An Intelligent Computer System for Assessing Student Performance

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Abstract—The purpose of the study is to identify and compare the influence of formative and summative assessment approaches based on an intelligent computer system that provides automatic feedback; the assessment is carried out in paper format, but obtaining feedback requires an appointment with a teacher. The study was conducted among 50 students in I.M. Sechenov First Moscow State Medical University (Russia) and Wuxi Institute of Technology (China). The assessment was carried out based on online tools and an intelligent learning system (ASP.NET web applications and MCQ tests). It was found that the average score of the formative test of students who passed an assessment test in the electronic format is higher than the score of those who passed the test in the classroom \( t(165) = 5.334, p < 0.05 \). Pearson’s correlation coefficient in the experimental \( r^2 = +0.329; p = 0.009 \) and control \( r^2 = +0.176; p = 0.076 \) groups confirmed a significant positive correlation. The solution can be integrated into the educational process as an additional student tool that will reduce the burden of teacher workload and increase the assessment objectivity along with the overall performance of students.

Keywords—Artificial intelligence; computer technology; e-learning; formative assessment; summative assessment.

1 Introduction

Modern higher education should encourage the development of professional competencies, teach students to solve complex problems, and motivate them to continuous self-education [1]. Today, information technology has become an important learning component and e-learning is developing at a faster pace [2,3]. The rapid development of computer applications and Internet technologies makes e-learning an integral part of the educational process [4]; this is the easiest way to access educational materials as each student has a tablet, laptop or a smartphone. Students can receive, complete, and take assignments through the Internet. The teacher can conduct exams, quickly assess student knowledge, and communicate results to students.
Assessment is an important component of the educational process as it allows students to quickly understand their own achievements, helps to develop self-monitoring, self-diagnosis and self-education skills in order to stimulate enthusiasm and thereby improve the quality of education [1]. Nowadays, there are various options and assessment mechanisms in the education system [5]. For example, testing has been widely used: Students are offered examination assignments based on true/false options, coincidence, multiple-choice or short answer. However, a traditional paper-based exam makes each teacher create an examination sheet, develop answer options, conduct an exam in the classroom, and then manually check the answers. This is a time-consuming process that may be accompanied by errors during the assessment. An automated system for conducting and evaluating exams or performance monitoring is not characterized by such drawbacks. It is a computer system that is used to test students' knowledge. The system is based on information technologies that combine the content of the training course, exam questions, and assessment modes; this provides informative test management for assessing student performance [3].

The systems of automatic academic certification of students have apparent advantages; therefore, they are actively being introduced into universities all over the world. Computer-based knowledge assessment of individual students makes it possible to classify students focusing on various factors, such as managing student performance, planning instruction and developing professional knowledge [6]. Research offers a variety of software and tools for the effective assessment of knowledge and stimulating student development, ensuring knowledge management, information exchange and communication. For example, a student assessment system for e-learning has been developed based on biometric technologies (voice analysis), self-assessment, intelligence tests and other methodologies [7]. The system of biometric and intelligent self-assessment of student progress (biasp) is widely used; the feature of self-assessment and teacher assessment allows the user to analyze the educational situation without examinations [8]. A comprehensive student assessment system based on the “model - presentation - controller” architecture implements the adjustment of the content, dynamic scoring, and other functions. There has been scientific research devoted to the mental assessment system in academic and career planning [9].

In the late 1950s and early 1960s, there was a great interest in developing systems for individual learning, which are known as intelligent or computer-based learning systems. They combine technological approaches and teaching pedagogy, knowledge and student models. Over the years, the interest in creating learning systems has grown; the integration of intelligent systems in education has become large-scale due to the socio-technological wave of Web 2.0 and Web 3.0. [10]. Today, the concept of Education 4.0 is being widely introduced. The term was coined due to the new social development era - Industry 4.0 - supported by computer technologies [11]. It was designed to meet the needs of the education sector through the improvement of artificial intelligence features [12] with a focus on seven aspects: personalized materials prepared for various types of training (interactive books and videos); elements of virtual reality; mobile connection (students use their own smartphones to access and interact with the system); course modules (adjusted to the needs of each student); learning analytics (tracks performance
and provides support programs); intelligent teachers (chabot with a robot teacher); electronic assessments [13].

The present study assesses the knowledge of medical students of I.M. Sechenov First Moscow State Medical University (Russia) based on an intelligent computer system for assessing student performance that provides feedback and formative assessment. The technical solutions were provided by the researchers from Wuxi Institute of Technology (China). The research is innovative in terms of the following two aspects: the platform-based assessment system (ASP.NET) is synchronized with course materials, creates formative tests, and comprehensive examination papers; it is available to a number of users via the Internet. Assessment elements are updated in accordance with the course progress; the system can provide feedback, implement online testing and adaptive management. The study compares the impact of the following two approaches on student performance and summative assessment: formative assessment based on an intelligent computer system with automatic feedback and paper-based assessments with face-to-face teacher feedback.

1.1 Intelligent systems in education and knowledge assessment

Intelligent systems have been introduced in the social sphere, transport, engineering, and healthcare in a number of countries [14]; universities also implement artificial intelligence systems to address administrative and methodological problems. Artificial intelligence systems make higher education more advanced by allowing it to retrieve and analyze external data to find out what skills are required in certain jobs, and then recommend changes to curricula and modules [15].

An intelligent computer system can be defined as the capacity of machines and systems to acquire and apply knowledge, as well as demonstrate intelligent behavior. This is the process of simulating human thinking by a computer [16]; a computer becomes an expert because it has been trained and tested by experts. Artificial intelligence reproduces the findings of intelligence and behavior-based analysis [17]. User interactions become an ecosystem that influences the development of the platform [18].

Machine learning is an important component. This is an element of Machine-to-Human workflows [19] that involves teaching a computer to carry out processes performed by people using an algorithm that can predict the result or continue the process [20]. The computer can recognize the real situation in order to make a decision. New data contribute to better result forecasting [21]. The introduction of systems can increase the productivity and efficiency of decision-making, as well as reduce costs by allowing data processing data on a massive scale, and identifying complex cause-effect relationships [22].

The application of intelligent computer systems is closely linked with the modern Education 4.0 model, which helps education meet the industry requirements, and ensures close partnership between the sectors of the economy, social sphere and the academic environment [12]. Education 4.0 evolved from Education 3.0; the teacher promotes collaborative knowledge combined with the e-learning portal based on intelligent systems (Fig. 1).
In education, artificial intelligence is used in personalization, automation, code deployment, predictive analytics, and security improvement [24]. At the resource level, artificial intelligence interacts with students; and in the business software, it changes the behavior of teachers and students and affects supporting tools, such as educational processes and their structure, as well as the content delivery [25].

It is believed that artificial intelligence technology can almost completely replace the teacher as the system has a built-in assessment function. Assessment is traditionally included in the teaching and learning process: skilled and experienced teachers are able to make an instant assessment of their activities and student performance in order to quickly decide on a second explanation, modernization of the course module, and the need to provide more material. At the same time, there is a large amount of work that teachers should take home. This includes the development of the course content and tests, material update, as well as the assessment of academic achievements. An intelligent computer system can evaluate student performance through the built-in function [13].

A number of online learning systems based on artificial intelligence include diagnostic assessments that allow teachers to analyze current knowledge of their students, predict their learning outcome and willingness to accept new information. This function is traditionally performed by the teacher who evaluates academic achievements of students and concludes whether they can continue further studies on the basis of professional experience. The advantage of artificial intelligence here is that it can automatically manage the learning needs of students, provide practical tasks and track the progress of individual students and groups offering feedback to both students and teachers. Feedback is provided as instant messages and tips that describe mistakes and recommend revising the related course material with a subsequent formation of its sample [26].

Today, the most common type of built-in assessment is a model developed on the basis of traditional test tasks. The intelligent algorithm selects test tasks from the question bank, divides test items into categories by their complexity, and provides assignments in accordance with the learning objectives [26].
Intelligent systems are increasingly used in areas where it is necessary to efficiently and accurately cope with large volumes of unstructured data, such as, for example, in medical diagnostics; therefore, in medical universities, such systems are taught to evaluate detailed verbal and written answers, for example, essays or the diagnosis. A group of highly qualified experts teaches the artificial intelligence engine, develops the standard pool of answers, which is later used in the assessment (Fig. 2).

The intelligent system scoring is based on the technology of latent semantic analysis (LSA), which is a natural language processing method that can analyze and evaluate texts based on the semantic meaning of words, and not just their surface characteristics. First, a text recognition model for a particular language is established; human experts teach the engine to evaluate each test element. Experts in a particular field provide hundreds of verbal explanations, which are later used to train the engine and formulate a standard response. After that, the program is tested by checking the correlation between the artificial intelligence assessment and the expert opinion. The correlation range between .95-.99 indicates that the machine will assess the response within the accuracy of 95-99% of the teacher assessment. At the same time, intelligent systems ensure the major knowledge assessment requirement - objectivity and accuracy; no student has the advantage of a positive teacher attitude [27].

1.2 Summative and formative knowledge assessment based on intelligent computer systems

Different approaches to measurements in the educational process give rise to different practices of their implementation; however, historically, the purpose of measuring student performance is to identify the differences that allow ranking students by their academic achievements. This type of measurement is based on the summative (final) assessment [28]. The summative grade reflects the traditional approach used to evaluate educational outcomes; students usually get it at the end of the academic year (exams). The advantages of the approach are that the summative assessment allows comparing student performance in different groups according to specific educational standards; it provides reliable data that are used for reporting and informs the governing bodies of
the education system [29]. However, it is not very relevant to day-to-day learning and student learning support.

Student-centered measurement models rely on formative assessment, which contributes to the teaching process and student support. Formative assessment is student feedback [30]. It refers to a progressive approach, which assumes that the purpose of assessment is to develop and support teaching and learning, as well as to make adjustments. Formative assessment can be provided much more often in order to give students feedback, suggest measures to improve the results and adjust the curriculum to current needs [31]. One of the model drawbacks is that the formative assessment is often carried out in a non-standardized and less rigorous manner than the summative assessment. This can impede the validity and reliability of the assessment tools and data [30].

Intelligent systems provide both types of assessments - summative and forming - and eliminate the problems of a unified approach to measurement in favor of an individual approach to each student. Students acquire knowledge by solving problems chosen to meet their needs. First, the system evaluates current student knowledge, accumulates information about the student, and considers the course material to be digested after the course/module completion. Then, artificial intelligence decides which content unit should be presented next, generates a problem, and develops its solution or extracts a ready-made solution. Student solution is compared with the artificial intelligence solution and the diagnostics is performed. After that, the system provides feedback and recommendations, and the student profile is updated [32].

The intelligent system, which includes formative and/or summative assessments, shapes student behavior that indicates key skills and knowledge. In addition, the system provides interpretations of this evidence in terms that are consistent with the assessment purpose. Thus, the combination of formative and summative assessment information in intelligent systems opens up new opportunities that can improve learning outcomes and student performance.

2 Methods and Materials

This study involved teachers of I.M. Sechenov First Moscow State Medical University (Russia) and Wuxi Institute of Technology (China). The educational module devoted to the study of human body systems was selected for the experiment. The module duration was 6 weeks. The module content included various academic disciplines (anatomy, physiology, biochemistry, pathology, clinical skills). The uploaded interactive materials were checked by a group of technical experts and teachers of the disciplines.

The students were provided with teaching aids and materials through the e-learning system. Researchers from Wuxi Institute of Technology developed online tools to support the intelligent learning system based on the ASP.NET web applications and electronic assessment, including online MCQ tests. Multiple choice question (MCQ) format is easily integrated into the learning environment through test automation. Add-on packages have also been developed; they are used to provide students with feedback on incorrect answers and to explain the mistake.
It was expected that 80 people would participate in the study; there were 80 invitations sent by email and only 50 of them were accepted. Thus, 50 four- and five-year students aged 21-23 participated in the experiment. 

In order to compare the impact of the following two approaches on student performance and summative assessment: formative assessment based on an intelligent computer system with automatic feedback and paper-based assessments with face-to-face teacher feedback, the participants were randomly and equally divided into two groups:

- Group A was asked to take formative tests based on an intelligent computer system; the feedback was provided by the system
- Group B took formative tests in paper format; the feedback was provided by the teacher.

Group A used their usernames and passwords to access the interactive platform.

The statistical data analysis was carried out based on the statistical package for the social sciences (SPSS). Standard deviation was calculated in order to estimate the deviation of the values from the average indicator. The average summative assessment of Group A and Group B was compared based on the t-test [33]. The relationship between the formative test result and the summative test result was determined by the Pearson correlation coefficient [34].

Each participant allowed us to collect and use the data. The information on the achievements of each participant is confidential and will not be disclosed.

3 Results

The composition of participants by courses and gender is shown in Table 1.

| Category                  | Group A | Group B |
|---------------------------|---------|---------|
| Men                       | 41.6%   | 38.2%   |
| Women                     | 58.4%   | 61.8%   |
| Subgroup 1 (4-year students) | 43.9%   | 45.8%   |
| Subgroup 2 (5-year students) | 56.1%   | 54.2%   |

The teachers of I.M. Sechenov First Moscow State Medical University (Russia) developed a six-week module; the classes were given weekly in units of 90 minutes. Each unit was followed by homework. Group A and Group B studied the module in the classroom. The students had to take a formative test every two weeks. 

Group B was offered a 30-question formative MCQ test, which they took in the classroom being supervised by the teacher. Having checked the tests, the teacher, who was the module coordinator, provided feedback twice commenting on the assessments in the classroom. The feedback was projected in a PowerPoint presentation after the module coordinator discussed the paper test with the student.

Group A also had an opportunity to take formative tests every two weeks. They were asked to take three formative MCQ tests online. Each test consisted of 30 multiple-
choice questions. Feedback was automatically provided after each attempt to answer a set of questions. The interactive test was based on the interactive software. The students took the tests in a computer lab or on a personal computer. The tasks were developed based on the educational practice of the teachers of I.M. Sechenov First Moscow State Medical University.

After completing the module, the participants took an exam. The tasks included 40 multiple-choice questions, essay questions, and structured practical questions. Group A and Group B were assessed in a different way. Group B was assessed by the teacher and Group A - by the artificial intelligence system. Then the assessments of Group A were rechecked by the teacher. Thus, the program the reliability of the program was analyzed. There was 99% agreement.

The statistical data analysis was carried out based on the statistical package for the social sciences (SPSS). Standard deviation and the t-test were calculated in order to estimate the deviation of the values from the average indicator. The relationship between the formative paper test result of Group B and the summative test result was determined based on the Pearson correlation coefficient. Similarly, the relationship between the formative computer test of Group A and the summative assessment was also verified by the Pearson correlation coefficient. It was determined that the p-value is <0.05, which allowed us to conclude about statistical significance.

The average summative grade at the end of the module was almost the same in the interactive environment group of students. Group A and Group B results are shown in Table 2.

| Category | Subcategory | Group A (Average ± SD) | Group B (Average ± SD) |
|----------|-------------|------------------------|------------------------|
| Gender   | Total       | 56.3±12.3              | 56.8±13.7              |
|          | Men         | 60.1±13.7              | 56.6±13.6              |
|          | Women       | 53±9.9                 | 57.3±13.8              |
| Subgroup | subgroup 1  | 62.5±13.8              | 58.1±12.8              |
|          | subgroup 2  | 51.2±8.8               | 54.5±13.9              |

It should be noted that in Group A, male students demonstrated a higher average grade. The average summative assessment of female students was higher in Group B, which took a traditional test in paper format. The average summative assessment was higher in subgroup 1 belonging to Group A (interactive testing) compared to the same group of students in Group B (paper testing).

The comparison of the results of the formative test between the experimental and control groups by gender and subgroups is carried out below (Table 3).
Table 3. Comparison of the results of the formative test between the experimental (A) and control (B) groups by gender and subgroups

| Category       | Subcategory       | Group A (Average ± SD) | Group B (Average ± SD) |
|----------------|-------------------|------------------------|------------------------|
| Gender         | Total             | 61.8±17.7              | 49.3±12.7              |
|                | Men               | 60.8±21.3              | 52.7±12.1              |
|                | Women             | 62.6±13.8              | 46.9±12.7              |
| Subgroup       | subgroup 1        | 71.9±16.3              | 52.1±10.1              |
|                | subgroup 2        | 58.3±16.8              | 46.1±11.8              |

Subgroup 1 in Group A (online formative testing) demonstrated a higher average formative test result (Table 3) compared to the same subgroup in Group B. This group received the poorest average summative assessment. The average result of the online formative test in Group A was much higher than the result of the paper test in Group B. However, the differences between the individual grades in Group A were greater as evidenced by a higher standard deviation.

It turned out that both male and female students of Group A, who were tested online, showed better results compared to Group B. Compared to the difference in the summative assessment, subgroup 1 demonstrated higher average scores in the formative test. The average score of the formative test in Group A was much higher than in Group B [t (165) = 5.334, p <0.05] (Fig. 3).

![Fig. 3. Comparison of the formative and summative scores of Group A and Group B.*](image)

Note: 1 - Group A, scores of formative computer tests; 2 - Group A, experimental online exam scores; 3 - Group B, formative paper test scores; 4 - Group B, experimental paper exam scores; * the independent sample t-test of the average summative scores of Group A and Group B, t (165) = -0.254, p> 0.05; the independent sample t-test of the average formative scores of Group A and Group B, t (165) = 5.334, p <0.05.

The final test scores and the formative test score of Group A were checked for correlation. In Group A, the Pearson correlation coefficient showed a positive ($r^2 = +0.329$) and significant (p = 0.009) correlation between the formative and summative assessment at the end of the module. An additional analysis of the data based on SPSS tools showed that a higher formative test score will contribute to a higher (32.8%) final exam score.

The summative and formative assessments of Group B were also checked for correlation. The Pearson correlation coefficient showed a positive ($r^2 = +0.176$) and significant (p = 0.076) correlation between the results of the formative and summative tests at
the end of the module. An additional analysis of the data showed that a higher formative test score will contribute to a better (17.6%) final exam score. It was found that the proportional productivity growth in Group A is almost twice as high as in Group B.

4 Discussion

New intelligent computer systems expand the assessment capacity of traditional systems. Some of the improvements include new methods of measurement borrowed from psychology and cognitive sciences; however, intelligent design initially did not require the participation of psychometrists. Modern advances in intelligent systems, cognitive science and education make it possible to integrate assessment and learning into new and powerful intelligent systems. They have the potential to improve learning experience and standardized test results. The development of an adaptive assessment methodology that improves the quality of the examination system by integrating an intelligent computer model is of interest [35]. It is proposed to use an adaptive assessment system with a database combination [36]. This approach increases exam efficiency by selecting questions in several forms. A computerized exam system reduces the workload associated with the development of exam papers, eliminates the need to come to the classroom, and improves the quality of the assessment process. The methodology of an intelligent exam system consisting of four modules is proposed (user management, course management, question and answer, examination and assessment management). An intelligent question bank system consists of a set of questions of different complexity. The major advantage of the method is the analysis of the student mastery of certain course modules [37].

In more complex simulated learning environments based on artificial intelligence, students interact with objects to conduct research, experiments, tests; they gain not only theoretical knowledge, but also practical skills. For example, in the EcoMUVE curriculum, a student dives into a multi-user virtual environment observing problems and trying to solve them [38]. At the same time, the actions and decisions made and implemented by the student in a virtual practical environment are constantly and unobtrusively evaluated in order to subsequently suggest solutions to the identified problems and lack of knowledge [39]. A number of universities use cloud-based e-learning systems, which increase the convenience of studying educational materials and assessing knowledge in the digital age. Cloud systems have evolved as e-learning cloud business models with a five-tier architecture, which includes hardware and software, resource management, services and business applications, as well as infrastructure, content, and applications [40].

Detailed answers are difficult to evaluate due to the factor of the subjective teacher attitude and time expenditure. An alternative to manual assessment is the integration of computer technology assessing a written assignment, for example, an automatic essay assessment [41]. The system uses a computer program that builds an assessment model extracting linguistic functions from the answers. An automatic essay assessment supplements selected response testing currently used in medical education. This practice is considered especially relevant to medical students who have to be able to describe the
clinical picture. It has also been proposed to introduce modified essay questions (MEQs); the assessment tool allows intelligent systems to evaluate a reasonable and integrated insight into the phenomena and processes within the instruction topic or subject [27]. It is proposed to use advanced intelligent systems, which monitor the behavior of students when assessing their knowledge, create an individual learning environment by modifying exams to suit student’s personal characteristics [42].

Advanced universities use artificial intelligence and big data platforms to support and mentor students while considering constantly changing employers’ requirements for graduate competencies [43]. Automatic feedback provided by an intelligent computer system can be complemented by the tutor who gives a detailed personal description, predicts grades based on previous learning outcomes and performance indicators [44]. It is proposed to use artificial intelligence systems at the stage of grouping students to select those who will be able to maximize their potential in the subject area [23].

5 Conclusion

Traditionally, summative assessment has been considered as an indicator of the learning process. It has been revealed that there is a positive relationship between online formative testing with automated feedback and summative assessment. The analysis has shown that frequent online formative testing with automatic feedback will contribute to the summative score of students. An additional analysis of the data has shown that a higher formative test score will increase the final exam score by 32.8%. At the same time, regular feedback (after each attempt) and an individualized instruction almost double student performance. The summative assessment of the group which received teacher feedback increased by 17.6%.

The positive correlation between the formative assessment and the summative assessment based on an intelligent system confirmed a positive effect of the approach on student performance. Male students showed the best results in online testing compared to female students who succeeded in paper format. In particular, this can be explained by the fact that there were more women in Group B (61.8%) than in Group A (58.4%).

As for the research module limitations, it should be noted that medical education cannot be completely transferred to the online environment due to the specific knowledge and practical skills needed by medical staff. When there is no teacher-centered learning, some students may lack motivation for passing formative tests and measuring knowledge online. Compared to the traditional approach that makes a student take an exam in the classroom, online assessment requires an initial investment of time, as well as a systematic and innovative approach. This will allow developing a course module that suits the students’ desired competencies. It has been concluded that talented students can independently regulate the learning process through formative testing at the intermediate stage of exam preparation. Firstly, a wide range of questions that can be loaded into formative tests contributes to better student performance. Secondly, online feedback is faster. The student does not need to arrange a consultation with the teacher to discuss the mistakes. There is an instant feedback.
This development can be integrated into the educational process as an additional tool to support students who are involved in studies and are scrupulous about their learning outcomes. It is also feasible to use intelligent computer systems to assess formative and summative tests or clinical essays that can be verified by artificial intelligence. The implementation of the system will significantly reduce teacher workload, provide more objective results, and improve summative scores.

6 References

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