COMPUTER-BASED ASSESSMENT AS A METHOD FOR ENFORCING PROFESSIONAL COMPETENCIES OF IN-SERVICE PRIMARY MATH TEACHERS

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Abstract

Computer-based assessment (CBA) is a method of learning and for learning. Nowadays, CBA is used in primary math education to develop interactive tests with immediate feedback. Multiple choice questions, matching, and other 'objective' types of items and its intelligent analyzer are the base of CBA. The diversity of the items, the types of answers, the type of feedback, and delivery considerations must all be carefully taken into account when developing an effective pedagogical design in general and for primary students in particular. However, the problem is that pedagogical design may be approached from the perspective of linear, systemic, and metasystemic thinking. This article investigates the affordability of Metasystems Learning Design (MLD) theory for CBA in diverse learning environments. Our previous research has demonstrated that the MLD principles implementation in educational software for primary math education has increased students' motivation to learn for those who received low marks at paper-to-pencil evaluation and, therefore, they performed better. This outcome can be used as a premise for future investigations of MLD and its applications in pedagogical design. The conceptual response to this question depends on how adult learning is incorporated into the in-service teacher preparation methodology during the twin transition period to learning society.

Keywords: math education, teacher training, computer-based assessment, immediate feedback

1. Introduction

A systematic process of gathering information from tests, surveys, exams, and other sources is known as assessment. It is used in traditional classroom settings as well as online learning to find out more about how well students are doing and how well they are responding to their educational institutions' programs of study. Either paper and pencil or computers can be used for assessment. The method of using computers for assessment, measurement, testing, and evaluation for educational purposes is known as *computer-based assessment* (CBA). This method, which has been in use since the 1950s, has undergone numerous improvements. On one hand, there are multiple definitions. Thus, CBA is (a) a 'method for learning on students' learning outcomes' (Van der Kleij, et al., 2012), a 'versatile education tool' (Thelwall, 2000), a tool 'to provide timely information on their academic progress' (Helfaya, 2019), etc. and it is used as an integral part of Computer Aided Learning (CAL) environments in formal and non-formal education. On other hand, there are some issues related to the 'affective-motivational effects of performance feedback' (Kuklick & Lindner, 2023) and the advantages of the assessment tool for early literacy skills (Bastianello, Brondino, Persici, & Majorano, 2023).

The unique characteristic of CBA is the analysis of item tasks with immediate feedback. Research suggests that primary teacher and their students pay more attention to immediate feedback than to delayed feedback. As was observed by Miller (2009), immediate feedback on CBA is used to support learning rather than measure students' learning at the end of the module. The 'acceptance' of CBA by teachers of primary students is crucial for the development of a computer-based assessment (CBA). By acceptance, we mean the interest, curiosity, and motivation to use CBA in the teaching-learning process. The advantages of CBA versus paper-and-pencil tests are the affordability to generate items and tests (Nguyen et al., 2017) and the intelligent analysis of students' answers (Yildirim-Erbasli & Bulut, 2023). However, everyday teaching practice in elementary math has put the method of CBA under the lens, especially in the case of the twin transition to a global knowledge society (Foster, 2023) – an approach used to foster the importance of digitalization and the greenest of technologies.

The majority of CBAs used in primary education are computer-based tests (CBTs). A computer test, a procedure for determining students' performance by delivering scholarly tests through a computer network medium, is the fundamental idea behind CBTs. This type of assessment can be given in oral, written, or mixed form using any digital device, such as a computer, smartphone, etc. CBTs are used in primary education as a diagnostic, formative, and summative assessment. Diagnostic assessment, developed in form of short answers and multiple-choice items, has the power to motivate all students. However, many researchers contend that formative assessment is the most significant type of evaluation (Bennett, 2011; Black & Wiliam, 2009; Bulut, et al., 2023; Yan & Chiu, 2023). Summative evaluation, which traditionally "measures" learning outcomes, could, in our opinion, be used as a learning strategy as well as a means of evaluating students' performance following a didactic process.

The pedagogical scenario of CBA thus presented itself as a good observatory to focus on teachers' knowledge in instructional / learning design, their' professional competencies in designing inclusive learning environments; and to establish whether and to what extent the core competencies of students are affected in one or another way by computer-based learning environments. The main aim of this study is to determine if there are psychological and pedagogical aspects of CBA that can be improved to make it more effective and, ultimately, to widen its adoption in schools. With this purpose in mind, it was conducted a study in the Republic of Moldova within a teacher-training module related to CBA in school education.

2. Theoretical background

Assessment and appreciation are the two methods used in the formal education of primary students. Assessment is a measure of performance/competence following certain norms and standards; and appreciation – of the decision-making process related to performance, and quality of learning outcomes in form of knowledge, skills, and attitude. This distinction can be seen in primary math education when teachers "appreciate" some students more than others (Gadanidis & Cendros, 2023; DeLegge & Kaur, 2023; Engelbrecht, Borba & Kaiser, 2023). Moreover, appreciation is more about appreciative intelligence and less about texting.

Traditionally, in the pedagogical design of CBA and CBTs is used Bloom's taxonomy is (de Bruyn, E., Mostert E. & van Schoor, 2011). The affordability of the immediate feedback, however, limits this strategy to only evaluating the lower levels of action verbs in Bloom's taxonomy, such as remember, select, solve, and classify (Armstrong, 2010). According to Mayer (2002), the taxonomy for CBA of problem-solving should include four categories of knowledge (i.e., factual, conceptual, procedural, and metacognitive) based on the Anderson et al. 2001 revised taxonomy. In his opinion, problem-solving is a cognitive process. This approach contradicts with STEM*x* paradigm, according to which primary students need cognitive, metacognitive, affective, and social learning strategies.

For instance, Nimasari, Gestanti, and Nurfitri (2023) highlighted that critical thinking skills are demonstrated in tasks that require analyzing, evaluating, and producing new content.

Let's examine this issue more thoroughly. The basic concept both of CBA and CBTs is the *test item*, which refers to a specific question or problem test takers are asked students to perform. Both closed-ended and open-ended questions can be included in the test item, such as true/false, multiple choice, completion, matching, and rating scales. Open-ended questions, in contrast, can be answered in more or fewer details, are more general, and can therefore integrate cognitive and metacognitive tasks and use constructive or/and elective answers. Metacognitive tasks are incorporated in an all-inclusive or selective learning portfolio.

In our opinion, three different paradigms of thought are used in the pedagogical design of cognitive and metacognitive tasks. This concept was initially investigated in an analysis of usage and development trends for digital textbooks (Railean, 2014). Therefore, in the case of CBA and CBTs the linear paradigm uses a *step-by-step* model of thinking. For instance, the instructional design of CBTs is related to 'linear testing' (Yildirim-Erbasli & Bulut, 2023), and, therefore, students are unable to move backward in changing their prior answers. Nevertheless, this approach offers several advantages over paper-and-pencil testing (PPT), such as flexibility of design, easy administration, and objective scoring (Brüggemann et al., 2023).

System thinking emphasizes considering the whole rather than individual parts. The main examples are intelligent tutoring and computer-based adaptive testing (CAT), in which the process of generation of the test items is intelligent and "adapts" to the knowledge level of those being tested. Thus, each test-taker receives a ‚unique test' presented at the most appropriate level of difficulty. Moreover, each educational system is like a tutor which operates in discrete steps. This means that each ‚new problem' is broken down into manageable steps, and is presented in form of a cycle, and each student must complete one step before moving on to the next. As an illustration, if a student completes step I, the current value of his or her input for the following step will be *Xi*, and the student's internal cognitive state will be *Si*. These values could be transformed into the output value *Xi+1* with state *Si+1*, and so on, following the corresponding procedure.

The problem is that in real life, tasks are ideally adapted to each solver. Metasystems learning design theory is concerned to answer by following questions: (a) Who is the actual learner?; (b) What are his/her ability and level of motivation?; (c) What environments does he or she live and learn in?; (d) What are the specific features of educational system/learning environments in times of openness?; (e) How do digital screens impact learning? The metasystems approach pieces of evidence the impact of a student's (meta)cognitive drive to learn in a diversity of learning environments, both physical and virtual; the role of digital screens on learning capacity; and the importance of ecosystems of learning and communication in an affordable pedagogical design. The learning environment in which CBA and CBTs are used should be more "inclusive" and should not rely only on the teachers' ability to gauge student progress. According to Klir (1990, p. 325), meta*X* is used as the name of things or systems, which are more than *X* in the sense that it is more organized, has a higher logical type of organization, and is analyzed in a more general case. Therefore, the metasystems approach requires more intelligent analysis of students' answers. This viewpoint examines both the direct and indirect effects of learning on changes in thought and behavior. The direct effect refers to using CBTs both in formative and summative assessment and indirect – development of the all-inclusive digital portfolio.

In an attempt to understand what the current knowledge, skills, and attitudes of schoolteachers are concerning the pedagogical design and application of CBA and CBTs it was conducted an online survey targeted schoolteachers in science.

Particularly, it analyzed the data of students who participated in the pedagogical experiment in which CBA for studying math was used. Our research questions are, as follows:

- What approaches do teachers in science, math, and technology use to evaluate CBA, in general, and CBTs, in particular?
- What is the importance of CBA and CBTs in the development of core competencies from the perspective of students?

These research questions were formulated starting from the CBA and CBTs specific features that, according to research literature, should characterize the affordability of pedagogical design and focus on core competence development of students interested in science, math, and technology. In our understanding, building on a solid numeracy foundation, the focus of mathematical, science, and technology competence is not only on knowledge but also on processes and activity, which could be applied in solving real problems. Therefore, by examining these research questions, we think to understand whether and to what extent the state-of-the-art in CBA and CBTs could be recommended for courses on teacher preparation. The final aim of this article is to highlight the psychological and pedagogical aspects of CBA and CBTs that could be improved from the perspective of teachers' and students' experiences to make this approach more effective and ultimately to widen the adoption of metasystems learning design in every practice.

3. Methods

3.1. Data collection, research context, and participants

In the endeavor to find answers to the above-mentioned research questions, it was adopted a mixed qualitative-quantitative approach of design a pedagogical experiment. First, data were collected through an online survey tool consisting of questions purposedly build to investigate the primary research question. The questionary for the survey was developed by the author. Online surveys aimed to elicit from respondents their habits in the didactical design of learning environment and teaching behavior. The survey was implemented using Google Forms and comprised a total of 14 questions. It was structured in two sections, as follows:

- General information about the respondents
- The evidence offered by teachers regarding their habits and teaching behavior

The second amount of data was collected from students, who took the CBTs after classes. Both procedures were presented before the module "*Computer-based assessment*" of the course in pedagogy for the training of teachers in science, math, and technology. Formal approval by the ethics committee was not required due to the type of data collected.

Overall, 64 teachers and 24 primary students participated in the pedagogical experiment. The most of teachers (78.1%) were between 21-30 ages. This unbalanced age ratio is a reflection of the current interest of in-service teachers in science, math, and technology for creative learning strategies that may enhance teaching competencies and, as a result, the cost-effective pedagogical approach of learning design. In terms of teaching experience, they work in a town/city (95.3 %) and most of them have a diploma in higher education (48.4%).

3.2. Data analysis

Two ways for data analyses were used in our pedagogical experiment. First, data from the survey was analyzed using the graphical representations provided by Google Forms. Second, data from students' answers in various CBTs were compared with data obtained on paper-and-pencil tests.

4. Results

4.1. The pieces of evidence offered by teachers in science, math, and technology

To understand the current state-of-art in teachers' knowledge regarding CBA and CBTs was developed a questionary delivered through an online survey. The results were obtained from 64 teachers. These results allow us to conclude that teachers use audio-visual aids to convey the teacher's message to students, as follows (a) video/audio files (35.9%); (b) simulations with educational software (31.3%); (c) personal photos/videos – 15.6% and (d) images from the Internet – 12.5%. However, to evaluate the student's learning outcomes the majority of teachers use oral communication (43.8%); 31.3% of them use tests on paper photographed and transmitted and only 20.3% apply computer interactive tests.

But, for those questions related to theoretical knowledge related to CBA and CBTs teachers answered in another way. Comparing responses related to CBTs and tests administered using paper and pencil we can conclude that CBA and CBTs are more (a) correct (46.9%); (b) accurate (28.1%) and (c) valid (25%). These results are based on the following arguments:

- digital assessment is sensible to the psychopedagogical characteristics of students
- in digital assessment the measure errors are minimal
- digital assessment allows us to obtain and provide the same results for all students.

The validity of these questions could be provided from the following data. Digital assessment in form of assessment, measurement, and testing tools are balanced if (a) state and schoolwork together for the most successful learning strategies (42.2% of responses); (b) CBTs are developed according to the principle of coherence, comprehensiveness, and continuity (40.2%), and (c) include diagnostic, formative and summative tasks (17.2%).

4.2. CBA elementary mathematics program

Early math instruction is focused on arithmetic, number relations, and conceptual understanding of numbers (collectively referred to as ‚math numeracy' here). According to Foster (2023) counting, number knowledge, quantity comparison, solving problems, and making connections between numbers and words are crucial to children's development in math achievement throughout elementary school. Starting from this position was developed a computer-based program that aims to enforce the competencies of students, who study *calculus* (i.e., addition, subtraction, multiplication, and division of real numbers) and *mathematical operations with fractions* (i.e., addition, subtraction, multiplication, and division of fractions).

The computer program was divided into three modules, as follows: „*Natural numbers*", „*Ordinary fractions*" and „*Decimal fractions*". Each module is defined into two three chapters and themes, each of them consisting of a theoretical and a practical part. The theoretical section includes core concepts of the chapter with interactive comprehensive explanations. Practical parts include CBTs. In the pedagogical design of CBTs were applied the following norms:

- Metasystems learning design principles (i.e., self-regulation, personalization, clarity, immediate feedback, dynamicity and flexibility, and cognitive ergonomics)
- Psychopedagogical norms:
- no more than 20 minutes for one CBT
- 30 -100 test operations for one computerized test
- Test items should be written using the rational mode of mind
- The students' answer is evaluated as correct, partially correct, or incorrect.

From this perspective, one test operation is equal to one task performed by the mind to solve a complex issue and the test item will have the form *745+123* = instead of *What is the sum of the following mathematical operation 745+123* =. Number 1/25 shows that this CBTs includes 25 tasks in form of exercises or problems, which is equivalent (in this situation!) to 60 operations of the test. A copy of the digital screen is presented in Figure 1.

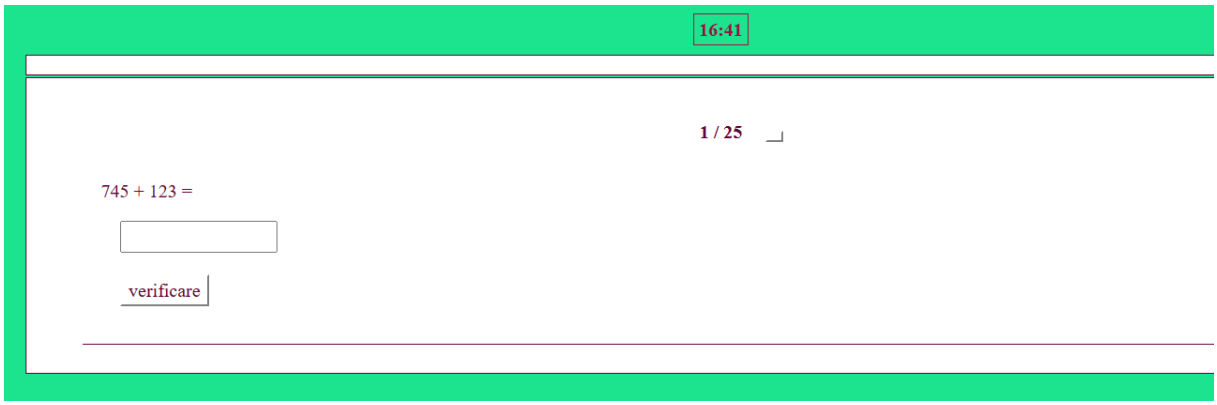

Figure 1. CBT on digital screen

4.3. Observation of changes in students‘ motivation to learn

Researchers look into test-taking behavior using data from interactive assessments, such as how long students spend on each item, how often they change their answers, and how they move around the items (Yildirim-Erbasli & Bulut, 2023).

Case study. After piloting the computer program, it was observed that students who performed better at paper-and-pencil examinations received lower results compared with students who received lower marks within paper-and-pencil examinations. This case requires future examination taking into account the diversity of learning environments and the intrinsic motivation of students to learn mathematics.

5. Conclusions

This study aims to investigate the method of CBA and CBTs, their specific feature in form of immediate feedback, and practical application in the math education of primary students. Our assumption, based on Miller’s research, is that CBA with immediate feedback needs to be used to support the learning process/progress and not to measure learning outcomes.

Traditionally, there are two forms of evaluation of students’ progress, known as assessment and appreciation. Assessment, either in form of paper-and-pencil or computerized assessment, is used to measure knowledge, skills, and attitude in form of data. Appreciation is the result of appreciative intelligence. This form of intelligence is common in humans ‘minds because of subjective perception of values and attitudes toward something or/and someone.

There are three main models of human thought: linear, system, and metasystems. Linear models use a step-by-step approach and system thinking follows the system paradigm, according to which the whole is composed of individual parts and, therefore, each student should complete one step before will move to the next. The learner's abilities and motivation to learn are at the center of the learning process according to the metasystems learning design theory. This theory also examines the influence of a student's (meta)cognitive drive to learn in a variety of physical and virtual learning environments, the impact of screens on learning, and the significance of learning and communication ecosystems in pedagogical design.

Starting with two research questions it was developed an online survey and a computer program for the math education of elementary students. Data shows that (a)teachers are interested in CBA and CBTs even though they use paper-and-pencil tests distributed within a digital environment; (b) students with lower marks who used computerized test perform improve their results and perform better than their colleagues with better results at traditional tests. This idea needs to be future investigated to understand if this is an effect or only a particular observation.

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