Scientific and technical report

1. Project Information

Project title (Romanian and English)

Predarea, învățarea și evaluarea într-o lume distanțată social

tEaching, Learning and EValuating in a sociAlly disTancing wORld

Acronym: ELEVATOR

https://www.cs.ubbcluj.ro/~avescan/elevator/

Romanian Partner: Babeș-Bolyai University
Foreign partner: University of Namur
Duration of the bilateral project: 2 years

2. Project General Objectives

The project has two complementary objectives related to learning: first, considering innovative solutions and approaches to design effective learning activities, and second, concerning the development of tools to diagnose and remedy students' misconceptions.

Given the context of health and distance learning, it was decided to already cross the two objectives in the first year. Several research activities were conducted: analysis of practical problems and teaching materials by researchers and practitioners (teachers), development of tools for qualitative data collection about learning activities and/or concepts being taught (concepts inventories), and data collection from practitioners and students (in four different classes). The data collected are numerous, allowing both qualitative and quantitative processing. Some of the data provide information on the pedagogical interest of the proposed learning activities, on the students' desires, and on the difficulties they may encounter in a distance learning context. Other data help identify misunderstandings between students about the concepts being taught. In general, the analysis of these data will lead to recommendations for improving the teaching materials and reflection to produce design principles for teaching materials.

3. Execution Phase Project Objectives

The activities performed to achieve the objectives are listed next, the major steps being represented graphically in Figure 1.

In year 1

- Analysis of practical problems by researchers and teachers in collaboration
- Building of an open-ended questions survey (including pre-post-tests) to collect data from students participating in a testing course (January-February 2021)
- Data collection for testing course (February-May 2021)
- Data analysis for testing course (May-December 2021)
- Building of concept inventories for three courses (Augustus-October 2021)
- Data collection with concept inventories (October-December 2021)

In year 2

- Data analysis for testing course (data of year 1) (January-June 2022)
- Building of concept inventories for testing course (January-February 2022)
- Data collection (February-May 2021)
- Data analysis for testing course (data of year 2) (May-July 2022)
- Data analysis for the three courses (January-June 2022)
- Improvement of the concept inventories (July-October 2022)
- Improvement of teaching materials, recommendations, innovations, reflection on the production of design principles for teaching materials according to identified misconceptions (**iterative process**)

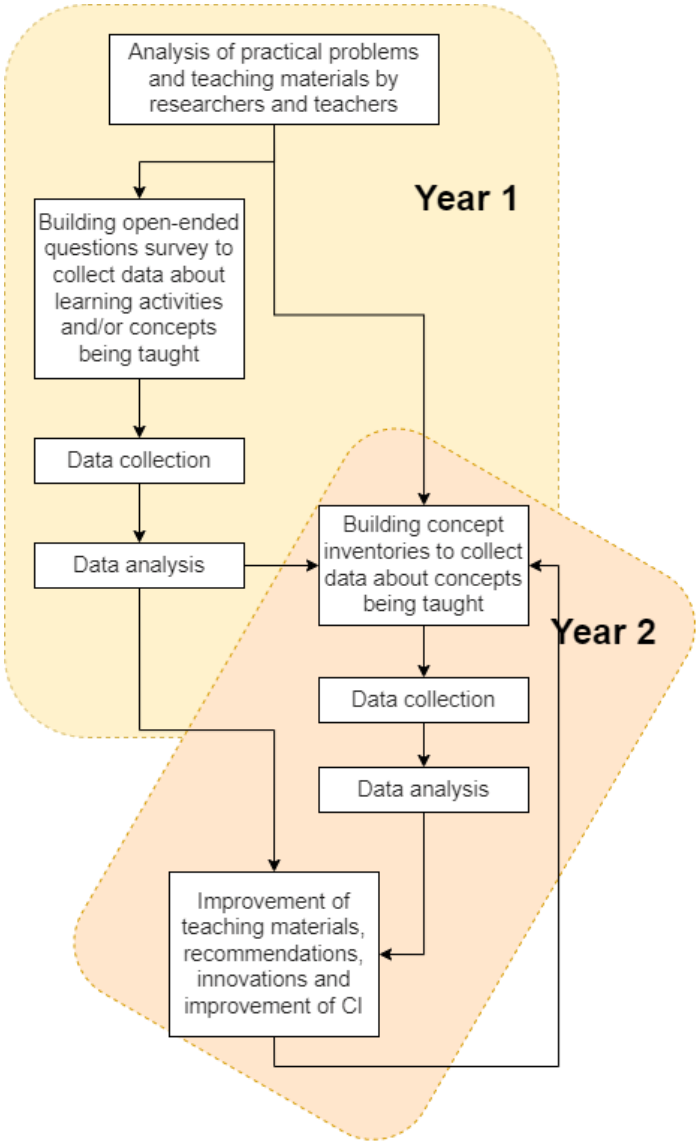

Figure 1. Activities of the ELEVATOR grant

The **outcomes** of the project are the following.

- **Four concept inventories** to measure students' lack of understanding of key concepts in four different courses, reusable from year to year to identify improvement points in these courses, and also as **self-assessment tools** for students
- A list of **misconceptions validated by the data collected** for each of the four courses evaluated
- **Recommendations for evaluation of teaching materials,** suggestions for solutions, and pedagogical innovations
- **Design principles for teaching materials** according to identified misconceptions

4. Scientific and Technical Description

In the current context, it is important to identify the elements that make teaching and learning online successful (**challenge 1**). This involves understanding how to adapt the teaching/learning process but also thinking about how to design activities that engage students in active learning so that they stay in the flow (being attentive during class). This is particularly important in a formal domain such as computer science, where practice is pervasive.

The learning activities nowadays are no longer pure transfer of knowledge from teacher to students but the students take part in building the knowledge: we, teacher and students, are partners in learning. The design of the learning activities needs to actively involve the students in the process of learning. It is not only a question of adapting teaching and its content, but also of thinking about evaluation. It is important that students, made more autonomous by the context, are able to assess themselves regularly, but also that teachers are able to propose assessment tools to correctly diagnose students' misunderstandings and highlight their understanding (acquired skills) (**challenge 2**).

To meet these two challenges, the project has two complementary objectives: the first one considering innovative solutions and approaches to design effective learning activities and the second one concerning the development of tools to diagnose and remedy students' misconceptions.

4.1. Research meetings and visits

Regular meetings were held from the very start of the project, some of the meetings being held online due to the Covid-19 sanitary situation. These meetings helped establish the planned activities and how to corroborate them with the design of the studies used. The two teams exchanged information about the context of learning and about how the methodology should be applied.

Research visits helped to weld the relationships between researchers, enabling more clear communication and understanding of concepts. During the year 2022, two research visits were carried out.

- During the week of 25th April 2022, the Romanian team (Alexandra Pasca, Camelia Serban, Andreea Vescan) visited the faculty of Computer Science of the University of Namur.
- From the 21th November to the 3rd December 2022, the Belgian team (Julie Henry - 2 weeks, Fanny Boraita Amador - from 21th to 24th November) visited the Computer Science department of the Babeș-Bolyai University.

The research visit to Namur (Belgium) was used by the Romanian team to present the research activities and results of the ELEVATOR project: grant objectives, methodologies, implementation, analysis, and results of the studies conducted in 2021 and 2022. The attendance was composed of local researchers in Computer Science. In Cluj-Napoca, the Belgium team presented different methods for evaluating and improving learning experiences in Computer Science, in particular the methods implemented within the ELEVATOR project, but also methods implemented in other contexts that could inspire the project team. The aim of these two seminars was to help disseminate the project results, the respective expertise of the two teams, and to help foster potential new collaborations.

Additionally, the time of visits was used to coordinate data analysis activities, as these require coordination among grant researchers to provide relevant results. This was also an opportunity to set up, define, and begin writing a paper that was submitted to the EASEAI workshop (within the FSE/ESEC conference).

4.2. Research studies

In what follows, we outline for each research study the proposed and applied methodology, accompanied by the obtained results.

Course SSVV (Software Systems Verification and Validation) that is taught by Assoc. Prof. Andreea Vescan at the undergraduate level. The study aims to validate the misconceptions identified from the previous year and validate the findings of the qualitative analysis with another cohort of students.

The first-year study revealed that there are some misconceptions of the students regarding testing in general, in particular about white-box testing and black-box testing.

Data analysis revealed eight **misconceptions about testing techniques**, both black-box testing (BBT) and white-box testing (WBT) concepts, and testing in general. These misconceptions are as follows:

1. *In BBT there is no access to design/architecture.*
2. *BBT can be done only for unit-level testing*
3. *WBT is done only for statements coverage*
4. *WBT does not test the functionality of the application.*
5. *Developers do not test*
6. *Testing is a guessing process*
7. *Code is immune to the same set of tests*
8. *Testers do not need programmer experience*

Thus, there are specific misconceptions to BBT (1,2), to WBT (3,4). Students also have misconceptions regarding software testing (in general 5,7). There are also misconceptions about the skills needed to test (6,8).

Validation of identified misconceptions through qualitative analysis. In the academic year 2021-2022, we have designed a new study to validate our findings from the academic year 2020-2021. The questionnaire was based on the eight identified misconceptions, adding also several open-ended questions (What is the concept "Software Testing" in your own words? What is the concept of "Black-Box testing" in your own words? What is the concept "White-Box Testing" in your own words?). The questionnaire was administered 4 times between theoretical and practical/laboratory work, with additional pre-test and post-test.
The results will be incorporated into the TOCE paper revision.

Analysis of data concerning the pedagogical design of the course, data collected in Academic Year 2021-2022. The purpose of this study (via pre- and post-test) was to evaluate the learning experience (including online learning due to covid) of the SSVV course and to suggest design directions. Then the questionnaires (pre and post) included questions about the design of the course. Which learning approaches are favored by students? Which teaching method suits them best? What is the impact of online teaching on your understanding? Their attention? Your engagement? And finally, what is their perception of the value of organizing the course into lectures/seminars/labs?

The results (processed by the external team, i.e. the Belgian team) still need to be confronted in more depth with the experience of the teacher in charge (Romanian team). However, some first findings can be described. For example, the distinction that students make between seminars and laboratories questions the added value of this pair of teaching approaches. In-class assignments are experienced as stressful and pressured, a result that can be related to the fact that students arrive at seminars without having attended the readings and without having seen/reviewed the material. Therefore, students logically prefer a combined individual work/take-home assignment/online learning approach. In addition, seminars that should emphasize extensive interaction between the teacher and the class, mixing questioning and application, are described by students as a place where the teacher should transmit concepts. As the lectures are little attended by the students, they try to find the content of the lectures in the seminars, which is not foreseen by the teacher.

Regarding online learning, the impacts are more positive than expected for the majority of students who seem to be used to this mode of teaching and appreciate its methods.

Course APM (Advanced Programming Methods) that is taught by lect. dr. Camelia Serban, at the undergraduate level, in the second year of her studies. The study aims to identify misconceptions regarding the Delegate Design pattern.

The concept of delegation is studied in the APM course both in the Java language and in the C# language. Initially, it is studied in the Java language. The way of implementation is with the help of functional interfaces. Initially, the students encounter difficulties in understanding this template and due to the fact that they somehow meet this concept in the OOP course using a pointer to function. The syntax and way of implementation in the Java language is a little different from what the students were familiar with in the C++ language.

In the second half of the semester, the study of the C# language begins, where this concept is resumed. Understanding it is now much easier, the syntax of the C# language is much more intuitive for this template, there is even the reserved word delegate, and it has a much more specific implementation.

Methodology. The study consists of two main steps. In the first step, four misconceptions about delegation were identified based on the teacher's experience. From these misconceptions, eight text statements about delegation are specified. In the second step, a Likert scale questionnaire (composed of eight text statements) was administered two times to students according to a specific schedule, allowing the evolution of delegation understanding.

Results. The results of the pre-test questionnaire fix the students' pre-misconceptions of the delegation concept. The second questionnaire revealed that students changed their position on the text statements provided after the theoretical classes. Furthermore, the perception of the delegation concept by students appears to stabilize after the C# courses. Thus, working on practical problems and learning by doing could have a positive impact on a better understanding of the abstract concept of delegation.

Course CMES (Computational Models for Embedded Systems) that is taught by Assoc. prof. Andreea Vescan at master level, *Software engineering* and *Distributed Systems in Internet* sections. The study aims to identify misconceptions regarding the Finite-State Machine concept.

The purpose of the published paper [Hen2022] is to present an approach used to identify misconceptions related to the concept of a finite state machine (FSM). In the learning process, identifying misconceptions of students, that is, when they appear and how to efficiently correct them, are important aspects of the best learning outcome.

A concept inventory (CI) is a standardized assessment tool designed to evaluate the student's understanding of the fundamental concepts of a topic. CI can be administered to students several times during the course of the learning period to measure how students' understanding of concepts changes.

***Methodology*.** This preliminary study is made up of two main steps.

- In the first step, four misconceptions about FSM were identified based on multi-year observations and teacher experiences. From these misconceptions, seven text statements about FSM are specified.
- In the second step, a Likert scale questionnaire (composed of seven text-statements) was administered five times to students according to a specific schedule, allowing one to measure the evolution of FSM understanding.

To highlight changes in the positioning of the students in relation to the statements provided and to link these changes to teaching interventions, a pre-questionnaire (before the beginning of the course CMES) is used to identify pre-misconceptions about the concept of FSM that the students have, based on their learning (self-learning or from previous courses).

The questionnaire was administered five times during the period covered by the teaching of the FSM concept: one before all classes (Q1, pre-test), two after each of the two theoretical classes about FSM (Q2 and Q3), one after the students have submitted the FSM lab work (Q4), and one after all classes (Q5, post-test). A two-week interval was between the Q1-

Q2 and Q2-Q3. Between Q3 and Q4, four to five weeks were given to the students. This longer period allows students to work on their practical sessions. Some work was delivered a week later. Finally, between Q4 and Q5, three weeks passed.

Results. The results of the pre-test questionnaire (Q1) fix the students' pre-misconceptions of the FSM concept. The other questionnaires revealed changes in positioning in relation to the text statements following the theory courses (Q2-Q3), indicating their influence. Additionally, the students' perception of the FSM concept seemed to stabilize after the practical work was done (Q4). Therefore, working on practical problems and learning by doing might have a positive impact on understanding the abstract concept of FSM. However, the post-test questionnaire (Q5) shows that some doubts remain, confirming the students' learning difficulty.

Course MIPPIP (Mathematics for primary education) that is taught by assoc. prof. Ioana Magdas - master section *Preservice teachers for primary education,* The study aims to identify misconceptions for the Fraction concept.

The concept of fraction is one of the fundamental concepts of elementary mathematics which is used in everyday life and on which knowledge depends on more advanced mathematical knowledge. There is a need for better training in fractions of mathematics teachers starting with those for primary education, which can be done after identifying their preconceptions and misconceptions about this subject.

For this, we developed didactical research. Initially, based on the literature and personal experience, we developed a CI on fractions based on which we developed a questionnaire that was directed at prospective teachers for primary education. After that, the questionnaire was administered in three different stages of the learning process: before the class started, after the formative intervention consisting of a course and a seminar about fractions, and, the last, at the end of semester. The purpose of this study is to validate the CI creation process by examining the presence of identified misconceptions in prospective teachers of primary education and to evaluate the overcomement of their misconceptions about fractions during and at the end of the instructional intervention.

Methodology. The teaching experiment was attended by third-year students from the Specialization in Primary and Preschool Education Pedagogy, Babeș-Bolyai University, Cluj-Napoca, Romania.

The didactic research took place in the first semester of the academic year 2021-2022, between November 2021 and January 2022. The experiment consisted of three tests, namely: an initial test (IT) before studying fractions, at the beginning of November; the Middle Test (MT), which was administered immediately after the formative activities were held; and the Final Test (FT), which was administered in early January at the end of the recapitulative semester seminar, that is, about 6 weeks after MT.

Based on the teacher's own experience and the literature, a list of misconceptions about fractions was established (5 text statements). Starting from these misconceptions, we developed the research tool, a theoretical test consisting of eight statements regarding the concept of fraction and related concepts.

Results. The results of the initial test confirmed the students' misconceptions about fractions. After the formative stage of the course and seminar application, some misconceptions

were changed. At the end of the experiment, the highest percentage of correct answers was close to 50%. If at the beginning of the experiment the average of correct answers to the proposed items was 14.6%, at the end of the experiment this percentage reached 34.2%, which shows that almost 20% of the students overcame their preconceptions and misconceptions about fractions. Furthermore, at the end of the experiment, an average of 20.1% of the respondents correctly argued the statements, although they chose a wrong answer. This fact shows that one in five students only partially understands the proposed statements and has general knowledge that is not sufficiently well structured, so they have difficulty choosing the correct answer. On the basis of the experience, it is therefore evident that more time needs to be allocated for the understanding and fixing of the fraction concept for future primary and preschool teachers, a concept that is extremely important in the study of mathematics from primary education and later on in middle and high school, but also for life.

4.3. Disseminations

4.3.1. Publications

The findings of the project were published in important conferences or journals. Some are still being submitted as of the writing of this report.
The results of the 2021 research investigations were submitted to the TOCE journal, a revision is under development with new results from the 2022 investigations.

In 2022 the research results from the CMES course were published to the EASEAI workshop within the FSE/ESEC conference. Other results are to be submitted to conferences and journals, namely results from the APM and MIPPIP courses.

[Ano21] Anonymous submission, Mixed Methods Research to Identify Undergraduate Misconceptions in Software Testing, ACM Transactions on Computing Education (TOCE) journal (submission 2021).

[Hen2022] Julie Henry, Bruno Dumas, Andreea Vescan, and Alexandra Maria Pasca. 2022. Student misconceptions about finite state machines: identify them in order to create a concept inventory. In Proceedings of the 4th International Workshop on Education through Advanced Software Engineering and Artificial Intelligence (EASEAI 2022). Association for Computing Machinery, New York, NY, USA, 2–9. https://doi.org/10.1145/3548660.3561330

4.3.2. Presentations

Presentation in Belgium

During its visit to Namur, the Romanian team (Andreea Vescan, Camelia Serban, and Alexandra Pasca) presented the undergoing activities related to the grant objectives, i.e., the design of the 2021 SSVV study, along with the validation of the identified misconceptions in the 2022 students cohort. Regarding the second objective of the project, the presentation also contained the activities applied to the constructed methodology to investigate solutions for early misunderstandings and diagnostic approaches. The following concepts were outlined and discussed during the presentation: Finite-State Machines (CMES), Delegate Design Pattern

Concept (APM), and Fraction Concept (class for Prospective Teachers for Primary and Preschool Education in Romania).

Presentation in Romania

During its visit in Romania, the Belgium team (Julie Henry and Fanny Boraita) presented different methods for evaluating and improving learning experiences in computer science, in particular the method implemented within the ELEVATOR project, but also methods implemented in other contexts that could inspire the project team: flipped classrooms and the use of metaphors.

The results presented were preliminary and did not confront the impressions of the teacher in charge. The idea was to generalize these results by confronting them with the experiences of the audience. A discussion the day after the presentation already clarified some findings.

Poster and video presentations

Regarding dissemination, a poster was also created with the aim and preliminary results of the studies used. In addition, a video presentation was produced for the grant scope and the results obtained.

The poster and the video can be found on the project website.

4.3.3. Web page of the project

In 2021, the project website was created. During 2021 and 2022 it was updated with information regarding various meetings, visits, and events that took place under the ELEVATOR grant umbrella.

https://www.cs.ubbcluj.ro/~avescan/elevator

The website contains the summary of the project, the objectives, the team members, and contacts. The websites were updated with the presentations that took place during the visits of the researchers to Belgium and Romania.

5. Executive Summary of Activities

Learning is a process of knowledge construction, and in this process, teachers and students are partners. Students no longer want to play a passive role in their learning process, but prefer to have an active role. Also, teachers need to facilitate learning and think about assessment, i.e. how to correctly diagnose student's lack of understanding and how to design better learning experiences to highlight the concepts and their understanding (acquired skills).

Our project investigates and proposes solutions related to both effective learning design activities and approaches to early diagnosis of misunderstanding, especially in an online learning context.

In 2022, to ensure the best collaboration between the Belgian and Romanian teams, online meetings were also held. These meetings were used to define and plan the activities that have been carried out.

Several research activities were conducted: analysis of practical problems and teaching materials by researchers and practitioners (teachers), development of tools for qualitative data collection about learning activities and/or concepts being taught (concepts inventories), data collection from practitioners and students (in different classes), data analysis by research team, and results (for all studies).

Research visits had the goal of improving the collaboration activities of the two teams. Teo research visits were carried out: during the week of 25 April 2022, the Romanian team visited the Faculty of Computer Science of the University of Namur and during the week of 21 November 2022 (3rd December 2022), the Belgian team visited the Computer Science department of the Babeș-Bolyai University. The occasion was used to present research activities and results of the research work of the two teams in front of an audience composed of local researchers in computer science. In Namur, the Romanian team presented research work (the grant objectives, methodology, implementation, analysis, and results of studies conducted to discover early diagnostic approaches). In Cluj-Napoca, the Belgian team presented their experience and activities in evaluating and improving learning experiences in computer science. The goal of those two seminars was to help disseminate the project work, the respective expertises of the two teams, and help foster potential new collaborations.

Furthermore, the time in presence was used to coordinate the data analysis activities for the collected data, as they require a high level of agreement between the analysts to provide relevant results.

6. Economic Capitalization of the Obtained Results

Our project studies efficient learning also in the e-learning context, from two perspectives: design learning activities for specific concepts and their understanding (acquired skills), thus providing early diagnostic approaches for misunderstandings of students.

Collaboration and knowledge transfer. Qualitative and quantitative analysis will be applied. The procedure for applying the qualitative analysis method will be transferred from the Belgium team to the Romanian team, and they will also be applied in classes at Babes-Bolyai University.

Generalization of learning design. Innovative e-learning designs generated are supported by bilateral cooperation in this project. The generalization of them may be sustained by the fact that the study will be applied to classes and students from both universities. Also, early misunderstanding diagnosis approaches will be used for different study levels: undergraduate and master.

Impact of results. The learning designs and diagnostic approaches obtained can improve both theoretical and practical parts of the software testing domain. The theoretical part refers to software testing courses that are taught in college/university. In the IT industry,

students will use concepts learned in the courses, so it will be better to make sure that students have understood the concepts before applying them incorrectly in industry.

Project managers,

PI Romania
Assoc. prof. dr. Vescan Andreea

PI Belgium
Prof. dr. Dumas Bruno