Capstone Project: From Theory to Practice

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Abstract: *Due to the didactic methods based on the tradition of theorizing, including the practical aspects of education, and scholastic custom, having become routine, which without doubt disadvantages the training and development of specific skills declared in the university curricula for studying engineering disciplines. Because some of the given disciplines should be practical, the author debates in this article the didactic strategies built around the creative, and/or research, and/or design activities of expert systems prototypes, capitalizing on the so-called Capstone Project concept. This work is a case study that falls within the field of Education Science and covers topics at the intersection of University and Vocational Didactics, and also Computer Science Didactics. Beside the presentation of the research approach, the author reviews the specialized literature related to the applicability of the Capstone Project. She then analyses, in a descriptive manner, the case study design; the data regarding the students' feedback was then collected after completing their experiences on the Capstone Project, made by their own conception; these are in places expressed in statistical terms.*

Keywords: Capstone project, Creative didactics, Design of didactic activities, Students' research activities, University-level engineering education.

1. Introduction

Certainly, the necessary professional skills that confirm the work capacity of an engineering graduate should be formed in correlation with the industry for the activity in which he is prepared. In our case, we are talking about the ICT (Information and Communications Technology) industry. Yesterday's engineering graduate student, the applicant for being employed in certain positions in various areas of the ICT industry, as also his skills, although analysed and often tested by recruiters, will be demonstrated continuously by the employed, and also will be verified over time by the prospective teammates and employer.

In this sense, the study programs responsible for the specialists' training in these fields should include subjects in which the flexibility of using certain strategies and

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didactic methods to form and develop future graduates, such as those widely applied in the professional life of a coder and/or programmer. For example: quality assurance tester for software and not only; web developer; cyber security specialist; systems analyst; software engineer; cloud systems engineer etc.

We attest to the existence of several reasons that complicate the successful formation of the mentioned skill set. Among these are: (1). The list of required formatting skills is lengthy; (2). The methodological particularities of skills' development fall into didactic strategies developed and implemented in the long term; (3). (Burlacu, N., 2016; Burlacu, N., 2021) The study of some subjects, especially the fundamental ones that are usually taught in the first semesters of the bachelor's degree level, tends to use certain teaching methods-learning-assessment, much closer to traditional methods; (4). There are not many university facilities that allow the integration of didactic methods that would support the development of research skills and ICT product creation.

Commonly, this practice can be applied in the final years, because students already have an accumulation of skills in several areas of professionalization. They are very well familiar with: programming languages; algorithmizing techniques; data structures; programming environments, and builder software that generates source code and where the developer does not necessarily have to write it himself.

The author sees the solution of a future, substantially more successful insertion in the labour market for graduates with degrees in various professional areas in ICT fields in the implementation of more flexible teaching strategies, based on the stimulation of creativity and engineering research to support today's students in the formation and development of a set of skills, extended from the version of skills specific to their field of activity, such as critical thinking, time-management, self-directed learning, analysis and synthesis of evidence, the ability to demonstrate in-depth knowledge on a specific topic, the potential to undertake independent research, commitment to improving the degree of personal development through reflection, as well as undertaking the obligation to increase emotional strength to adapt to change etc.

In this context, the author proposes the massive avoidance of didactic methods based on the tradition of theorizing, including the practical aspects of education, custom that have become routine, which undoubtedly disadvantages the training and development of specific skills declared in university curricula for studying engineering disciplines, which should be primarily practical. Thus, in the present research, the author debates the didactic strategies built around the creative and/or research and/or design activities of some expert system prototypes, valorising on the concept of the Capstone Project, in a case study held at the Technical University of Moldova (TUM) within the Applied Computer Science (ACS) and Information Management (IM) study programs, during the 2019-2022 academic years.

Currently, the Capstone Project concept is not defined in the specialized literature, but it has an impressive scope in the USA educational system from which it was inspired. Broadly speaking, the given concept can be found in the scientific literature under a different name to the Capstone Project. For example, in describing their teaching and research experience, the authors of certain scientific studies regarding the Capstone Project used notions such as (Grant & McLaren, 2007) “capstone course” or (Gallagher & McGorry, 2015) “capstone experience”.

The novelty and originality of this article consist in informing of actors from the European education area, interested in the development of university didactics and, in particular, of the didactics of engineering disciplines – university teaching staff; methodologists concerned with the organization of the didactic process, especially at the educational micro-management level, i.e. the organization of teaching-learning-evaluation activities; scientific researchers; staff members responsible for study programs; and also the students - about the specific approaches of a course based on the Capstone Project concept, on the example of engineering education in the Republic of Moldova.

2. About Capstone Project

2.1. The Analysis of Specialized Literature

The majority of researchers agree (Burke & Dempsey, 2021) that “Capstone projects are unique in the way they assess your knowledge and skills gained through an educational program. In the following sections, you will find some of the main defining features of designing and conducting a capstone project”. At the same time, the same authors (Burke & Dempsey, 2021) try to dispel the existing myths about Capstone Projects. Thus, in their opinion “The most prevalent myth associated with a capstone project is calling it a mini-thesis, which does not do it justice, as there are fundamental differences between these two final-year assessments. Yet, we have heard both students and academics referring to it this way for years. Even though it is understandable, given that thesis have been in the academic lexicon for centuries, it undermines the important role that capstone projects play in education, which relates to enhancing educators’ research-based practice capacity, instead of primarily adding value to a research base”.

In the scientific literature, there are contradictory opinions regarding when and where Capstone Projects (CP) can be integrated. The authors of some papers state that CPs are the projects that can be carried out by students in the last year of professional studies, usually at the university level (Margaret E. Madden et al., 2013). Others come up with ideas for implementing CPs in the study of STEAM subjects in high school classes, especially Mathematics (Lynette Hammill, 2011). The Capstone Project has the ability to include several components, thus CP being distributed as an individual task per student, it would represent a final work with several parts, as follows (Margaret E. Madden et al., 2013):

- **"Interdisciplinary Major (25-48%):** A student-designed, forward-thinking major with at least two different fields of study", one of them mandatory will be the field of their professionalization;
- **"Integrative Core (42-49%):** Problem-based multidisciplinary, own student-driven applied learning occurring throughout the curriculum";
- **"Internship Experience (2-10%):** Required real-world experience away from home campus".

2.2. Theoretical and Applied Considerations Researched by the Author

In our view, since Capstone Projects are a pinnacle of evidence-based practice, they could be used as ways of summative and/or final assessment with the aim of demonstrating the entire set of knowledge, skills, and abilities acquired by the learner throughout the study period (of a course, training etc.). Such a project is one that culminates with the entire educational experience accumulated, as a rule, either at the end of a course or at the end of a year of study etc.

In the university environment of the Republic of Moldova, as a form and idea, they can be somewhat associated with end-of-year theses or examination projects in disciplines that have a corresponding potential. Their applicability is very extensive, especially in the final years of university studies and, in our opinion, especially in the areas of training new engineers. All these types of activities can be completed, as appropriate, with the development of applications based on personalized, practical, and unique tasks. Assignments for such types of activities can be formulated and disseminated both individually for each student and for a distinct group of students.

Regarding project activities valid for a group of students (Burlacu, 2022):

"In case of acceptance by the teaching staff and/or the institutional regulations regarding collaborative work, the assignments are formulated for the entire work group, thus it is possible to organize both the collaborative activity within each team, as well as the interconnection of several work groups, with common interests in regard to collaboration and mutual assistance, either during the integral development of one or multiple projects, or only on certain dimensions and themes of the project(s), depending on the inter-group conventions, but also on the conditions stipulated by the teacher".

Individual projects are preferable in cases when (Burlacu, 2022):

- "The topic of the project and / or the field of its development is clearly delimited by the research problem and does not foresee its expansion at the level of a group project;

- The type of activity is determined as being individual in the internal normative acts of the educational institutions and / or the external ones, issued by the relevant ministries, their originality being one of the basic criteria explicitly reflected in the rigor documents;
- If the teaching staff considers it appropriate to distribute individual tasks for the elaboration of some projects (either based on solving problems or based on research etc.) in order to clearly outline the area and / or the theme and / or the objectives of the activity for each individual student". Such a decision should be dictated by the intention:
    - to be as correct as possible in carrying out an assessment, measurement and marking of the product of the learner's activity;
    - to reduce and / or eliminate possible copying, plagiarism, and academic fraud during evaluative activities and / or in the teaching process, in general (Burlacu & Irimiciuc, 2017).

3. The Methodology

3.1. Target Group & Didactic Environment

This study reflects the experience implemented at TUM, the Faculty of Computers, Informatics, and Microelectronics (FCIM) within the Expert Systems (ES) and Expert Management Systems (EMS) courses, included in the VI semester of the Applied Computer Science (ACS) and Information Management (IM) study programs, respectively. The research experience took place throughout the 2019-2020, 2020-2021, and 2021-2022 academic years, on a total sample of approximately 164 students. All students were in the final (third) year of studies in the undergraduate cycle. Although at first glance it seems that the disciplines of Expert Systems and Expert Management Systems have only a specific tangent in the given scientific and professional fields, the truth is that these courses have more similarities than differences. Therefore, based on the structural and content congruence of the subjects in question at the faculty level, the decision was made to combine the third-year groups from the study programs with the specialties of the *Applied Computer Science (ACS)* and *Information Management (IM)* into a single stream.

The analysis of the content components of the Expert Systems and Expert Management Systems courses confirms the need to study the same academic content in the same proportion and with the same modules / themes / concepts / programming principles etc. for both specialties. Given the fact that until the formative assessment, the content taught in the theory lessons has an identical structure for both specialties, there are no differences in the teaching of the subject during the lecture hours.

While in the case of IM groups at the level of laboratory lessons, there is a need to intervene with some additional details in the interpretation of the application of the theoretical concepts addressed in the course. The phenomenon can be explained by the fact that at the time of starting the study of the discipline - either Expert Systems or Expert Management Systems - the curricular background, responsible for the professional training of the representatives of the ACS and IM groups, is different.

At the time when the Expert Systems / Expert Management Systems course had started, the students of the ACS and IM groups had some knowledge of the logic programming language PROLOG, which is one of the operationalization tools in the laboratory lessons, although the prerequisites for the ACS and IM students were dissimilar, thanks to some differences from one study program to another study program, which is normal and justified.

As for PROLOG, it is a rather archaic programming language, with a certain area of applicability, which is decreasing day by day and, unfortunately, not far from being very popular, which also complicates things, but which, at the same time, caused the (re-) conceptualization of the Expert Systems / Expert Management Systems course in such a way that it should: (1). not to be exceeded, (2). to come at least with a dose of motivation, able to capitalize on all the knowledge of the final year students, (3). to demonstrate to them that, although they know a lot, the field of specialization can always surprise them with something new, (4). to generate intrigue situations for them during their own learning, which at the end (5). to materialize in some educational outcomes at least unexpected for them as learners.

These purposes should be able to arouse some interest and satisfaction after working in the course, at most to wish to continue to carry out research and / or studies in the field of Expert Systems / Expert Management Systems, especially since this does not only mean PROLOG.

3.2. The Applied Assessment Process

In order to determine for us, as instructional designers, the state of affairs at the beginning of the course regarding the knowledge of some key concepts related to the application of the PROLOG language, the area of its use, the degree of perception of the concepts related to ES / EMS etc. we have created and disseminated a Google form for completion among the representative sample of ACS & IM students. Finally, the completed forms were processed and demonstrated a certain level of knowledge of the items to be evaluated among the students.

Speaking in statistical terms, the series of data obtained from the initial survey demonstrates that the simple arithmetic mean of the marks accumulated by the sample of respondents was approximately 6.57 (out of 10 maximum possible points). We note that the average of the accumulated score could have been affected by several factors. We assume that some students did not have the most serious attachment to the purposes of filling out the form, and others managed to forget about it after the vacation and the winter session some notions and / or failed to strengthen to a more serious level the usual knowledge previously within the courses that form the set of prerequisites.

An additional pro argument that made us accept the assessment process scenario described below and the fact that both the Expert Systems course from Applied Computer Science and the Expert Management Systems course from the Information Management study programs are taught in the year III studies and provided for a very small number of contact hours, corresponding and credits, running only during 6 weeks in the spring semester, but which must come with convincing educational outcomes regarding the level of professional skills of the future licensed specialists in Computer Science at the end of the semester and the final year of university studies in the undergraduate cycle. Obviously, for the same reasons, it was necessary to customize the course evaluation process. Therefore, it was decided to approve the following staged assessment scenario:

Stage I - the formative assessment included an individual theoretical research project with themes formulated for each student. The research condition formulated by the course holder required the descriptive and comparative analysis of at least two programming paradigms, one of which, necessarily, was the logic programming paradigm. In the assignment's conditions it was also stipulated as mandatory the following: (1). The analysis of the concepts and principles of the functionalities of the programming paradigms with their exemplification through various code sequences developed in various programming environments that facilitate the development of applications through the given paradigm; (2). Optionally, the student could review some descriptions of the programming environments that he used in his research.

Stage II is equivalent to the thesis of the year for the representatives of the ACS groups and to the examination project for the students of the IM groups consisting of the elaboration and detailed description (conceptual and behavioural) of an expert system prototype for a socio-economic or scientific field by using the language of PROLOG programming.

The themes for the given research were formulated individually for each student; they have a unique character at the level of the entire torrent. When formulating the assignments, the area of scientific interests of each student was taken into account. The themes were stated here, such as (see Table 1):

Table 1. Examples of themes for developing the prototype of an expert system / expert management system

No.	*Topic of the expert system prototype / expert management system to be elaborated*
1.	Creation of an expert system emulator of methodological recommendations for studying the English language.
2.	Prototype of an expert system for methodological recommendations for studying the Romanian language by foreigners.
3.	Development of an expert system emulator for a job recommendation.
4.	Creating an expert system for recommending musical bands.
5.	Prototype of an expert system for determining tourist destinations.
6.	Building an expert movie recommendation system emulator based on user preferences.
7.	Creating an expert system for suggesting electronic devices, based on user needs.
8.	Development of a prototype of an expert system for the selection of automobiles.
9.	Development of an expert system prototype for restaurant menu automation.

Stage III provided for the elaboration of the examination project for the representatives of the ACS groups. The students were asked about the problem of transposing the idea of the expert system prototype developed earlier in the year thesis (at stage II) (see Table 1) into an expert system emulator created by means of another ICT tool. As an alternative computer tool for ES / EMS application development any other programming language than PROLOG could serve, programming environments traditionally recognized as dedicated to working with other programming paradigms, such as C / C++ / C#, JAVA, PHP, Python etc. In the basic conditions of this assessment project, the obligation to equip the SE / SEG emulator application with a graphic interface, but also functionalities that ensure human-computer interaction, was specified.

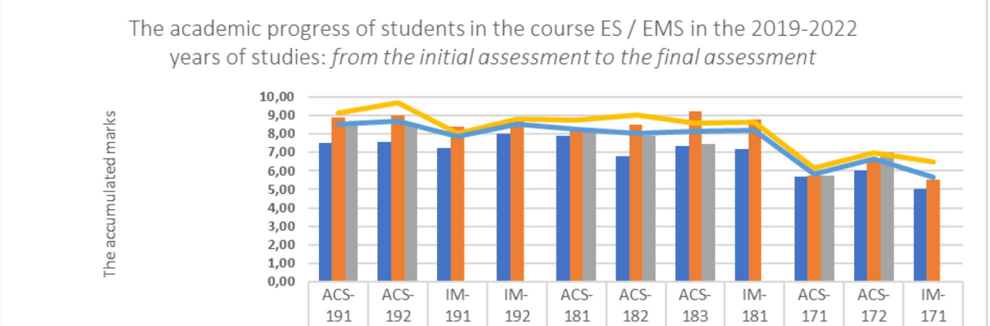
Throughout the semester, during the organization of both formative and final evaluations, the themes proposed for research were formulated, placed on the cloud, and proposed to the students for analysis and subsequent registration with the restriction that in an academic group the respective theme has to be chosen only by one student. The restriction was specified in this way because it was desired to carry out individual projects and not in groups.

An additional reason for accepting this particular assessment formula was the desire to increase the rate of the uniqueness of works, to create more pronounced conditions for fair competition between representatives of the same torrent and / or academic groups of students. Since the assignment is only repeated at a rate of 1:1 in an academic group or at a rate from a minimum of 1:1 (for the formative assessment of stage II & III) to a maximum of 1:3 (for the formative assessment of stage I) in a students' stream then within their public presentations (which were also mandatory) (1.) the similarities and differences between the projects with the same and/or similar themes as approach, originality, complexity, creativity etc. will be evident; (2.) the principles of objectivity, transparency, impartiality etc. will be respected as mentioned above.

This way of organizing evaluation activities is very flexible from the perspective of its applicability because it can be used in the traditional didactic process, as well as the hybrid one, as well as the online one, a fact that characterizes it as a tool for organizing assessment, having a strong educational potential for developing the spirit of fairness, personal involvement and fair competition of the learner, but not only. The projects were publicly supported; therefore, the given form of carrying out the educational activity allowed both the training and testing of the public speaking skills of the students.

4. Capstone Project: Achieved Results and Students' Perception

The actual data collected for the given study were accumulated throughout the teaching-learning-assessment process of the university course of Expert Systems and Expert Management Systems and was formed from the set of grades obtained by the representatives of the ACS & IM groups during 2019-2020 & 2020-2021 & 2021-2022 academic years from initial assessment tests, formative assessment no.1, year thesis assessment and final assessment (see Figure 1).



	ACS-191	ACS-192	IM-191	IM-192	ACS-181	ACS-182	ACS-183	IM-181	ACS-171	ACS-172	IM-171
Initial assessment (Diagnostic)	7,50	7,55	7,25	8,00	7,87	6,80	7,33	7,17	5,67	6,00	5,00
Formative assessment 1	8,86	9,00	8,37	8,83	8,20	8,50	9,22	8,75	5,75	6,50	5,50
Thesis of the year	8,62	8,53			8,13	7,89	7,44		5,75	7,00	
Final assessment (Exam)	9,14	9,67	8,00	8,80	8,73	9,00	8,56	8,64	6,17	7,00	6,50
General average	8,53	8,69	7,87	8,54	8,23	8,05	8,14	8,18	5,83	6,63	5,67

Figure 1. The averages, per group, of the grades accumulated by students gr. ACS & IM (2019-2022)

The MS Excel program was used for data processing, and for their more explicit representation, the use of custom combined diagrams (Combo Custom Combination) was used, which is intended for the more complex representation of data, including those that are embedded as diagrams (set either by row or column value) in other charts. In other words, Combo Custom Combination is a chart made up of a combination of other charts. At the end of the processing of the collected data, the progress of the academic success of the students in the discipline in question became evident.

Figure 1 illustrates the dynamics of the students' academic success based on the grade averages they earned as representatives of the ACS and IM in the didactic assessments of the Expert Systems / Expert Management Systems course in the 2019-2022 academic years. The given diagram reflects the average success of all groups of students that make up the general sample of the study (N=164) from the initial assessment and the formative assessment in relation to the marks from the assessment of the year's thesis, but also in relation to the results (grades) of the final assessment (yellow curve). The maximum grade value is 10 and the minimum grade value is 5 for all samples taken into account when processing the data and creating the chart in Figure 1.

At the end of the course, we were curious to get feedback from the learners who for the first time, both for them and us, went through didactic activities in a hybrid and online format, through online assessments, organized by us on several levels around the culminating projects, described in this paper. Being in the final year of studies, often many of the beneficiaries of the course had something to say, comment on. Moreover, during the lessons, but also the consultation hours, we intentionally initiated some discussions that would help us find out the students' opinions regarding the didactic and evaluative course designed for the ES / EMS discipline.

Speaking about the feedback received from the students at the end of the ES / EMS course, among them there were testimonies from which it emerged that the majority of the representatives of the student-respondent contingent found that they had made some discoveries about themselves, such as is shown in Table 2.

Table 2. Students' feedback reflected in the questionnaire at the end of the SE / SEG course

Findings made by respondents	*No. of positive reactions, %*
They determined the personal ability to aggregate the knowledge obtained both in the course and during other university courses;	*70%*
Students determined that they have a much higher creative potential than they imagined;	*58%*
Respondents understood that even though they were already at the end of their university studies, there was knowledge and/or information that they had heard about at the ES/EMS course. Also, students applied given knowledge and/or information for the first	*65%*

time in the ES/EMS assessments that they were challenged to perform them in the format proposed by the teaching staff;	
They found that now, at the end of the course, they understood what it's like to really ("for real", quoted from the students' expression) theoretical research with applied impact;	*62%*
Thanks to the format of public presentation and support of the projects, students revised their attitude towards the intellectual, and creative capacity and the degree of involvement of many of their colleagues;	*31%*
For the first time students, our respondents heard and, respectively, for the first time they tried to transpose an application prototype, created based on a programming paradigm, into an IT product created with alternative IT tools, not necessarily very actively recommended by specialists from various ICT fields;	*77%*
Given the fact that students were very thoroughly informed on the issue of research originality, but also on the issue of plagiarism, for the first time they were faced with the obligation to respect research ethics, the appropriate citation of bibliographic reference sources;	*87%*
The students were surprised that they managed to achieve a result that at first, they perceived as unrealistic one to achieve.	*70%*

What could be more valuable than personal experience on the road of professional training? Or, as per (Hurston, Z., N., 1997) "Research is formalized curiosity, it is poking and prying with a purpose".

5. Conclusions

Our research allows us to come up with the following findings regarding the methodology of applying didactic assessment based on Capstone Projects. The described approach could serve as a guiding material and/or a source of inspiration for colleagues interested in integrating Capstone Projects into their professional practice.

The assessment methodology presented in the paper is a long-term assessment strategy focused on practical and research activities generating learning products with added value from a formative, qualitative and creative point of view.

Given that the public presentation of the research project results component was part of the design of the assessment method described above, which was later executed, allowed students to (1). Develop the ability to structure arguments, materials, and/or evidence collected during research; (2). Increase their ability to analyse, synthesize, and present research content; (3). Improve their competence in formulating and issuing reasoning regarding the object of research; (4). Form constructive networks (networking) with their colleagues, based on the principles of transparency, involvement, and honesty; (5). Increase their competence in the computer-aided design and implementation of applications grounded in the ES / EMS field, using an expansive spectrum of IT tools; develop their academic writing skills in compliance with the deontological norms of research etc.

Due to establishing the appropriate connection between the objectives and the outcomes of the discipline, the students were able to form and develop their strategic thinking, which greatly benefited them at the interview stage regarding the elaborated projects.

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