the direct observations on the students's feedback and of the experienced professor.

3.1 Study Context for Teaching Model Checking

The data was collected in the "Software Engineering" master program (second year of study, after 3 years of an undergraduate degree) and "Distributed Systems in Internet" master program (first year of study, after 3 years of an undergraduate degree), i.e. "Computational models for embedded systems" course in which one of the topics involved model checking concepts and tools. Eight hours were dedicated to the "model checking" concepts: fours hours for the lectures and four hours for the practical (in class and take home) work.

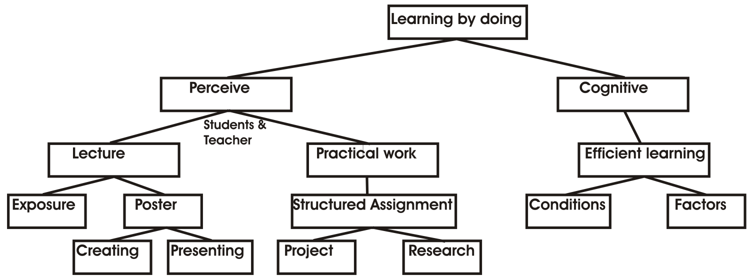

Figure 1: Learning By Doing Methodology.

The content of the lectures were based on the information from Katoen's book [4] and the practical work on the book of Ben-Ari [5]. The concepts in the lecture were: System verification, Model checking, Transition system, Linear-Time Properties, Linear-Time Logic, Computation Tree Logic. Also, in the lecture several exercises were conducted using the JSpin model checker, presenting first concepts as: Promela Model, Concurrency and Interleaving Semantics, Linear Temporal Logic, and Rendezvous channels (synchronous).

3.2 Adoption of *Learning by Doing* Methodology

The instructor incorporated *learning by doing* activities at the lecture level and at the practical work level. Figure 1 presents a schematic view of how we applied the *Learning by doing* method by using various activities as poster-based lecture, project-based assignment and research-based learning. We are interested in how the students and the teacher perceive application of this method at both lecture and practical work level, and discovering the conditions and cognitive factors that result in obtaining academic performance.

In what follows we will outline the activities for each level, displaying details. We argue that poster-based lecture and research-based assignment positively influence the learning of using the JSpin model checker tool.

3.2.1 Learning by Doing. Lecture Example. Adoption of *learning by doing* in lecture hours involved creating a poster with information regarding concepts related to model checking. We mention that this activity was conducted subsequently one week after a "classical" teaching lecture that used as didactic activity only *exposure* about model checking, thus the students were familiar with the subject when the poster-based learning was conducted. The poster-based *learning by doing activity* focused on remembering concepts regarding model checking presented in the previous lecture, and also concentrated on deep/profound learning. The students could use for creating the poster either notes from the previous lecture or various web-based resources (lectures from other universities, published papers in conferences or journals, etc).

The time provided for the students to create the poster was *30 minutes*. The topics concerned various aspects of Model checking, stated as follows: Model checking in Software Engineering, Model checking in Component Based Software Engineering, Model checking in Embedded Systems and Model checking in IoT.

The students in class formed teams (3 to 5 members) and each team received one of the proposed topics. After composing the Poster, each team presented the content in about 5 minutes.

The elements that the created poster should have contained are stated next: Definition/description of model checking, Characteristics (5 to 10 bullet points), Why is model checking interesting/important?, Tools, Example = simple + real world application, and Interesting fact(s).

3.2.2 Learning by Doing. Practical Work Example. The practical work that was related to the "Model checking" topic was structured in two different activities: project-based learning (i.e. source code implementation) (A) and research investigation (B). Thus, the assignment had two different perspectives (practical and theoretical) and involved different abilities to be used by the students:

- *Project (A)* - using a model checking approach to design, implement and verify properties of a provided (or created/composed by students) statement problem (Promela modeling and JSpin LTL properties).
- *Research (B)* - conducting a research investigation on a topic related to model checking and embedded systems.

The assignment was given in class (2 hours work) and could be finished home and brought next to the laboratory.

The provided topics for the research investigation were: Model checking used in Air traffic control systems, Model checking used in Electronic payment protocols, Model checking used in Software engineering, Model checking used in the nuclear engineering domain, Architecture evolution with model checking, System safety assessment and model checking, Model checking software architecture, Model checking embedded systems. The students may also have proposed a topic related to model checking.

The students formed teams (3 to 5 members) and each team implemented the proposed problem and conducted a research-based investigation.

3.3 Student Survey

An online survey entitled "Teaching model checking" was provided at the end of the semester. Table 1 provides several of the survey questions related to the model checking' s teaching methodology and perceptions of the students related to learning.

Three major aspects were pursued: *learning by doing* at lecture (questions regarding lecture, QL), *learning by doing* at practical work (questions regarding practical work, QP) and perceptions about how learning occurs (questions regarding occurrence of learning, QO).

Table 1: Student Survey Questions Description.

Identifier	Questions's Target Aspects
QL-exposure	Using Exposure as a didactic method.
QL-poster	Using "Poster" as a didactic method.
QL-creatingPoster	Creating the poster.
QL-presentingPoster	Presenting the poster.
QP-structuring	Structuring: Project and Research.
QP-implementation	Sufficient simple problem?
QP-implementation	Need new second complex problem ?
QP-research	Was better understood the concepts?
QP-research	Student-worksheet was helpful?
QO-conditions	Conditions for efficient learning.
QO-learning	Factors in learning more efficient.
QO-self	Self-appreciation

The questions for perceptions about how learning occur were inspired from Manea's approach [18] to efficient management of academic learning.

All questions used a 5-point Rating-scale: Strongly Disagree, Disagree, Agree, Strongly Agree, and Not Applicable (this last scale was used only to be able to eliminate the respondents that did not participate at the poster-based lecture.).

The number of students completing the survey was 64, only part of them participated to both exposure/poster lectures, but all of them participated in the practical work activity. Several information regarding characteristics of the respondents are provided in Table 2.

Table 2: Suvey respondents data information.

Information	Number
Number of respondents	64
Female	27
Male	37
Age [21 years old, 26 years old]	21 (5), 22 (18), 23 (29), 24 (7), 25 (3), 26 (2)

4 RESULTS AND DISCUSSIONS

The aim of our study is to receive the student's preferences regarding poster-based and research-based *learning by doing* approaches and the experience of the teacher. Cognitive factors that influence learning performance are also investigated. With these new obtained information as results of our investigations, we can next improve our teaching-learning strategy for the next classes. Next, the student and teacher experience and the cognitive factors that favorably influence learning are discussed.

4.1 Student and Teacher Experience

This section presents the student's preferences and teacher's experience in applying *learning by doing* method at both lecture level and practical work level.

4.1.1 *Student Experience.*

The current section presents the students' preferences and perceptions regarding *learning by doing* methods to both lecture and practical work.

Results for QL-based questions. First we specify the obtained results for the QL-based questions.

According to the survey results, applying *exposure* as a didactic method helped around 95.65% of the respondents (that were present at the lecture, i.e. 44 of 46 respondents) to better understand the concepts related to model checking.

The results of the questions related to the application of the "poster creating" with concepts related to model checking during the lecture hours may be found in Figure 2. From the set of students that answered to the questionnaire approximately 39.06% did not participated in the lecture but from the others that did participate, 87.17% answered positively (with *Agree* and *Strongly-agree*), i.e. using this method helped them to better understand the concepts related to model checking.

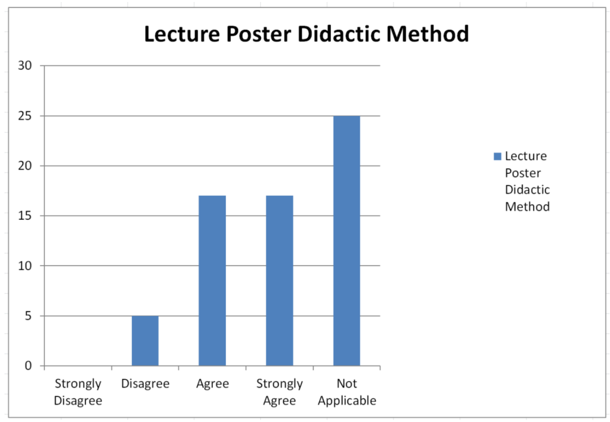

Figure 2: Results of the QL-poster question regarding using "Creating poster using Teams" as a didactic method.

We have also asked the students to be more precise about the poster-based learning by doing lecture, thus the two perspectives of the activity were investigated: *creating the poster* and *presenting the poster*. Both questions results provided that the respondents that were present at the poster-based *learning by doing* activity stated that both activities help them to better apprehend the concepts, 97.29% regarding *creating the poster*, and 82.05% regarding *presenting the poster*.

The aggregated analysis of QL-based questions is provided in Table 3.

Table 3: QL-based questions aggregated results.

QL-based questions	*Agree* and *Strongly agree*
QL-exposure	95.65% (44 of 46 participants)
QL-poster	87.17% (34 of 39 participants)
QL-creatingPoster	97.29% (36 of 37 participants)
QL-presentingPoster	82.05% (32 of 39 participants)

Results for QP-based questions. Next, we consider the results for the QP-based investigations. Applying *learning by doing* at the practical work alleged that we have structured the assignment in two different activities: project-based and research based learning. Thus, the questions investigated if the students were contented regarding this structuring, and each perspective was deeply investigated. Figure 3 shows that 90.47% of the respondents (that participated in the practical work activity) found this structuring to be favorable and supportive in understanding and learning the concepts and tools related to model checking.

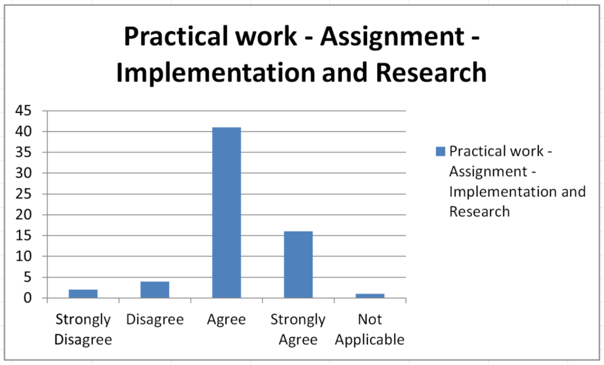

Figure 3: Results of the QP-structuring question regarding using two different activities in the practical work (implementation-based and research-based).

For the project-based learning, the students were asked to state if the provided problem was too simple or not, and if they felt the need to solve two problems (a simple one and a more complex one). The results stated that even if 91.66% of the respondents considered necessary the simple problem example to better understand the concepts and requirements of the assignment, the reaction of the students regarding a new more complex assignment was approximately equal: 48.38% requested a second complex assignment and 51.61% did not desired a second more complicated assignment.

For the research part, the students were asked if by *solving* the research, the concepts have become clearer or not, and if the provided student-worksheet (questions helping them to focus on various aspects of the investigated paper, [1]) helped them to focus on the key aspects of the investigated paper. See Figure 4 for details. The results showed that 88.33% found the research activity to be helpful and constructive in understanding the concepts of model checking, whereas 11.66% did not. Also, 87.93% of the respondents stated that the provided student-worksheet helped them in understanding the content and ideas of the paper.

The aggregated analysis of QP-based questions is provided in Table 4.

Concluding based on student's experience, they perceived the poster-based lecture, project-based assignment and research-based learning as helpful in understanding better the concepts of model checking. They all contributed to improvement of usability of the model checker tool by the students.

4.1.2 Teacher Experience. The teacher, who is the author of this work, found that the preparation for both lecture and practical work activities required a significant amount of effort and time.

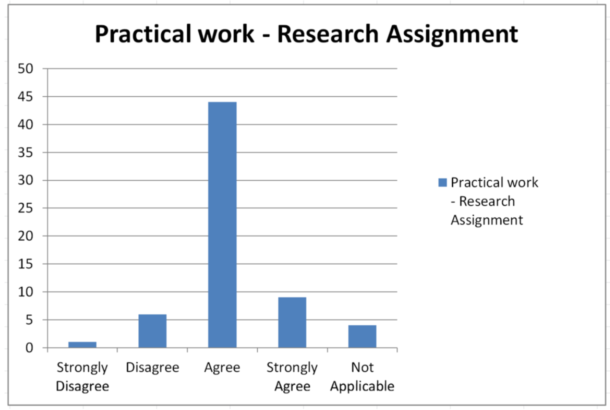

Figure 4: Results of the QP-research question regarding if this research activity was helpful in understanding better the model checking concepts.

No extra work was required for the exposure-based lecture because the slides were prepared from the last didactic year. For the poster-based *learning by doing* lecture a preparation was required: $A3$ paper size, colour pencils, establishing a priori the topics to be investigated in the creation of the posters, number of teams and number of members per team, time for creating the posters and time for presenting the posters. Even if the poster creation and presentation time slots were established before, some adjustments were required due to the number of actual presence of students in class.

A positive effect of poster-based *learning by doing* method was that the students become curious to know whether their classmates provided different information from their in the created poster. The students were also able to confirm their understanding by listening the other teams.

Another challenge refers to efficiently coordinating the poster-based lecture activity: explaining the aim and what to do to the students before starting the activity, difficult to manage the time of presentations due to delays of previous teams.

Using *learning by doing* activities at both lecture and practical work assignment created a more lively classroom atmosphere: first, the students weren't engaged in the poster-based activity but then they managed to communicate with each other and create and present the posters. As the course progressed through the semester, students seemed to be more comfortable with asking questions to the teacher and classmates during the activities and also outside the class.

Table 4: QP-based questions aggregated results.

QP-based questions	*Agree/Strongly agree*
QP-structuring	90.47% (57 of 63 p.)
QP-implementation-simple problem	91.93% (57 of 62 p.)
QP-implementation-complex problem	48.38% (30 of 62 p.)
QP-research-general	88.33% (53 of 60 p.)
QP-research-student-worksheet	87.93% (51 of 58 p.)

Regarding the practical work assignment more effort was needed referring to the research-based topic, to search and sort the topics related to model checking in various domains to be investigated by students. Another aspect that the teacher needed to considered was to reserve special time for research-based assessment: preparing some key questions for students regarding the content of the papers, feedback questions regarding the student's perception about this type of assignment for a practical work.

Concluding, the teacher observed a better usage of the model checker tool in the second laboratory, and the direct discussions with the students during assignment delivery revealed the fact that the students felt more confident and knowledgeable in using the model checker tool.

4.1.3 Validation: Learning by Doing versus Exposure Didactic Methods. We hypothesize that the grades obtained by the students with applied *learning by doing* didactic method (class of 2019) are different from the grades obtained by the students applied with *exposure* didactic method only (class of 2018). We mention that the structure of the exams for 2018 and 2019 classes was very similar both concerning the type of the questions (open questions, multiple choices, practical exercises) and the difficulty of them. Also, the same person graded the exam in both classes. The "Model checking" topic was incorporated in both classes as an exam subject and the final grade included the assessment of the laboratory work. The posters were considered as bonus points and added to the final grade.

An independent t-test [12] is used to compare two population means where you have two samples. The hypotheses may be stated as: H_0: $\mu_1 = \mu_2$, and $\mu_1 \neq \mu_2$.

The descriptive statistics information regarding the grades obtained in 2018 and those obtained in 2019 are provided in Table 5, mean and standard deviations are stated. The test was conducted on the entire set of students because all the students participated in solving the laboratories and the respondents are a subset of the students enrolled in the class.

Table 5: Descriptive statistics for the grades obtained in 2018 and 2019.

Number of students	*2018 exposure*	*2019 learning by doing*
#students with grades	79	79
#absent students	30	21
Mean	6.0886	7.1139
StdDev	1.49520	1.83266

We performed the independent t-test between the grades obtained in 2018 and the grades obtained in 2019 by the students. We use the same sample size, i.e. 79, an assumptions needed for the independent t-test (79 students in 2018 and 95 students in 2019). We randomly select 79 students out of the 95. The results obtained, i.e. p-value =0.000173 is < 0.05, thus we reject the null hypothesis.

Thus, there is *a significant difference between the two group of grades (obtained in 2018 where no learning by doing was applied (only exposure) and grades obtained in 2019 when leaning by doing was applied)*, the mean 7.1139 of the 2019 grades being higher than the mean 6.0886 of the 2018 grades, thus the 2019 group did significantly better at the course (as obtained grades).

The APA Publication Manual [2] states that it is "almost always necessary to include some index of effect size or strength of relationship in your results section". The general principle to be followed is to prepare and provide not only the information about statistical significance but also with enough information to assess the magnitude of the observed effect or relationship. Practical significance is generally assessed with some measure of effect size.

A common measure of effect size is d, known as Cohen's d effect sizes Cohen [9]. This can be used when comparing two means (in our case for the t-test), and is simply the difference in the two groups' means divided by the average of their standard deviations. Cohen suggested that d=0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size. This means that if two groups' means don't differ by 0.2 standard deviations or more, the difference is trivial, even if it is statistically significant.

We have computed the d value for 2018 and 2019 grades and the obtained value is: 0.613048, thus *a medium to large effect size*.

The quantitative and qualitative analysis provided above allow us to answer the first of the research questions.

Response for Research question 1: Learning by doing approach is effective in teaching Model checking. The results obtained by our analysis (quantitative = perceptions and opinions of the respondents and an independent t-test statistical test, and qualitative = perceptions and opinions of the respondents and teacher) acknowledge the effectiveness and efficiency of learning by doing approach that encompass poster-based lecture, project-based assignment and research-based learning).

4.2 Cognitive Factors that Favorably Influence Learning

In efficient learning certain conditions must be met. One of the questions of the survey covered this aspect.

Results for QO-based questions. As seen in Figure 5, 51.56% of the respondents are of the opinion that the basic condition for efficient learning is *systematic learning throughout the semester*. Thus, the role of the student in obtaining academic performance is perceived by the respondents as being important, by constantly participating and involving in learning activities. The second condition in the hierarchy of importance of efficient learning is *drawing schemes to facilitate better understanding of the subject*, this condition being selected by 21.87% of the respondents.

Effort invested in learning is considered by the respondents as being on the third place as an essential condition of learning, thus determination and personal motivation level may constitute an important factor in achieving academic performance.

Motivation for learning constitutes an inexhaustible resort regarding recording performances. Therefore, through the previous to the last question regarding QO-learning we wanted to find out the student's assessments regarding non-cognitive factors that influence efficient learning. Thus 46.87% from the respondents consider that efficient learning occurs in subjects they like, 32.81% of the respondents believe they are most effective in learning courses where they appreciate the teaching style of the teacher, and 20.31%

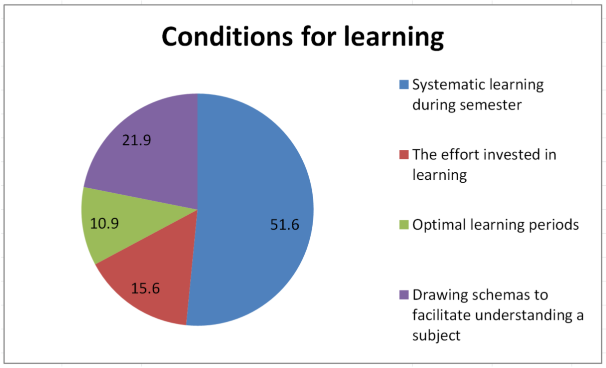

Figure 5: Results of the QO-conditions for leaning.

of the respondents said that their learning is efficient in courses that they consider to be fundamental in preparation for the desired profession.

Regarding QO-self, the self-appreciation question concluded in the following results: two of the students considered themselves to be very good, while the vast majority consider themselves *good students* (46.87%) and *average students* (48.43%), and only one of them considered to be *weak student*. We may state that those results indicate a high self-esteem of the entire respondents.

The aggregated analysis of QO-based questions is provided in Table 6, the first answer in the hierarchy being stated.

Table 6: QO-based questions aggregated results.

QO-based questions	First hierarchy answer
QO-conditions	*Systematic learning* (51.56%)
QO-learning	*Subjects they like* (46.87%)
QO-self	*Average students* (48.43%)

The quantitative and qualitative analysis provided above allow us to answer to the second research question.

Response for Research question 2: The factors of cognitive order that favorably influence learning are: the basic conditions for efficient learning is "systematic learning throughout the semester" and "drawing schemes to facilitate better understanding of the subject". The respondents consider that efficient learning occurs in "subjects they like" and they are most effective in learning courses where "they appreciate the teaching style of the teacher".

5 APPLYING LEARNING BY DOING TO TEACH MODEL CHECKING CONCEPTS AND TOOLS. DISCUSSIONS

In this section we discuss about applying *learning by doing* method (that used various activities as poster-based lecture, project-based assignment and research-based learning), and provide suggestions for those who may be interested in adopting it in their classes.

5.1 Concerns about Applying *Learning by Doing* in Large Classes

In previous section we found out that about 87.17% of the respondents (that participated in lecture) found poster-based *learning by doing* activity helpful and 90.47% from the respondents (that participated in practical work) found the structuring assignment in both implementation and research-based levels to be favorable in efficient learning. The teacher is concerned about the scalability of applying those methods to a larger class.

The number of students participating at the lectures allowed to split them in teams and make reasonable arrangements about number of teams and duration of the presentations for the posters. But for larger classes and full presence of students during lectures, the managing and coordinating such activities would be challenging. We intend to explore how to implement *learning by doing* method efficiently in a large scale classroom in future work.

5.2 Reflection and Suggestion for Future Adoption of *Learning by Doing* Method

We would like to provide some suggestions for those interested in adopting *Learning by doing* method in their classrooms based on reflection about our own experience.

- Adapt the number of teams in the poster-based *learning by doing* lecture based on the number of students present: less teams with more members. If the number of members is too high for them to organize, split the poster creation in more sub-activities.
- Use class-wide announcements to clarify any question address by only a team. This will minimize the chance that the same question will be asked by several teams.
- Prepare a set of questions for the practical work research-based *learning by doing* activity. The students should use those questions to guide when reading and reporting on the approach stated in the investigated research paper.
- Prepare a set of debrief questions such that the students will reflect on what they have done and how they have approached the problem solving.

6 CONCLUSION

The work describes the use of *learning by doing* activities in a "Software Engineering" and "Distributed systems in Internet" master sections to teach and learn model checking concepts and tools. The investigation reports on students and teacher perceptions of the activities, and also presents conditions and factors for efficient learning.

Students experience data was collected through students surveys and the results revealed that *learning by doing* based activities helped their learning, i.e. 87.17% answered positively (with *Agree* and *Strongly-agree*). The instructor found that applying those activities in both lectures and seminars engaged the students in participating in class activities and that preparing for those activities was more labor intensive than the standard *exposure* teaching method. Both students and teacher perceived the synergy of all activities as augmentation of knowledge relating to model checking, both concepts and the usability of model checker tool. Also, incorporating the research-based assignment contributed too.

The study revealed that the cognitive factors that favors effective learning were *systematic learning throughout the semester* (51.56%) and *subjects that students like* (46.87%). The percentage of students that considered that their learning as being efficient in lectures where they enjoy the teacher's teaching style was 32.81%.

Future adoption of Learning by doing method may use the suggestions provided by the instruction based on reflection about her own experience, i.e. adapting the number of teams in the poster-based lecture and preparing a set of questions for the research-based activity at the practical work, and last but not least to prepare a set of debrief questions to reflect on what the students have done and how they have approached the problem.

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