An Intelligent Tutoring System Concept for a Gamified e-Learning Platform for Higher Computer Science Education

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Abstract: Intelligent Tutoring Systems (ITSs) are increasingly used in modern education to automatically give students individual feedback on their performance. The advantage for students is fast individual feedback on their answers to asked questions, while lecturers benefit from considerable time savings and easy delivery of educational material. Of course, it is important that the provided feedback is as effective as direct feedback from the lecturer. However, in digital teaching, lecturers cannot assess the student's knowledge precisely but can only provide information on which questions were answered correctly and incorrectly. Therefore, this paper presents a concept for integrating ITS elements into the gamified e-learning platform *IT-REX* so that the feedback quality can be improved to support students in the best possible way.

Keywords: e-Learning; Intelligent Tutoring Systems; Feedback Strategies; Spaced Repetition; IT-REX

1 Introduction, Motivation, and Research Questions

In today's education system, more and more content is being taught to students via digital media. This has also been driven by the COVID-19 pandemic, which has primarily shifted classroom teaching to the computer or smartphone at home. However, universities are still trying to adapt to digital education efficiently. Although it may seem essential to increase students' morale, the resulting learning effect must be significant enough to be worthwhile. Therefore, to improve the effectiveness of digital tasks and assignments, it is necessary to evaluate all students' results and help them progress by guiding them in the right direction. To accomplish this, students must be offered individualized feedback and guidance based on their level of knowledge so they can further improve [HT07]. The interaction between lecturer and student in digital education leads to two major issues: (1) Improve lecturer feedback since it takes more time and is more complex in digital education than in face-to-face classes. If feedback is not given optimally, it tends to be less accurate and does not optimally support students [Su20]. (2) Increase student motivation to engage with the educational material and catch up on any deficits. Thereby, students often lack transparency in areas of teaching they have deficits and in areas they are already doing well [CLG10]. The objective is to achieve student motivation and participation with gamification elements from the IT-REX platform [Sp22].

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E-learning platforms are used to digitally distribute educational material to students and provide the opportunity to, e.g., upload and collect assignments, solve tasks, and view grades. The purpose of an *Intelligent Tutoring System (ITS)* is to supplement human lecturers with intelligent systems so that feedback to students can be expressed in an individualized and precise manner [WHK20]. ITSs are used not only to support students with individualized feedback but also to assess student performance and indicate the next steps accordingly.

This paper considers the gamified e-learning platform *IT-REX* [Sp22] as a basis for further integration of the ITS concept. Thereby, we explore how ITS elements could be used to improve digital teaching. This leads to our research question for this paper:

RQ1: *"How could an Intelligent Tutoring System help to improve the quality of feedback to students compared to established e-learning platforms?"*

2 Integration of the ITS Concept into the Gamified E-Learning Platform IT-REX

As described in the previous section, e-learning platforms and the ITS concept complement each other but are not systematically integrated into a single platform. Therefore, we provide a concept of how both approaches can be combined: We propose as a basis *IT-REX* [Sp22], a gamified e-learning platform that we have designed in previous work. Now we want to enhance *IT-REX* with an ITS concept. *IT-REX* enables lecturers to provide *lecture slides*, *videos*, and *quizzes* in an easy and structured way. However, an ITS needs more in-depth information about the relationships between these educational materials. Existing ITS in the field of computer science are limited to the complementation of textbooks, in which the fixed and consistent content is carried out without a teacher having access to it or being able to adjust it.

To capture relationships between educational material, we propose using tags to link chapters in lecture slides to videos, quizzes, and other material. Tags can also be used to create hierarchies between lecture topics, which can be used to navigate the student back to the introductory chapters if they get stuck on a particular topic. Furthermore, tags allow the ITS to provide detailed feedback to recommend the fitting material for the students to close their knowledge gaps. In addition, we propose that all educational materials include a textual description of the competencies in a lecture video or script to give students a quick overview of what they have learned. This initially requires much input from lecturers but can be addressed later, e.g., with artificial intelligence (AI).

Abb. 1 presents an overview of our ITS concept. In the remainder, whenever we write „*ITS*“, we mean the combined ITS components proposed by this work and included in *IT-REX*. This includes the student’s progress through a course, how the student improves skill levels within a course, learns new material with learning strategies, and consolidates existing

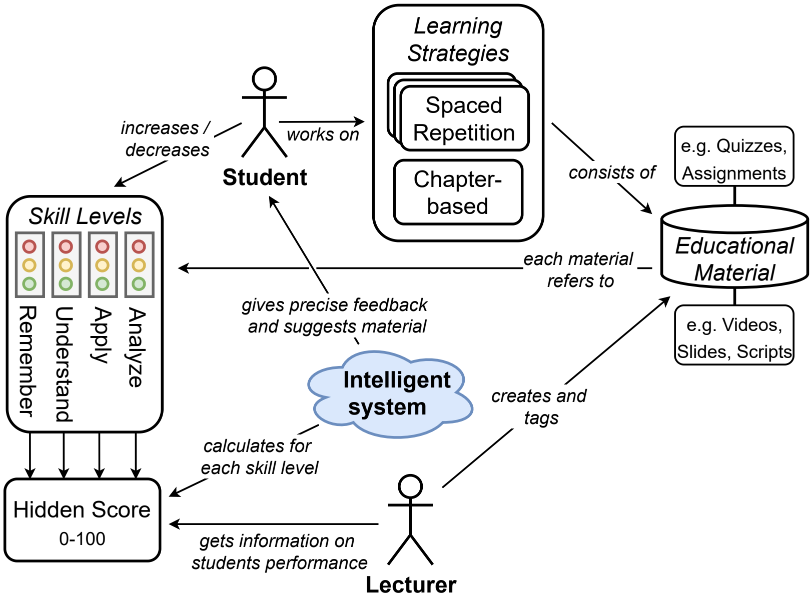

Abb. 1: Interaction of ITS components in the e-learning platform.

knowledge with repetitive tasks. The concept also shows the criteria used to measure and assess the student and how this affects the system's feedback to the student.

2.1 Skill Levels

Depending on learning taxonomies, the ITS assesses the students' skills, giving them an overview of the areas in which they need to improve. In learning theory, the learning objectives of learners are assigned to different taxonomy levels, depending on their degree of difficulty. A taxonomy is a kind of classification system. The best-known taxonomies are the *„Bloom's taxonomy levels"* [Bl73]. The taxonomy levels, according to Bloom, which are focused on in this paper exclusively, include [Bl73]: **(Remember)** Students are able to remember what they have learned, e.g., by remembering facts, terms, or concepts. **(Understand)** Students are able to understand what they have learned, e.g., by organizing, summarizing, or describing facts. **(Apply)** Students are able to apply what they have learned, e.g., by solving problems and identifying connections in new situations. **(Analyze)** Students are able to analyze what they have learned, e.g., by examining and breaking information into components or making inferences. These learning taxonomy levels are named „*skill levels*" in this paper and indicate different strengths and weaknesses of a student.

In our approach, we compute these learning taxonomies based on students' answers to course materials such as quizzes and assignments. Each quiz, assignment, and exercise of a course contributes to one of the skill levels. The ITS automatically determines the progress of the corresponding skill level based on the set tags and content of the assignment. For example, suppose the ITS detects that a quiz has been answered incorrectly. In that case, it will suggest to the student educational material from previous chapters or areas that address the task's basic information, thus repeating the skill level of remembering and understanding. This association is achieved through the previously described tags and is then applied by the system. This means that if a student has already missed the precondition of a question and fails it in the task, the ITS sends the student back to the fundamentals to learn them again. This shows the student what knowledge is required to solve the corresponding task.

2.2 Learning Strategies

Our approach includes two learning strategies that teach the student the course content and provide the knowledge within the e-learning course. Depending on the different learning strategies, feedback needs to be targeted differently to students. **(Chapter-Based Learning)** In higher education, chapter-based learning is most common, where the lecturers provide educational material for each chapter, and the students work through them one after the other. The individual chapters can either build on each other in content or be completely independent but are unlocked in a specific order. After the content of a chapter (e.g., videos or scripts) has been worked through by students, they can directly check what they have learned by answering a chapter quiz. Successful quiz completion is also a prerequisite for unlocking the next chapter. **(Spaced Repetition)** Spaced Repetition uses the concept of flashcards and is designed to reinforce what has been learned previously. The students have to answer questions from the previously learned chapters in random order. In contrast to the *„Leitner System"* [Le01], commonly used for flashcards, this concept does not manage the questions in virtual boxes. Instead, there is a question pool containing all the questions from the chapters worked on. If a question is answered correctly, it is added to the question pool after a specific time. If, on the other hand, a question was answered incorrectly, it is directly added back to the question pool.

2.3 Scoring System

Since students should not know the assessment and scoring system in the background of the ITS, it is called *„hidden score"*. Note that individual student performance may vary by chapter. This enables chapter-based feedback to be provided to each student. The hidden scores are, therefore, not only comprehensive for an entire course but also for the individual learning taxonomy levels. Thus, the student's performance at the individual levels is calculated and can be displayed individually per chapter within a course. Its value is in the range between 0 and 100. In calculating the score, several pieces of information must be considered to calculate an appropriate increase or decrease of the score. For this, we have developed the following metrics: (1) The hidden score grows less quickly if the student uses hints when answering a question. (2) The more frequently the same question is answered in a short period, the slower the hidden score grows. (3) If a question is answered correctly many times and then incorrectly once, the hidden score drops slowly at first. In addition, other metrics can be introduced into the score calculation, e.g., how much time was needed for a task or how often the answer was changed and corrected.

To show students their progress, traffic lights are used, which, depending on their color, describe the current state of knowledge. The color of the traffic light depends on the value of the respective hidden score. These visually appealing elements are key components of the gamified e-learning platform.

2.4 Feedback Strategy

Feedback is essential for improving knowledge and acquiring skills in educational contexts. The general purpose is to change student thinking or behavior to improve learning. There may also be feedback for lecturers regarding the effectiveness or efficiency of their instructions, but this paper focuses exclusively on feedback for students. While it is considered that well-structured feedback can drastically improve student learning, it also emphasizes that feedback must be given correctly and at the right time [FG11, Sh08]. The following types of feedback are used in our approach, ranked by complexity: **(Verification)** Tells the students whether their answer was correct or incorrect, also known as *„knowledge of outcome"*. **(Correct Response)** Tells the students the correct answer without additional information, also known as *„knowledge of correct response"*. **(Try again)** If an incorrect answer is given, the students have one or more attempts to correct it, also known as *„repeat-until-correct"*. **(Topic contingent)** Provides more detailed feedback on the general topic of the question and may take the form of a simple repetition of the material. **(Response contingent)** Provides more detailed feedback based on the student's specific answer, usually giving the student information about why their answer was wrong while explaining the correct answer. These types of feedback can be used in combination with each other and with different timings - immediate or delayed. Which feedback each student receives is decided at different layers. This is done in the form of a decision tree and includes the following layers: **(Student achievement)** The overall performance of a student. **(Task level)** The difficulty of the task; divided into a lower and a higher level. **(Timing of feedback)** The timing of the feedback, either immediate or delayed. **(Prior knowledge)** Students' prior knowledge through the previous completion of the task, divided into low and high. **(Amount of repetitions)** The number of repetitions depending on prior knowledge. **(Hint types)** The types of hints are divided into three different categories: (1) Orientation guides attempt to summarize or describe the overall topic and present the problem space in a more precise picture. (2) Instrumental hints attempt to provide more specific advice to the student based on individual questions. (3) Bottom-out hints, usually the answer itself.

3 Conclusion & Future Work

The presented concept of aligning with feedback strategies in a gamified e-Learning platform to achieve the best possible success could greatly help students increase their success in learning. While other ITS approaches target a specific domain and tailor it to it, this concept is domain-independent and could fill any potential scope. To evaluate our research question, we need to analyze student responses, assess learning outcomes in a case study, and examine student reactions to various forms of feedback. This case study is part of our future work.

At the current state of the concept, the lecturers still have to give a lot of input into the ITS to make it work. This could gradually move toward using more AI and thus being trained to automatically mark videos and quizzes to link them together. Using AI will make the ITS smarter and take additional work away from the lecturers. Another possibility would be to implement and use a filter to detect irregularities and errors and ensure error tolerance. In relation to the calculation of the hidden score by the ITS, this filter would be able to assess error tolerance so that the student's ability level can be correctly estimated even if the student should answer the same question incorrectly once after having answered it correctly several times.

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