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A Case Study based exam at Computer Science at Lodz University of Technology

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Abstract. *This paper describes the process of introducing changes in diploma examination system in the Computer Science discipline at Lodz University of Technology, Poland. The main aim of this paper is to share the experience with other universities to speed up an introduction of modern examination techniques, to launch an open discussion and encourage business partners to support the examination system to improve the quality of education. It also includes a discussion on how to effectively check the students' qualifications.*
Keywords: *case study, final exam, diploma thesis, computer science*

1. Introduction

The tradition of the final exam during the first and the second degree studies is well established and has hardly changed for more than two decades. However, along with the development of teaching methods, this element of study must be also modified [1]. This paper describes the process of introducing changes in diploma examination system at Lodz University of Technology, Poland in the Computer Science discipline. There are two main aims of this paper. Firstly, we would like to share our experience with other universities to help them introduce changes quicker and in a more efficient way. Secondly, this paper intends to start an open discussion with a corporate partner and encourage experts to support universities, develop the examination system and to improve the quality of education.

This paper describes the examination process that was used in the previous years. It presents the university's preparations for the introduction of the new techniques and shows the results and opinions of students and examiners after the test examination. Afterwards it describes introduced changes and modifications, as well as opinions gathered after the actual final exam. The last chapter outlines the ideas that will be introduced in the coming years.

2. The examination process at Computer Science

The typical final semester of the first and second cycle studies, in addition to regular classes, consists of three key elements - the diploma seminar, thesis preparation and the final examination. The final grade also takes into account an average grade for the entire course of study. The individual grade weights have been constant for years at our university and amount to, respectively, 60% of the average grade for the course of studies, 20% for the presentation and review of the thesis and 20% for the final exam. The presented ratio shows that the final exam is not a key player in the final grade. Particular examination stages are described below in the following subsections.

2.1. The seminar

The seminar is held weekly with each student presenting their progress to the entire seminar group. The presentation usually lasts from 15 to 25 minutes, so there are up to 3 or 4 students per seminar. This means that students typically present their progress only 2 to 3 times. If they make a presentation at the beginning of the semester, the first demonstration usually covers only assumptions without an in-depth analysis. Each time a discussion is encouraged to support students in their research and to enrich the thesis. There is no shortage of open-ended questions from both colleagues and professors. In many cases promoters and experts are invited to the interview. Pandemic and remote seminars attract more interest from field experts as they can easily join an interesting discussion. At our university we closely cooperate with the Central Poland ICT Cluster - that is, a set of companies interested in employing our best students.

2.2. The thesis preparation

The second and most demanding element of the examination process in terms of the workload is the diploma thesis itself. Usually, students have 4-6 months to implement it, though some work on it for a longer period of time. Some students start their research work during the 2nd or the 3rd year of the first-cycle studies or the first year of the second cycle studies. Students may select the topic of the thesis in two ways - either by choosing it from the list offered by the supervisors of the theses, or by suggesting their own topic and finding a supervisor. Personally, I prefer the mixed variant in which I define the framework of the technological stack or the general purpose of the work and then, together with the student, I define the subject of the work. As a promoter of over 200 engineering and master's theses, I believe that this solution best meets the needs of our students. I try to associate the final project with the interests of the graduates so that the adventure with the

implementation of their largest project so far is attractive for them. An initial topic is reported to the Field of Study Council which can reject, modify, or accept it. Then, I define the goal and the schedule of work with each student. I also define which tools we will use - e.g. the GIT repository and the Kanban board and the communication channel, e.g. Trello, JIRA or Teams.

During the project implementation, numerous meetings are held during which progress and possible problems are discussed. At this time presentations for the seminar are also being prepared.

After the practical work related to the implementation and testing of a given IT solution is completed, students start preparing the written part. I always suggest making an extended abstract including the names of individual chapters, their scope and an estimate of their length. The preparation of an extensive "table of contents" of the future diploma thesis allows students to write it in 2-3 weeks. It is possible as previous analyses have already been formulated and at this stage it is only necessary to describe the results.

2.3. The final exam

The third element of the examination process is the final examination itself. Traditionally, it consists of project presentations and discussions that usually last up to 15-20 minutes. The presentation includes a video or a demonstration of a completed project. The student can complete the presentation during a thesis questioning session. Then, the second part of the exam begins in which 3 members of the faculty ask one question each. The promoter's question usually focuses on the methodology used in the project. The second question asked by the reviewer is more general and concerns the specialization that the student has completed. Finally, the last question concerns the entire course of study and is asked by the chairman of the commission.

In general, the first two questions are not problematic for most students. It may be different when it comes to the third general question. In addition, the questions relate rather to the level of knowledge, though there are also analytical questions. The answer to the question is given orally, and the student has time to prepare, though it usually does not exceed 2-5 minutes. The answer is assessed on an ongoing basis by the members of the committee. The asked questions do not refer to student's creativity or do not check the qualification on the higher level of the Bloom's taxonomy pyramid.

Moreover, some committees, e.g. at the Faculty of Chemistry at the Lodz University of Technology, have a closed list of questions that the candidate chooses at random during the exam. Other committees, e.g. at the FTIMS Faculty, developed a range of topics for individual specialtie. Such a list is publicly available and

well-known to students. Ultimately, students benefit from informal sources and the exchange of questions.

Nevertheless, the examination process is transparent, accepted by students and faculty members and has not been changed for many years. However, the key element of the exam was missing.

3. The main reason for the changes

The continuous development of technology and the focus of studies on practical skills meant that the final exam ceased to fulfil its role [2] [3]. The division of computer science into many specialties means that the questions are either very detailed, and the answer to them requires the use of a computer, or very general and not entirely related to the work itself. More importantly, questions do not verify students' analytical abilities but focus solely on their basic knowledge. Using Bloom's taxonomy (Figure 1 [1]), it is easy to notice that the solution used so far did not allow verifying the highest levels of the pyramid. Especially levels such as Creation and Evaluation, or even Application remained outside the examination circle.

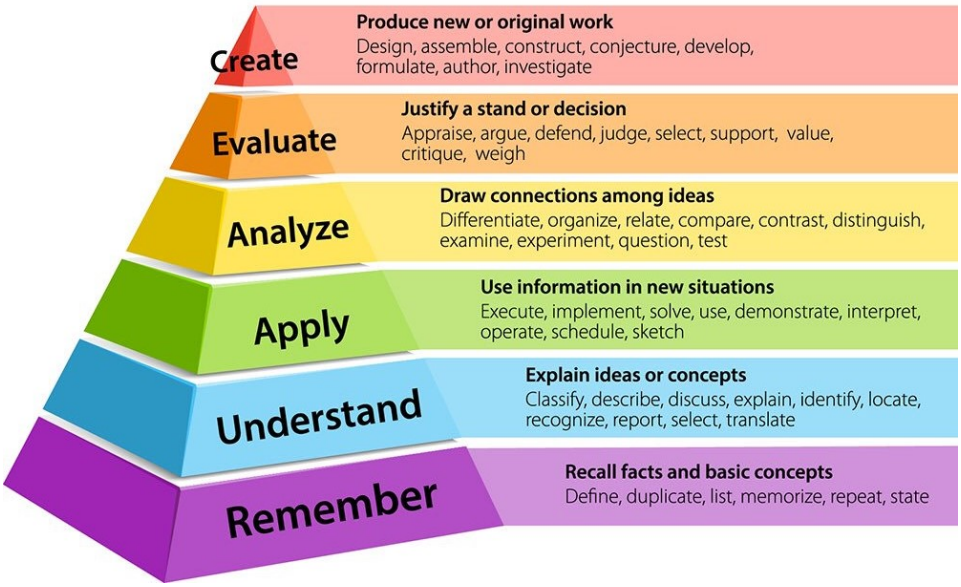

Figure 1. Bloom's Taxonomy Pyramid

[1]Thanks to https://montague.step.hollins.edu/planning/

The university authorities, listening to the opinions of experts from enterprises and academics, decided that it was necessary to modify the examination process. The process of change started in 2019. It was proposed to separate the presentation and defence of the thesis from the final exam. A new form was introduced, called the Competence Examination. The method of conducting the Competency Examination was left to the discretion of an individual Field of Study Councils. However, the TUL's Centre of Education prepared a guidebook and a set of trainings for examiners. The introduction of the exam was preceded by a thorough analysis of educational models.

3.1. Different models

At the beginning of the preparations, we examined various learning taxonomies to adapt the final exam to modern needs and adjust the shape of the exam to achieve the best effectiveness. Beside the Bloom's taxonomy we took into consideration the following taxonomies:

- the Heick Learning Taxonomy [4],
- the Marzano & Kendall Taxonomy [5], [6],
- the Taxonomy of Significant Learning (Fink's taxonomy) [7],
- Danielson's Depth of Knowledge Framework[8],
- the SOLO Taxonomy [9],
- UbD's Six Facets of Understanding [10], [11].

The learning theory is well developed as shown by various publications [1], [12]. However, the problem of competency assessment is more complex [13], [14]. We know from the experience of academic teachers that there are many IT projects. However, we have found that many students find it difficult to apply their knowledge and combine different threads and technologies. We have also discovered that many students have difficulty breaking down complex topics into smaller problems. Earlier changes to the computer science program have been implemented since 2017 and have allowed introducing case studies, PBL and reverse education in college. Ultimately, in the case of IT, a case study was proposed as a method of conducting the competence examination. This form seemed to be the best possible solution because students often solve problems and tasks embedded in real problems during their studies. Moreover, employees of the faculty participated in numerous trainings, both in the field of project teaching and case studies. Ultimately, each final project is a separate Project or Problem Based Learning implementation. Finally, as a university, we introduced Design Thinking into the curriculum a few years ago.

4. The preparation phase

It has been initially established that the introduction of the new examination procedure will start at the second degree of studies in the 2020/2021 semester. At the same time, in order to better prepare students for the changes, a preliminary Competence Examination was introduced. This approach made it possible to check the procedure itself, the difficulty of the described case, potential questions and the response time. The author of the chapter was commissioned to prepare the first case study in the field of computer science. The main constraints for an exam were the following:

- the exam should not last more than 2-3h,
- the same case will be given to all students,
- the exam will consist of two parts - preparation and an oral exam,
- students will not be allowed to use the Internet,
- students will not be allowed to use any external materials,

The most complex problem concerned defining the questions. According to Bloom's taxonomy authors should focus on higher levels like Evaluation, Analysis, Application and Comprehension. Based on TeachThought Learning taxonomy (see Figure2) we should focus on Interdependencies, Abstraction and Whole parts of the circle diagram. It is worth noticing that the three others like Self, Function and Parts are verified during study courses.

Using the Marzano and Kendal taxonomy (see Figure 3) authors should focus on Knowledge Utilization with minor impact of Analysis, especially the Generalization and Matching. But authors should also take into consideration preparing an interesting case study connected to students' lives.

Finally, taking into account Danielson's Depth Of Knowledge Framework we would like check the 'Extended thinking' level of students competences (see Figure 4). The main aim of study is to prepare students to design and create new solutions and algorithms, apply different concepts and technologies and analyse and critique current solutions. They should be able also to prove their ideas and argue with experts using facts.

The second problem faced by authors was the range of thematic areas of individual specialties. It is worth noting that at that time three different optional blocks of courses were conducted - Application environments for the Java platform, Distributed systems and mobile platforms, and Intelligent database systems. During further investigation, it has been decided that the first case will be common to all specialties but due to the variety of elective blocks, separate questions will

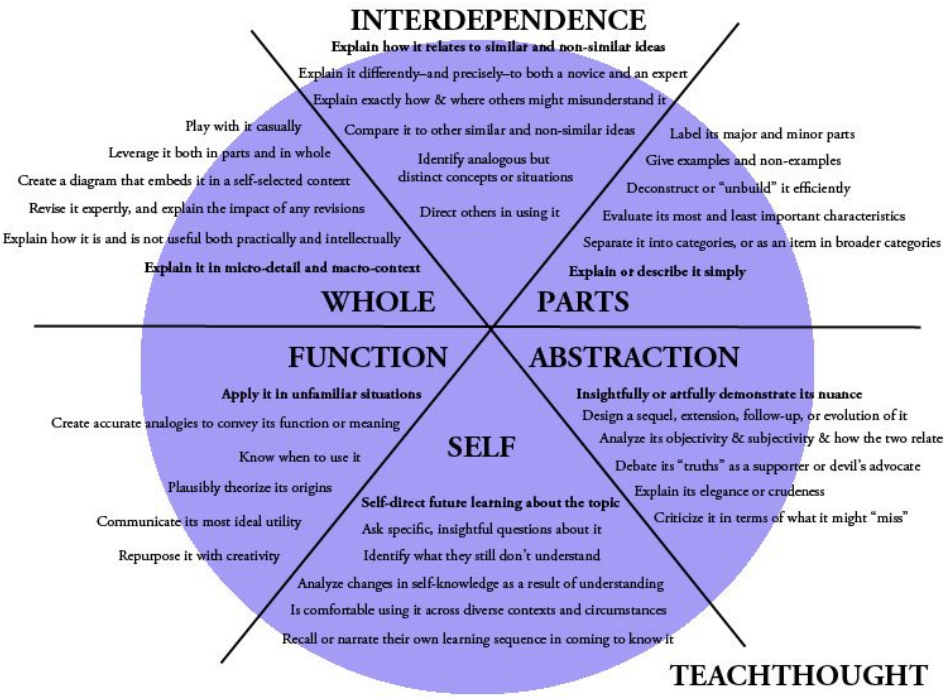

Figure 2. TeachThought Learning taxonomy [15]

be prepared for each of them. The third substantial problem was preparing a case description that would be comprehensive enough to make it possible to answer the questions based on the experience and skills of students without the use of external materials or the Internet.

Initially, it was planned to acquire and reuse ready-made case studies. Unfortunately, most cases concern solutions outside the IT area, focusing mainly on economic or legal problems. We also asked the members of the Central Poland ICT Cluster for help, but at this stage they were not interested in close cooperation in this area. Problems that are solved during recruitment usually focus on a given technology, not on the general issue. Another reason probably concerns the lack of protection of the intellectual property related to the software, which results in a reluctance to publicize the architecture and details of solutions used by companies.

In the absence of ready-made solutions that would meet the stated requirements, it was decided to develop our own case study. After analyzing the problems, I have developed a case study based on the popular Spotify service which shares music. While the solution itself is a commercial product, many of its components

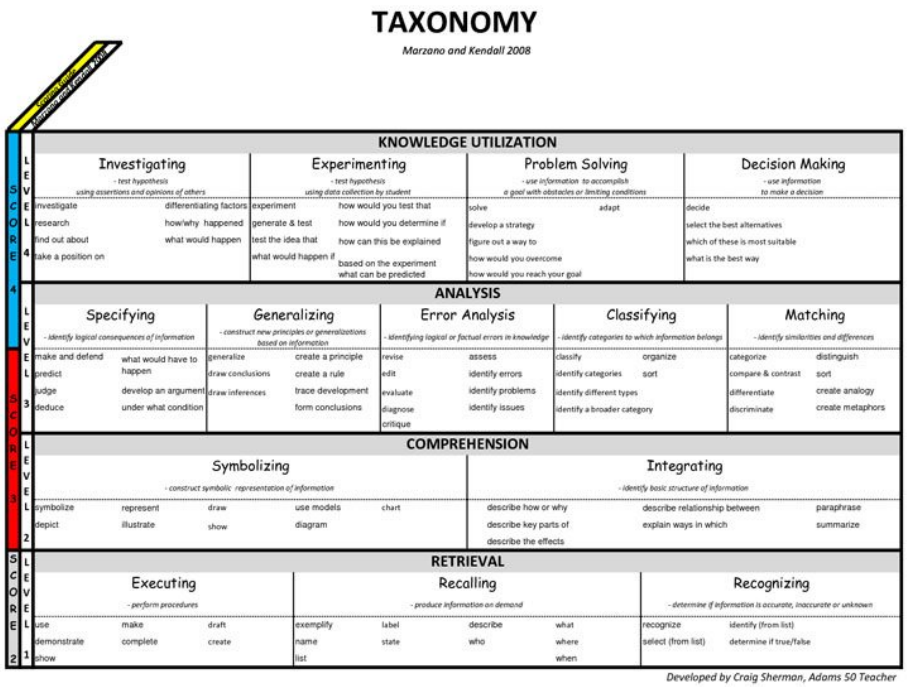

Figure 3. Marzano and Kendal taxonomy [15]

are described in an open source domain. Moreover, the subject matter is interesting and familiar to students who like to use similar solutions. The development of the case study related to searching for a compromise between the detailed expert knowledge and a rough description of the service. The service itself contains many different modules and, therefore, it looked great for our first case study.

The experts from particular specialities were invited to cooperate in order to better match the case description to the problems posed. As a result of the discussion, it was decided that the description would contain about 6 pages, focusing on the technologies used in Spotify service. To simplify the exam, the questions were divided into 4 sections:

- knowledge, where we check the student's ability to extract and integrate information,
- application, where we check the student's ability to redefine the problem,
- analytical, where we check the student's ability to analyse and justify the solutions ,

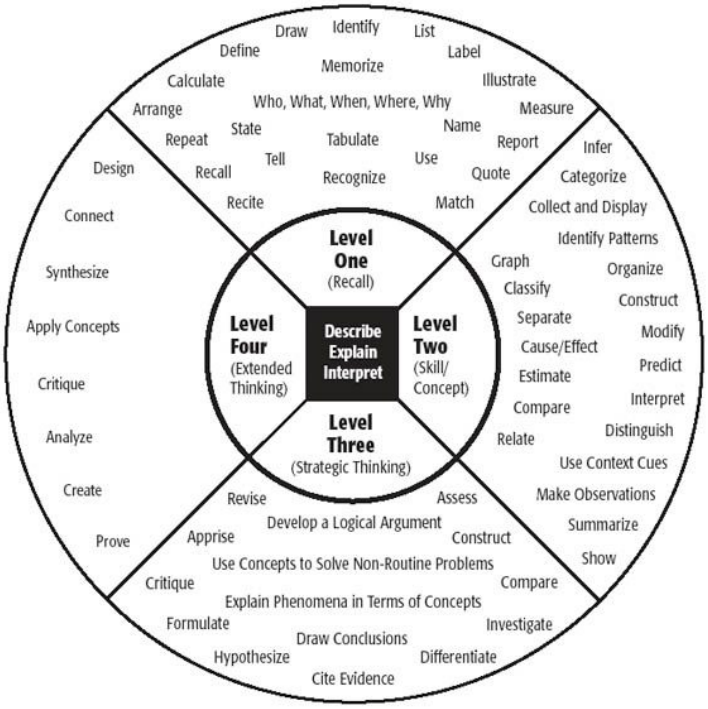

Figure 4. Danielson's Depth Of Knowledge Framework [15]

- evaluation, where we check the student's ability to evaluate and design concepts.

Initially, we decided to prepare 3 questions for each level. One minor modification to the initial constrains has been made. Due to the Covid 19 pandemic, the first exam was conducted remotely, so we decided that students will be allowed to use the Internet.

The whole procedure was designed from scratch thanks to the support of the University Training Center and faculty staff involved in the educational organization. As a result, the exam forms, the matrix of educational effects and the educational note were prepared.

The sample of the educational effects matrix is presented in Figure 5. In total, 36 questions were developed – 12 for each specialty, which were related to the joint case study. Sample questions for each elective specialization are provided in Table 1.

The case study preparation took approximately 60 hours in total. The additional 10 hours for each committee member should be summed up to develop and discuss the final version of the questions.

Question number	Specialization	Question Level	Question itself
1	JavaEE/DB	General	Present the advantages and disadvantages of the Client-Server architecture and P2P architecture on the example of Spotify.
2	Distributed systems	General	What technologies made it possible to quickly scale the Spotify application, justify your answer
3	JavaEE	Application	What Spotify uses Natural Language Processing Technology for. Give another examples of NLP usage.
4	Distributed systems	Application	What is the role of the Kafka system in the Spotify platform? Do you see a technological alternative to the efficient functioning of the streaming platform?
5	DB	Application	Classify the data that can be processed by the Hadoop platform
6	JavaEE	Analysis	How are relational databases different from NoSQL solutions? How do both types of solutions approach the issue of consistency and accessibility? Why is relational databases not being used in the Spotify app?
7	DB	Analysis	Suggest a backup strategy for relational and non-relational databases?
8	Distributed systems	Analysis	Is a decentralized communication model really the optimal solution for Spotify, justify your answer?
9	DB	Evaluation	What is the purpose of data mining and analysis in relational and non-relational systems, based on the example of Spotify? Present the stages of creating analytical models.
10	Distributed systems	Evaluation	What tools in a distributed infrastructure would you use to diagnose and discover the causes of most of the failures described in this chapter? Justify your choice
11	JavaEE	Evaluation	What is stateless login with the use of tokens. What are the alternatives to the login mechanism?

Table 1. Sample questions for different levels of difficulty and various specialization

The case study preparation took approximately 60 hours in total. The additional 10 hours for each committee member should be summed up to develop and discuss the final version of the questions.

5. Testing the Exam

The first exam was conducted in December 2020. Students were given access to a case report on the university's WIKAMP e-learning platform. The exam was conducted simultaneously for all students of a given specialization. It was specified that students should not communicate with each other, but it was not possible to verify compliance with this rule.

Students had 2 hours to familiarize themselves with the case and answer the questions. After that, the students were randomly questioned and their answers were sent online to all test participants. At the same time, other students were asked to complete a given reply or ask additional questions, if necessary.

After completing the exam and discussing the answers, students were asked to complete an evaluation questionnaire to assess the difficulty and understand the new form of the exam. Additionally, there was a discussion with each examiner to verify his experience and introduce necessary changes. The results are presented in the next chapter.

5.1. Final adaptation before the first deployment

After the end of the test case-based exam, a survey was conducted among students. Unfortunately, only 14 of over 30 students answered the questions. The general perception of the new form of examination was positive. The average value assessing the curiosity of the presented case was 3.6 / 5. Students indicated that they spent an average of around 22 minutes reading the case report. The survey also shows that all questions were clear and understandable. The biggest surprise, however, was that the answers to low-level questions were more difficult than the answers to higher-level questions, including evaluation or analytical ones. The students also noted that they were more confident about the correctness of the answers to the low-level questions. This proves that the degree of difficulty of the questions increased in line with the expectations of those preparing for the exam. The influence of access to Internet resources was also examined. Only 21% of students indicated that they found a solution to the question, though as many as 79% declared that they used the Internet during the exam.

There were also negative signals from students. They mainly concerned lack of information about the Spotify case that was used. During the exam, they tried to obtain additional information about the service, which resulted in wasting valuable time. However, a few people mentioned that the description should be longer in

order to better answer the asked questions. It was also problematic that part of the description was not directly related to the questions. The main reason for this was that questions from different specialties referred to different parts of the case report.

One case for all specialties was a bad idea because it was difficult to find a description appropriate for different areas. Additionally, a general description means that it is not deep enough. If it were more specific, it would increase the number of pages to be read. On the other hand, keeping the page limit means that the questions are not related to the case description, and the meaning of the description itself remains in doubt. Ultimately, a lengthy description and detailed questions, even within a given discipline, may result in the fact that a given technology will not be within the scope of each student's interest. As a result, the answer will not be complete, and it will not prove his or her competencies. The solution to this might be to consider the possibility of using electronic sources during the exam. An open question could eliminate the possibility of contacting with third parties during the exam.

The final decision made by the committee came down to producing different case reports and questions sets for each specialty. Unfortunately, this decision had its consequences. It exerted a profound impact on the workload, which is described in the next chapter.

6. First official Case Study Exam

The first official case study based exam was done in January and February 2021. There were 42 students to be examined in total. Table 2 presents the distribution of the number of students, the number of examinations and the number of examination boards.

The faculty members prepared 9 different case studies, three for each specialty. The number 3 came from the requirement set out in the study regulations that each student can take the exam 3 times. We had also prepared 9 different sets of questions. We decided to keep the four questions levels according to the previous analysis. However, we decided to reduce the number of questions for each case to 8, but still the total number of questions reached 72. We decided that at the level of evaluation question students would be able to select one of the two topics. Moreover, we made a decision that the exam would be conducted in-situ at the university. The source of case descriptions was scientific and research projects were carried out by the faculty staff. All case reports were reviewed and approved after the required corrections were made by the Field of Study Council. The Council made a decision that both questions sets and cases studies themselves would not be disclosed. The reason for the decision was the possibility to reuse them.

Name of specialization	Number of students	Number of exams	Examination boards number
	Exams in January and February 2021		
Inteligent database systems	15	2	1
Distributed systems and mobile platforms	9	1	1
JAVA EE	18	2	2
	Exams in June 2021		
JAVA EE	7	1	1
Artificial Intelligence and Machine Learning	7	1	1

Table 2. Number of students for each specialization

On the day of the exam, in order to prevent contact between students, it was decided to admit students every 15 minutes. They collected examination cards and started working independently. Using the Internet was not allowed. After 2 hours, the students took the exam, where they answered the previously asked questions within 15 minutes. One of the committee members took note of the written replies and asked additional questions in case of any doubts about the answer. The scheme of examination is shown in Figure 6.

The very organization of the examination process was quite a logistical challenge, as, at the same time, students from different specialties were working on their answers. It was reflected in a survey conducted after the exam in which students indicated noise and confusion as, among others, two elements worth improving in the future.

However, the oral exam was an effective form of verifying the competencies of students, especially in the areas of analysis and evaluation of solutions. It is worth pointing out, however, that both students and examiners indicated that 15 minutes for an interview was insufficient. Both groups applied for an increase in time in subsequent editions. Unfortunately, an increase in time would cause numerous logistical complications. In the presented solution, 9 students could take the exam based on the same case report without exchanging information with one another. Introducing a longer period of time would allow at least the first and the last students to meet and exchange ideas or questions.

7. Second evaluation of Case Study Exam

The second official case study exam took place in June 2021. To maintain similar standards for the same year of study, the same principles were applied. The case study descriptions were reused after minor modifications. However, new sets of questions were developed for each of them. Once again, the students had to answer 7 questions, remembering that the most difficult of the top level of Bloom's

taxonomy was the selection. In addition to previously prepared cases, one extra specialization was added - Artificial Intelligence and Machine Learning.

The total number of students who attended the exam in June was quite low and equaled 14 in total.

8. Conclusions and possible further modifications to be implemented

By analyzing the mock exam and the two versions of the exams based on the case study, several conclusions presented below can be drawn.

8.1. Thesis re-usage

Due to the large amount of work involved in the preparation of case reports, it is worth considering the use of diploma theses from previous years. I suggest introducing an extended summary of the work, in which, apart from the assumptions, the technological stack and the main assumptions of the work would be described. Each student could prepare a 4-6 page study, which would be used in the future. On the one hand, such a description would be a good practice for writing scientific articles and, on the other hand, the best papers could be selected as cases for subsequent examination years. The most dubious and unsuccessful work could be also considered. Then, possible potential solutions arising during the exam could be taken as a future topic. Thus, the percentage of assignments that are a continuation of previously started research would be increased. It could lead to the development of the scientific effectiveness of individual departments and institutes.

It is also worth pointing out that composing questions for work is easier than preparing a case report. The use of extended summaries after minor editorial corrections would facilitate the introduction of the competency examination at the first-cycle studies, where the number of students approaches 100.

8.2. Thesis as a case study

Another way to implement the case-based method is to use the seminar and the student's own work as the exam topic. We can redefine the process of thesis evaluation and select the reviewer at the beginning of the engineering or master thesis preparation. Then, both the reviewer and the dissertation promoter could attend the student's presentation. This would allow them to ask detailed questions about the work in progress and to evaluate the progress itself. In such a case, I suggest that you also admit other students who would be graded not only for their answers but also for the quality of the questions they ask and the suggestions and solutions they provide. The approach in which their thesis would be defended is currently

used in the third cycle of studies. However, it is not familiar to first and second degree students who do not participate in the defence of doctoral dissertations.

8.3. External sources of cases

Finally, the most promising approach is to attract companies and prepare case studies based on actual problems that have been solved in recent years or are in the public domain. In the first case, students could analyze the usage of alternative technologies or improve projects' results based on modern solutions. The results of the exam could then be shared with companies to prove that they would profit from cooperation. Another way is to use cases based on social or local government problems and solutions and then test them to improve the examination process.

8.4. Internet access and case study based exam duration

Both considerations of an Internet access and the duration of the case study exam go hand in hand. The more sophisticated the problem, the more time and resources are needed, hence the need for an Internet connection. It is worth emphasizing that nowadays, most IT problems are solved with the support of websites, online documentation or forums such as stack-overflow, Quora. Moreover, employers expect their employees to find a solution to the problem quickly, not necessarily independently. On the other hand, the competencies should relate to the person concerned and it is necessary to eliminate third parties who might answer in place of the person being examined. We are currently analyzing the possibility of conducting exams in the room with an access to the computers with sniffers installed. Then, not only the answer itself could be assessed, but also the sources used by the student. Such an approach would be closer to the real conditions in which it will work. What is more, incorrect answers found on the Internet and accepted without a moment of reflection would be the evidence of the low competencies of the examined person.

As part of your considerations, it is also worth considering extending the time between receiving the task and giving an answer. However, it can cause bigger problems to appear, but, on the other hand, how will such a case differ from the diploma thesis itself?

To sum up, the most promising solution is to reuse the thesis from previous years or base it on business-delivered cases. The early reviewer selection looks promising but must be tested.

Acknowledgment

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References

[1] Kay, J., Barg, M., Fekete, A., Greening, T., Hollands, O., Kingston, J. H., and Crawford, K. Problem-based learning for foundation computer science courses. *Computer Science Education*, 10(2):109–128, 2000. doi:10.1076/0899-3408(200008)10:2;1-c;ft109.

[2] Bergen, P. V. and Lane, R. Exams might be stressful, but they improve learning. 2014. URL https://theconversation.com/examsmight-be-stressful-but-they-improve-learning-35614.

[3] Reeves, T. C. and Laffey, J. M. Design, assessment, and evaluation of a problem-based learning environment in undergraduate engineering. *Higher Education Research & Development*, 18(2):219–232, 1999. doi:10.1080/0729436990180205.

[4] Heick, T. 50 ways to use bloom's taxonomy in the classroom. 2019. URL https://www.teachthought.com/learning/ways-to-use-blooms-taxonomy-in-theclassroom.

[5] Marzano, R. *Designing a new taxonomy of educational objectives*. Corwin Press, Thousand Oaks, Calif, 2001. ISBN 0803968353.

[6] Marzano, R. *The new taxonomy of educational objectives*. Corwin Press, Thousand Oaks, CA, 2007. ISBN 1412936284.

[7] Fink, L. *Designing courses for significant learning : voices of experience*. Jossey-Bass, San Francisco, Calif, 2009. ISBN 9780470554807.

[8] Danielson, C. Charlotte danielson's framework for teaching. 2011. URL https://www.somersschools.org/site/handlers/filedownload.ashx?moduleinstanceid=3836&dataid=2343&FileName=Danielson%20Framework%20for%20Teaching%20and%20Learning%20revised%202011.pdf.

[9] Thompson, E. Holistic assessment criteria - applying solo to programming projects. *Proceedings of the Ninth Australasian Computing Education Conference (ACE2007)*, 2007.

[10] Jay McTighe, G. W. *Understanding by Design*. 2005. ISBN 1416600353. URL https://www.ebook.de/de/product/3569746/jay_mctighe_grant_wiggins_understanding_by_design.html.

[11] Center, T. P. P. Six facets of understanding. 2021. URL https://thepeakperformancecenter.com/educational-learning/thinking/blooms-taxonomy/learning-taxonomies/six-facets-understanding/.

[12] Irvine, J. Taxonomies in education: Overview, comparison, and future directions. *Journal of Education and Development*, 5(2):1, 2021. doi: 10.20849/jed.v5i2.898.

[13] Johansson, E. The assessment of higher-order thinking skills in online EFL courses: A quantitative content analysis. *Nordic Journal of English Studies*, 19(1):224, 2020. doi:10.35360/njes.519.

[14] Meissner, R., Jenatschke, D., and Thor, A. Evaluation of approaches for automatic e-assessment item annotation with levels of bloom's taxonomy. In *Learning Technologies and Systems*, pages 57–69. Springer International Publishing, 2021. doi:10.1007/978-3-030-66906-5_6.

[15] Staff, T. Six alternatives to bloom's taxonomy for teachers. 2021. URL https://www.teachthought.com/critical-thinking/5-alternatives-to-blooms-taxonomy/.

Program Learning Outcomes	Knowledge based questions			Applications related question			Analyticial questions			Evaluation questions		
	11	12	13	21	22	23	31	32	33	41	42	43
1. Student knows and understands the main development trends of IT							x	x	x	x	x	x
2. Student knows and understands the theoretical foundations of computer science, its advanced ideas and selected issues from various departments of computer science to a thorough level	x	x	x	x	x	x						
3. Student knows and understands the non-technical conditions of conducting engineering and research activities related to IT, also regarding economic, legal and ethical aspects												
4. Student can analyse a complex problem and propose its innovative solutions, showing creativity in combining knowledge in the field of computer science and other, specific for a given problem, disciplines and adapting to changing and unpredictable conditions							x	x	x	x	x	x
5. Student can design, implement and evaluate an IT system that meets the imposed requirements, while selecting techniques and IT tools appropriate for this purpose, and, if necessary, adapting or creating these techniques and tools							x	x	x	x	x	x
6. Student can combine IT theories, specialist knowledge from various IT departments and the results of research in the process of building a solution	x	x	x	x	x	x	x	x	x	x	x	x
7. Student can formulate and test hypotheses related to simple research problems							x	x	x	x	x	x
8. Student can communicate, in a foreign language, with a diverse group of recipients, conduct a debate, work individually and in a group, including as a group leader, and plan and implement self-education										x	x	x
9. Student is ready to perform professional and social roles in a responsible manner, based on legal and ethical principles, including as an initiator of activities for the benefit of society and professional group, thinking and acting in an entrepreneurial manner												
10. Student is ready to critically evaluate his knowledge and received content, including assumptions, arguments and data presented in support of them, to recognize the importance of knowledge in solving problems and to consult experts, and to identify topics in which he can act as an expert himself							x	x	x	x	x	x

Figure 5. Educational effects matrix

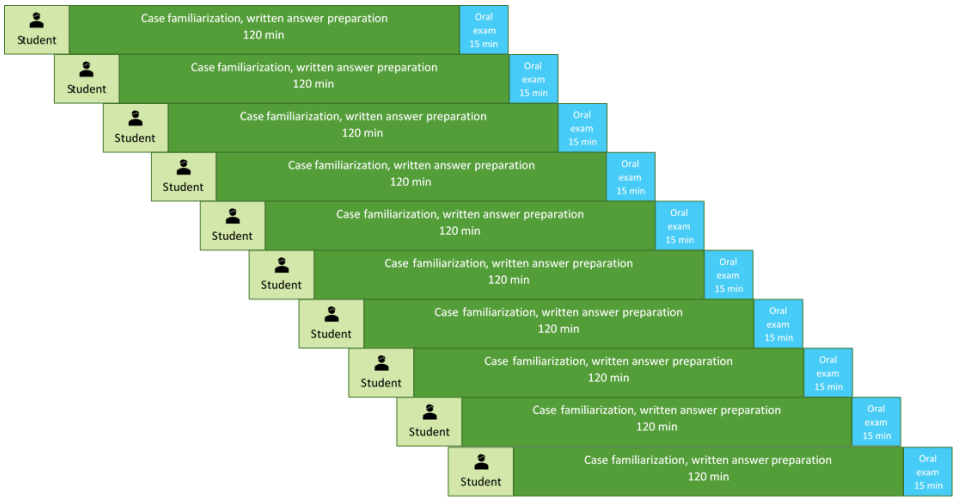

Figure 6. General exam schedule