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Research Article

AI in education: Pedagogical and ethical analysis of the implementation of ASSISTments in the school environment

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ABSTRACT

The problem behind our research that was investigated was the evaluation of an artificial intelligence in education tool, namely ASSISTments by seventy one science and technology students in a small city. The objective was to find to what extent the students assimilate this tool. The data collection and instrumentation were done by the tool itself. The data analysis methods used were pie charts based on the answers of the students to questions examining the level of acceptance of the tool by them as well as linear regression investigating the relation between the students' grades and the level of acceptance of the tool by them. The main research results show a high level of acceptance of ASSISTments by them. Additionally, pedagogical implications of the use of ASSISTments were examined.

Keywords: derivatives, AI in education, intelligent tutoring systems

INTRODUCTION-AI IN EDUCATION

There exists some criticism on the implications of using artificial intelligence (AI) by Stephen Hawking and Bill Gates (Tahiru, 2021) but in the study we are discussing (Tahiru, 2021) the discussion is about "soft AI". Namely, machines at present cannot achieve the aim to perform general intelligent actions. Yuki (2022) is the first humanoid lecturer and acts assistive to the human lecturer.

AI as defined by McCarthy (Tahiru, 2021) is "the science and engineering of making intelligent machines". An AI machine is "a machine that behaves in a way it would be considered intelligent if it was a human being".

AI technology is radically changing the pedagogical landscape in schools and classrooms and provides a kind of an intelligent assistant to educators.

a. The administrative task is automated (Parychek et al., 2023).

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b. The applications of AI use smart content. Textbooks are transformed into a useful tool for exam preparation.

c. Intelligent tutoring systems (ITSs) are developed (Guo et al., 2021).

Apart from the pedagogical challenges, AI raises ethical issues in education as well, which highlights the necessity of establishing guidelines for its use and implementation in the field of education (Borenstein & Howard, 2021), so that it becomes useful and not harmful for the members of the educational community and the educational process in general (Reiss, 2021).

In recent years AI has helped in many education related applications such as massive online open courses (MMOCs) (Alhazmi et al., 2023; Yim & Shu, 2024), TeacherBots as well as in knowledge games such as "Jeopardy" (Best, 2013), where the IBM Watson system won the best players in the world (Tahiru, 2021).

The framework of artificial intelligence in education (AIEd) is technological, organizational and environmental (UNESCO, 2023a, 2023b). The technological context (UNESCO, 2023a, 2023d, 2023e) includes technologies that are either in use or available on the market that are not currently in use. The organizational context (Francesc et al., 2019; Xu & Ouyang, 2022; UNESCO, 2023a) is related to the available resources and characteristics of the organization such as its structure, the communication process, organizational readiness and its size. Also important are the organization's human resources, the connection structures between employees, the communication processes within the organization and the number of resources not being used. Environmental context (Francesc et al., 2019; Oxford University Press, 2023; UNESCO, 2023a) provides the factors that can lead or restrict innovation such as the support for industry, support for technological innovation, rules by the government, cultural factors, and influence by stakeholders.

Related is the expectation-confirmation-model (ECM) (Lai & Cui, 2014; Prasetya et al., 2022). The question is what are the opportunities, advantages and challenges of adopting AIEd. Also, in which region is AI research focused?

In terms of AI opportunities, it has been shown that students benefit from using AI. The benefit is concept, design, exploration and perspective. According to du Bulay (2016), AIEd systems perform better than computer-assisted instruction (CAI) systems and compared to human teachers' performance they are almost as good as one-to-one tutors.

The challenges of AI are first of all technological. A learner model, domain expertise, teaching expertise, and interfaces are the fundamental components of AIEd. The aim of an AIEd/ITS system aims to help the individual student. In recent years teachers and parents are part the AIEd ecosystem.

Knowledge representation, knowledge acquisition, and knowledge derivation are the three main AI perspectives in knowledge processing (Dai et al., 2020). Zhai et al.'s (2021) research questions are

(a) development with the knowledge presentation model as the focal point;

(b) extraction, which focuses on hot to learn from data mining; and

(c) application, which highlights information derivation as a means of facilitating human-computer interaction.

Human-computer interaction aimed to enhance traits like creativity, accountability and critical thinking which have an effect on student outcomes and perceptions.

According to Horáková et al. (2017), artificial neural networks (ANNs) are a lot better than regression and decision trees. Magnisalis et al. (2011) have also examined alternative methods, with promising outcomes, such as Bayesian networks, association rules, clustering, fuzzy c-means fuzzy, and genetic algorithms. Natural language processing (NLM) as a tool for preprocessing before running AI algorithms has been proposed by Vattam et al. (2011).

AIEd systems have been built by using classification, matching, recommendation and deep learning (Zhai et al., 2021). Feedback, reasoning, and adaptive learning are the three types of AI applications in education. In terms of feedback with the use of AI, the system gives direct feedback according to students' entry to help them progressively understand the meaning of the tasks and perform the practical ones of them. In terms of reasoning the graphic structure and students' involvement methods have been used by Nabiyev et al. (2016).

Vattam et al. (2011) have been studying a way to make learning easier for different kind of students, proposing the adaptive learning model. The adaptive educational system is a shaping and adaptive automated system that can be modified (intervention goal) to the special skills, personal interests and predilections of individual students (pedagogical goal). Research to date has concluded that the design of dimension is a realistic alternative worth exploring when implementing an adaptive system. In any case, in order to design successful adaptive systems in education, educators, curriculum writers and system designers should take advantage to investigate modeling of the problem-solving process in the domain-specific knowledge and the use of big data (Magnisalis et al., 2011).

In Kessler (2018), teachers are exploited as curriculum designers. The user's characteristics are limited to domain knowledge. The deeper inner characteristics such as the human psyche and productivity are only just being observed and studied (Magnisalis et al., 2011). At this point the necessity of an ethical framework for the use of intelligent teaching systems is identified, in order to achieve the all-round development of the personality as a general purpose of education. on the other hand, given the fact that AI tools are substituting for human actions, the question arises whether these tools can be held morally responsible for their actions and choices. As Sun and Ye (2023) mention an increasingly significant area of AI research is the design of intelligent systems with moral considerations. Autonomous weapons systems and self-driving technology, for example, will have an immediate impact on public safety. However, AI's potential influence on people extends beyond mere bodily harm; it can also have an impact on their ability to survive and thrive. As mentioned by Sharkey (2016), robots used in the classroom as teachers or teaching assistants could have to determine what actions of the kids are appropriate or inappropriate (Sun & Ye, 2023).

In previous years the measurement of learning achievements was assessed in two directions: Learning outcomes and perceptions. In newer studies, creativity and responsibility play an important role and affection computing is adapted towards this aim (Arroyo et al., 2009; Floyd et al., 2005; Magnisalis et al., 2011). The learning-by-teaching model has as a basis that students can learn by teaching others and getting feedback (Chin et al., 2010). In the ITSs, students are encouraged to be polite to an intelligent virtual teacher and this has been shown to help students who need special help (McLaren et al., 2011).

Regarding research trends of AIEd, the Internet of things (IoT) was used in (Ngai et al., 2009). Certain research mimic physical contexts in order to detect and comprehend human cognitive activities (Chin et al., 2010; Magnisalis et al., 2011; Seni, 2012; Williamson et al., 2018).

It has been witnessed that some studies focus more on the techniques rather than the learning itself (Kessler, 2018).

A review of the AI technologies for education is given in Zawacki-Richter et al. (2019). A review of the AI techniques for higher education is given in Hinojo-Lucena et al. (2019). Robot teachers to address teacher shortages are considered as a solution in Edwards and Cheock (2018), despite the great debate and the ethical objections raised (Sharkey, 2016). The AI developments in education are broken down into four categories in (Chassingol et al, 2018):

(1) personalized educational content,

(2) creative teaching techniques,

(3) enhanced evaluation, and

(4) communication between students and teachers.

They claim that the goal of AI is to imbue machines with intelligence, and that intelligence is the attribute that permits an entity to behave appropriately and adjust to its surroundings. The important parts of AIEd are

(a) content,

(b) teaching methods,

(c) assessment, and

(d) communication.

The most known systems presented are Why2Atlas, BeetleII (VanLehn et al., 2022), and AutoTutor (Al Emran & Shaalan, 2014).

From a pedagogical point of view, the flexibility of content adaptation, the choice of appropriate teaching methods, the use of assessment as a learning tool and the upgrading of the pedagogical relationships of students with each other and with teachers are the spearhead of contemporary pedagogical reflection, to which the use of AI in education aspires to respond to some extent. From another point of view, there is growing interest in the ethical issues involved. The Council of Europe document refers to numerous relevant research and studies (Holmes et al., 2022, pp. 39-40). It also refers, inter alia, to the research carried out by Jobin et al. (2019), who identified and grouped the ethical principles that have been formulated for the application of AI in 84 groups. It is worth noting here that defining the ethical framework is not enough, as there is also difficulty in putting it into practice. In any case, the above ethical considerations should not act as a deterrent to the use of AI in education in general, but in the clear definition of the scope of application and the expected results.

A review of the state of the art and current applications of AI in education can be found in Holmes and Tuomi (2022). According to this paper AI can help automating teacher tasks and augmenting human cognition in learning. In this work it is supported that the educators should be put at the center of new exciting achievements. AIEd might save teacher time by relieving teachers from marking. The focus is on teaching (i.e., student focused AIEd), education administration (i.e., system focused AIEd) and teacher support (i.e., teacher focused AIEd). The concept of mastery learning is also examined which requires individual-level differentiation or 'personalization' of instruction for students, where AIEd systems would be helpful.

Special mention is made to systems that started explicitly as systems for test preparation such as ASSISTments (Heffernan & Heffernan, 2014). Also, the need for using symbolic AI alongside machine learning is outlined. In Limna et al. (2022) it is mentioned that quantitative analysis methods such as questionnaires may be developed. The implications of AIEd could be applied to school administrators, teachers and students to improve educational performance through AI. AIEd opens up new possibilities, challenges, and opportunities for educational practices. One of the most important aims of AIEd is to offer personalized learning. AIEd also helps teachers during the instruction process. It also allows for teacher feedback, offers an automated grading system and makes adaptive learning and distance learning possible. Chaudry and Kazim (2021) mention that AIEd reduces teachers' workload, provides contextualized learning for students, provides revolutionary assessments and include ITSs. Hrastinski et al. (2019) mention the importance of the scaffolding technique in AIEd, a technique that is also embedded in the ASSISTments environment (Heffernan & Heffernan, 2014). AIEd is used to support student collaboration and aid both students and instructors in teaching and learning. In our work, exploiting the ASSISTments environment, we have used the hints option for helping the students find the right answer, used questionnaires to evaluate the level of absorbing of new mathematical concepts by students. We have chosen ASSISTments, in order to 'put the teacher in charge'. Up to now, and to the best we are aware of, this is the only work that used ASSISTments to evaluate the level of acceptance of an AIEd environment in calculus.

INTELLIGENT TUTORING SYSTEMS

ITSs are dynamic instructional models that combine AI and traditional teaching methods. The important feature of these systems is differentiated learning according to the capabilities and aims of each student (Mousavinasab et al., 2021).

In Nwana (1990), a review of the ITSs until 1990 is given. According to this paper ITSs are computer programs that use AI techniques in order to provide help to experienced tutors. ITSs could be addressed as efforts to simulate human behavior that could be termed as 'good teaching'. ITSs are related to the fields of computer science, cognitive psychology and educational research. They belong to cognitive science.

ITSs function without a teacher present by simulating one-on-one human tutoring, supporting learning activities relevant to students' needs, and providing focused, real-time feedback. All of these functions are made possible by AI techniques (Luckin et al., 2016).

Intelligent Computer Aided Instruction (ICAI) is a synonym with ITS. Researchers who abstain from the use of the term intelligent, use the term knowledge-based tutoring system (KBTS) or adaptive tutoring system (ATS). The motivation for computer-based tutors is, as follows:

(1) research needs, and

(2) practical needs.

A computer tutorial program should include a representation of the subject matter being taught, knowledge of the students, and teaching methods (Self, 1974). The use of AI techniques in computer assisted instruction (CAI) is inevitable (Carbonell, 1970).

According to Yazdani (1983), ITSs are AI's answer to CAI packages. ITSs consist usually of four components. One component is addressing the expert knowledge, one is considering the student model, one related to the tutoring process and the user interface. The self-improving (learning) concept was introduced by Kimball (1982) and O'Shea (1982). The self-improving (learning) concept was used by Kimball (1982) and O'Shea (1982).

Some of the early ITSs were SCHOLAR (Carbonell, 1970, 1971), SOPHIE (Arroyo et al., 2009), GUIDON (Clancey, 1983), and WEST (Burton & Brown, 1976) (a spinoff from SOPHIE). GUIDON was built for training medical students on top of the well-known MYCIN (Shortlife, 2012) and NEOMYCIN (Chin et al., 2010).

Koedinger et al. (2013) describe the functions of an ITS to be

(a) select,

(b) evaluate,

(c) suggest, and

(d) update.

Kulik and Fletcher (2016) describe the effectiveness of ITSs. A comparison between CAI systems and ITSs is performed by VanLehn et al. (2002). An interesting system is the cognitive tutor (Corbett, et al., 1997). While the students are using the computer, it has been noted that inexperienced teachers use the ITS to take the place of the teacher and relieve them of similar tasks like grading papers. On the other hand, an experienced teacher views ITSs as a partner who supports them in giving each student individualized instruction and support. Also, it has been shown that ITSs typically improve student performance above the level that is achieved by traditional teaching.

VanLehn (2012) compares the relative effectiveness of human tutoring, ITSs and other tutoring systems. The tutoring systems may be answer-based, step-based and subset-based. The systems may be instruction aided by computers, instruction based on computers, learning based on computers and training based on computers. If feedback and hints are provided on each step, we may talk about an ITS. It has been shown that human tutors are more effective in assessing the students, selecting tasks for them, formulating strategies for tutoring, controlling the dialogue with the learners, offering domain knowledge, motivating the students, giving feedback, scaffolding and the ICAP framework (VanLehn, 2012). The Why2Atlas qualitative physics ITS, is mentioned and it is noted that Bloom's 2 sigma challenge (namely that individualized learning increases efficiency by 2 standard deviations) inspired dialogue based tutoring. All self-generated correct solutions are equally effective (Anderson et al., 1995). The results show that ITSs perform almost as well as human tutors (VanLehn, 2012).

One of the most known ITSs is the Andes physics tutoring system (VanLehn et al., 2005). This system upgrades homework problem solving support. Regarding cognitive tutors it is mentioned by Schute et al. (1994), that they treat the tutoring system as part of a broader change of the instruction, and they convince the students in using ITSs. Considering the comparison between web-based homework (WBH) and paper and pencil homework (PPH) the conclusions are that

(a) it is difficult for instructors to grade every PPH problem they assign, and

(b) with WBH students receive immediately the results of their answers, which might help them realize their mistakes and improve performance.

However, PPH has an advantage compared to WBH, because when humans grade PPH, they often score the derivations rather than only the results. WBH on the other hand grades all assigned problems. Students do more of the assigned problems and thus learn more. Andes1 was one of the first large scale applications of Bayesian networks and the first application of Bayesian networks to the ITSs. Andes2, provided a new, more concise knowledge representation and made its user interface as much like PPH as possible.

To conclude, the main features of ITSs is that they provide differentiated learning without the teacher's intervention as well as the help they provide to the students via scaffolding or hints.

Research methods in ITSs include (Guo et al., 2021):

(1) Experimental design, which involves setting up a controlled environment where one or more variables are manipulated to observe the effect on the subjects. The subjects are often students using the ITS. Data is collected through the ITS itself, tracking student interactions and performance. The data is then analyzed using statistical methods.

(2) Surveys and questionnaires: These are used in order for the ITS to be evaluated by the students and teachers by using appropriate questions. The data is analyzed using descriptive statistics.

(3) Interviews and focus groups: The data is collected through direct conversation or discussion with specific focus groups. The data is then analyzed using qualitative analysis methods.

(4) Case studies: These apply investigation of a specific case related to the learning process. Data is collected through a variety of methods, including observation, interviews, and the ITS itself. The data is then processed using a combination of qualitative and quantitative methods.

(5) Data mining: This is implemented by analyzing large datasets to discover statistical cross-correlations. The data is collected automatically by the ITS as students use it. Finally, the data collected is automatically analyzed.

(6) Learning analytics: This involves the assessment, gathering, processing, and disseminating of information about students and their environments. The data is collected automatically by the ITS as students use it. Again, the data collected is automatically analyzed.

(7) User testing: This involves observing users as they interact with an ITS to identify any issues or chances for improvement. The participants are usually students using the ITS. The data is collected through observation and the ITS itself. The data is then analyzed to identify usability issues and areas for improvement. We have chosen the surveys and questionnaires method among the students as a convenient way to get feedback from a case study, which involved experimenting of the students with the ASSISTments environment.

In addition to these methods, specific AI techniques are often applied in ITS research. For example, action-condition rule-based reasoning, data mining, and Bayesian network are among the most frequently used AI techniques in ITSs (Guo et al., 2021). The choice of research method depends on the research question being investigated. Often, a combination of methods is used. For example, an experimental design might be used alongside surveys and interviews to triangulate findings.

ASSISTments

ASSISTments is considered as an ITS, although it does not offer automated differentiated learning. The term "ASSISTments" stems from the combination of the words "assignment" and "assessment". ASSISTments have evolved in some respects to be an antithesis of an AIEd system (Hefferrnan & Hefferrnan, 2014). The main idea behind ASSISTments is to "put the teacher in charge!" The teacher controls at which pace every student will learn in order for example not to have a student working in the first chapters of the syllabus of a class while another working at the last chapters. The differentiated learning approach was adopted in the early stages of the development of ASSISTments with the cognitive tutor tool (Koedinger & Corbett, 2006).

An additional feature of ASSISTments are the so called "skill builders". In this case, each student receives random questions related to his/her curriculum and finishes if he/she gets three correct answers in a row. Additionally, for more complex questions, the so called scaffolding method is used, where the original problem is divided into more simple consecutive problems and the student solves the problem step by step if he/she failed to provide the correct answer.

Moreover, hints are available in order to help the students with specific questions. These two techniques exploit a meta-cognitive scaffolding method. Finally, the so called randomized controlled trials are available, where the student gets random questions related to his/her course.

THE DERIVATIVES ASSISTments

The assessment of ASSISTments was made by 12th grade science and technology students on the subject of derivatives and specifically the definition of the derivative and the derivative properties. The ASSISTment used, as follows.

Multiple Choice Questions

1. If $\lim_{h\to 0}\frac{f(1+h)-f(1)}{h}=5$ then the function f is differentiable at $x_0=1$ with $f'(1)$ equal to

a. 0 b. 1 c. -5 d. 5

Hint: $f'(x_0)=\lim_{h\to 0}\frac{f(x_0+h)-f(x_0)}{h}$

Correct answer: d

2. If $\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}=2x$ then $f'(2)$ is equal to

a. 2 b. 4 c. $2x$ d. 0

Hint: $f'(x)=\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$

Correct answer: b

3. If $\lim_{h\to 0}\frac{f(x-h)-f(x)}{h}=-2x$ then $f'(x)$ is equal to

a. x b. $-x$ c. $-2x$ d. $2x$

Hint: $\lim_{h\to 0}\frac{f(x-h)-f(x)}{h}=-\lim_{h\to 0}\frac{f(x-h)-f(x)}{-h}=-\lim_{u\to 0}\frac{f(x+u)-f(x)}{u}=-f'(x)$

Correct answer: d

4. If $f:R\to R$ is a function with $\lim_{x\to 1}\frac{f(x)-f(1)}{x-1}=-1$ then f is differentiable at $x_0=-1$ with $f'(-1)$ equal to

a. 1 b. -1 c. 0 d. we don't know whether $f'(-1)$ exists

Hint: $f'(x_0)=\lim_{x\to x_0}\frac{f(x)-f(x_0)}{x-x_0}$

Correct answer: d

5. If the functions $f: R \to R$ are differentiable at $x_0 = 2$ with $f(2) = -2$, $g(2) = 3, f'(2) = 1, g'(2) = -3$ then $f \cdot g$ is differentiable at $x_0 = 2$ with $(f \cdot g)'(2)$ equal to

a. 9 b. -3 c. 3 d. -2

Hint: $(f \cdot g)'(x_0) = f'(x_0) \cdot g(x_0) + f(x_0) \cdot g'(x_0)$

Correct answer: a

6. If the functions $f: R \to R, g: R \to R$ are differentiable at $x_0 = 1$ with $f(1) = -1$, $g(1) = 4, f'(1) = 0, g'(1) = 6$ then $f - g$ is differentiable at $x_0 = 1$ with $(f - g)'(1)$ equal to

a. -5 b. 5 c. -6 d. 6

Hint: $(f - g)'(x_0) = f'(x_0) - g'(x_0)$

Correct answer: c

7. If the functions $f: R \to R, g: R \to R$ are differentiable at $x_0 = -1$ with $f(-1) = 2$, $g(-1) = 1, f'(-1) = 5, g'(-1) = -2$ then $\frac{f}{g}$ is differentiable at $x_0 = -1$ with $\left(\frac{f}{g}\right)'(-1)$ equal to

a. $-\frac{9}{4}$ b. $\frac{9}{4}$ c. 9 d. -9

Hint: $\left(\frac{f}{g}\right)'(x_0) = \frac{f'(x_0) \cdot g(x_0) - f(x_0) \cdot g'(x_0)}{g^2(x_0)}$

Correct answer: c

8. If $f(x) = e^x + \sin x$ then f is differentiable at $x_0 = 0$ with $f'(0)$ equal to

a. 3 b. 4 c. -2 d. 2

Hint: $(f + g)'(x) = f'(x) + g'(x)$, $(e^x)' = e^x$, and $(\sin x)' = \cos x$

Correct answer: d

9. If $f(x) = x \cdot e^x$ then f is differentiable with $f'(x)$ equal to

a. $(x+1) \cdot e^x$ b. e^x c. $(x-1) \cdot e^x$ d. $x \cdot e^x$

Hint: $(f \cdot g)'(x) = f'(x) \cdot g(x) + f(x) \cdot g'(x)$, $(e^x)' = e^x$, and $(x)' = 1$

Correct answer: a

10. If $f(x) = \alpha^3 x^3$, $\alpha \in R$ then f is differentiable with $f'(x)$ equal to

a. 0 b. $3\alpha^2 x^3$ c. $3\alpha^3 x^2$ d. $3x^2$

Hint: $(c \cdot f)'(x) = c \cdot f'(x)$ and $(x^v)' = vx^{v-1}$

Correct answer: c

11. If $f(x) = e^{\lambda x}, \lambda \in R$ then f is differentiable with $f'(x)$ equal to

a. $e^{\lambda x}$ b. $\lambda e^{\lambda x}$ c. 0 d. $\lambda x e^{\lambda x}$

Hint: $\left(e^{f(x)}\right)'(x) = e^{f(x)} \cdot f'(x)$, $(c \cdot f)'(x) = c \cdot f'(x)$, and $(x)' = 1$

Correct Answer: b

12. If $f: R \to R$ is differentiable then also the function $g(x) = \left(f(x)\right)^2$, $x \in R$ is differentiable with $g'(x)$ equal to

a. $\left(f(x)\right)^2$ b. 0 c. $2f(x)$ d. $2f(x)f'(x)$

Hint: $\left(g\left(f(x)\right)\right)' = g'\left(f(x)\right) \cdot f'(x)$ and $\left(f^v(x)\right)' = vf^{v-1}(x) \cdot f'(x)$

Correct answer: d

13. If $f(x) = \sqrt[3]{x}$, $x > 0$ then f is differentiable with $f'(x)$ equal to

a. $\frac{1}{3\sqrt[3]{x^2}}$ b. $\frac{1}{2\sqrt[3]{x}}$ c. 0 d. $\frac{1}{\sqrt[3]{x}}$

Hint: $\sqrt[\nu]{x^\mu} = x^{\frac{\mu}{\nu}}$ and $\left(x^{\frac{\mu}{\nu}}\right)' = \frac{\mu}{\nu} x^{\frac{\mu}{\nu}-1}$

Correct answer: a

14. If $f(x) = \frac{1}{x^2+1}$ then f is differentiable with $f'(x)$ equal to

a. 0 b. $-\frac{1}{(x^2+1)^2}$ c. $-\frac{2x}{(x^2+1)^2}$ d. $\frac{1}{2x}$

Hint: $\left(\frac{f}{g}\right)'(x) = \frac{f'(x)\cdot g(x) - f(x)\cdot g'(x)}{g^2(x)}$, $(c)' = 0$, $(x^\nu)' = \nu x^{\nu-1}$, and $(f+g)'(x) = f'(x) + g'(x)$

Correct answer: c

15. If $f(x) = x^{-2}$, $x \neq 0$ then f is differentiable in R^* with $f'(x)$ equal to

a. $-2x^{-1}$ b. $-\frac{2}{x^3}$ c. 0 d. $-2x$

Hint: $(x^{-\nu})' = -\nu x^{-\nu-1}$ and $x^{-\nu} = \frac{1}{x^\nu}$

Correct answer: b

16. If $f(x) = \frac{x^2}{2}$ then f is differentiable with $f'(x)$ equal to

a. x b. $\frac{2x}{4}$ c. $2x$ d. 0

Hint: $\frac{f(x)}{c} = \frac{1}{c} f(x)$, $(c \cdot f)'(x) = c \cdot f'(x)$, and $(x^\nu)' = \nu x^{\nu-1}$

Correct answer: a

17. If $f(x) = e^x + \sqrt{t} + \ln 2, t > 0$ then f is differentiable with $f'(x)$ equal to

a. $e^x + \frac{1}{2\sqrt{t}}$ b. $e^x + \frac{1}{2\sqrt{t}} + \frac{1}{2}$ c. e^x d. $e^x + \frac{1}{2}$

Hint: $(f(x) + c)' = f'(x) + 0$, $(e^x)' = e^x$

Correct answer: c

18. If $f(x) = x^2 + x + 1$ then $f'(\sin x)$ is equal to

a. $(\sin^2 x + \sin x + 1) \cdot \cos x$ b. $2 \sin x + 1$
c. $(2 \sin x + 1) \cos x$ d. None of the previous answers

Hint: $f'(x) = (x^2)' + (x)' + (1)' = 2x + 1$

Correct answer: b

19. If $f(x) = \sin x^2$ then $f'(x)$ is equal to

a. $\cos x^2$ b. $2x \cdot \sin x^2$ c. $2x \cdot \cos x^2$ d. $2 \sin x \cdot \cos x$

Hint: $(\sin f(x))' = \cos f(x) \cdot f'(x)$, $(\sin x)' = \cos x$, and $(x^v)' = vx^{v-1}$

Correct answer: c

20. If $f: R \to R$ is a continuous function with $\lim_{x \to 1} \frac{f(x)}{x-1} = 3$ then f is differentiable at $x_0 = 1$ with $f'(1)$ equal to

a. 2 b. 1 c. 3 d. 0

Hint: $\lim_{x \to 1} \frac{f(x)}{x-1} = 3 \Longrightarrow \lim_{x \to 1} f(x) = 0$, $f(1) = \lim_{x \to 1} f(x) = 0$, $\lim_{x \to 1} \frac{f(x)-f(1)}{x-1} = 3$, and $f'(1) = \lim_{x \to 1} \frac{f(x)-f(1)}{x-1}$

Correct answer: c

THE CASE STUDY

In our evaluation we have used questionnaires with closed questions. The answers were quantified according to scales. Quantitative evaluation is supported by Jackson (2019). Quantitative techniques are also supported by Froelich et al. (2021) when classes are being evaluated by students. The questionnaire, which was used in our case, is compared with 'comparator' groups techniques in Huxham et al. (2008). While 'comparator' groups techniques seem to be slightly superior to questionnaires, in terms of how much the

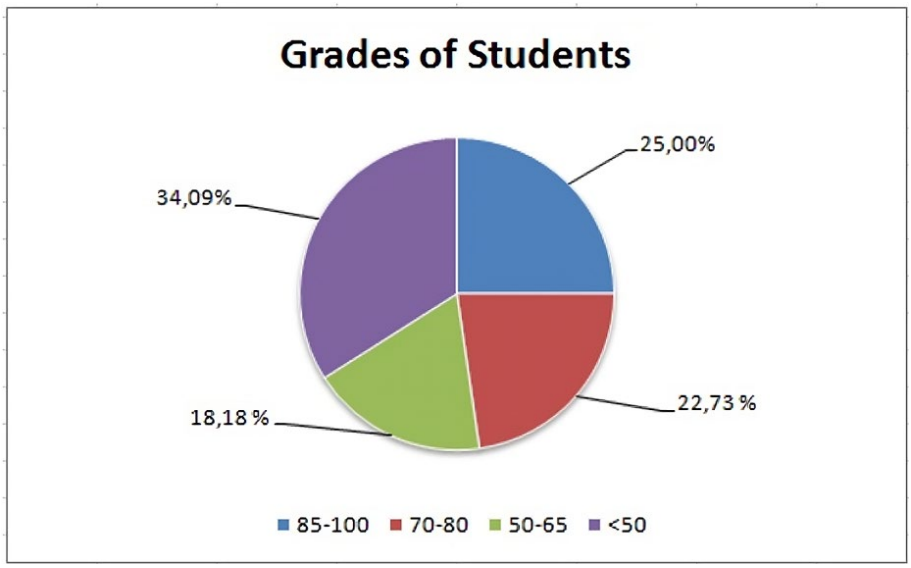

Figure 1. Ranges of grades for the students that used ASSISTments (Source: Authors)

teacher improves his educational techniques, based on the feedback he/she gets, questionnaires seem to be more convenient and an easier tool to use.

The evaluation of ASSISTments was made at a small city. In this evaluation 71 science and technology students of the 12th grade from a calculus course took part. Their success rates can be seen in the pie chart in **Figure 1**. As can be seen from the chart, the grades of the students were distributed almost equally among the different grade ranges. What is disturbing is that 34.09% received below 50%. However it is promising that 25% got excellent grades

EVALUATION OF THE ASSISTments ENVIRONMENT BY THE STUDENTS

The ASSISTments environment has been evaluated in 32 schools in two years by Feng et al. (2023a). Heffernan and Heffernan (2014) describe the ASSISTments project as an ecosystem of teachers, a platform and researchers working together. It describes how the platform supports teachers and contributes to research. Feng et al. (2023b) used ASSISTments in 63 schools in North Carolina in 7th grade mathematics classrooms. However, to the best we are aware of, up to our work, there exists no evaluation of ASSISTments in the subject of calculus in a small city. Unfortunately, due to financial limitations, we were able to evaluate the tool in only three schools of a small city, but in a novel subject. The authors believe that the results of the evaluation of the students in the subject of calculus will be helpful in estimating the influence of ASSISTments to the students of 12th grade in this specific subject.

From the evaluation by the students it becomes clear that the purpose of the lesson in the specific environment was clear or at least clear enough. It is obvious from the students' evaluation that the purpose of the lesson in this environment was clear or at least fairly clear. On the other hand, the total percentage of students who answered negatively or not fully positively is high and corresponds to 48%, i.e., it corresponds to slightly less than half of the students. It is therefore of particular interest to establish the reason for this high percentage, in order to determine whether the reasons are only of a technical nature or are also related to issues of moral and anthropological concern (**Figure 2**).

From the evaluation by the students it is shown that almost half of the students were not bothered with the interaction with the environment, a large proportion, namely, 43% was a little bit bothered. The students' answers show that the students' negative and hesitant attitude towards the environment is not only due to the fact that it is a tool and a teaching method that is completely unknown to the students (**Figure 3**).

From the evaluation by the students it becomes evident that most of the students, namely 68%, answered that they think they should be more familiar, or a little bit more familiar with the environment (**Figure 4**).

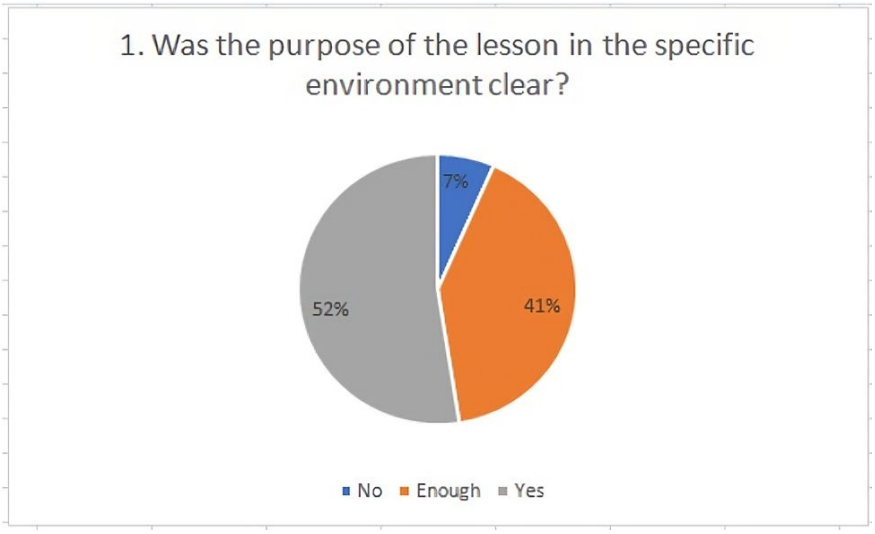

Figure 2. First question (Source: Authors)

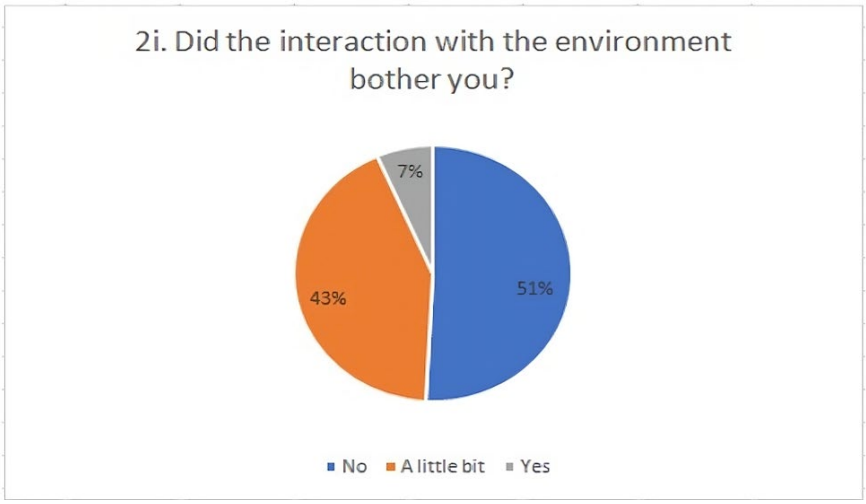

Figure 3. Question 2i (Source: Authors)

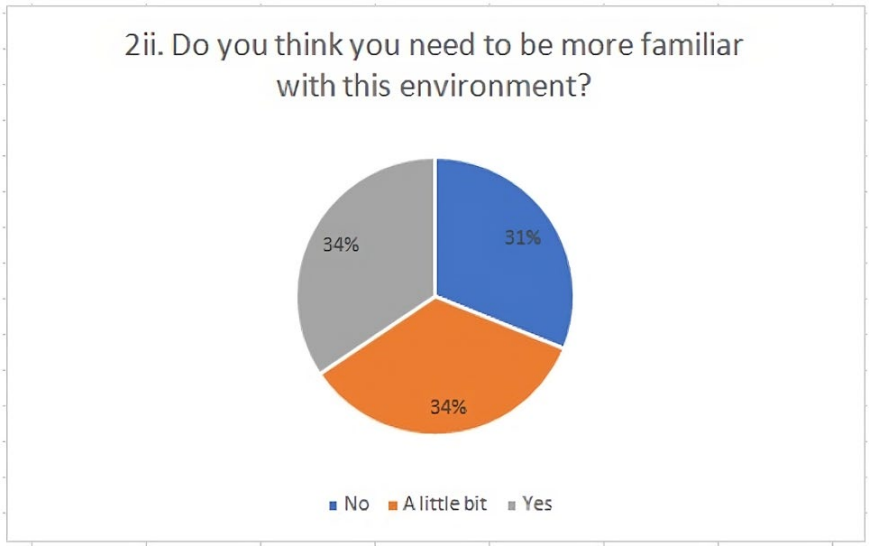

Figure 4. Question 2ii (Source: Authors)

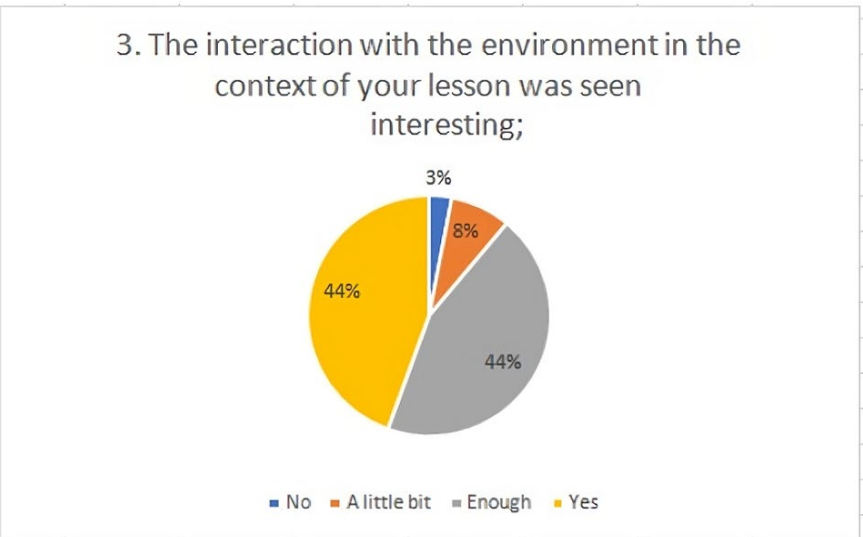

Figure 5. Question 3 (Source: Authors)

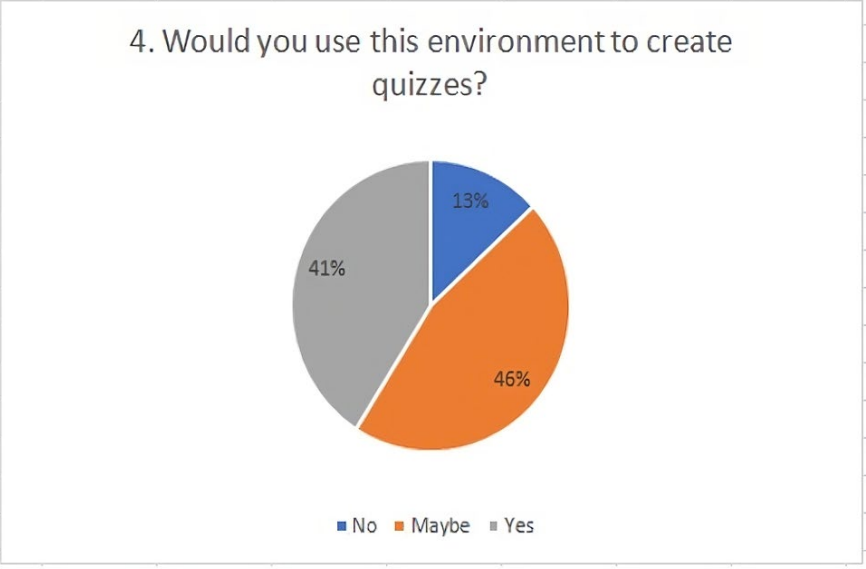

Figure 6. Question 4 (Source: Authors)

From the evaluation by the students it seems that the interaction with the environment in the context of the lesson was interesting (only 3% answered strictly no). The students' evaluation shows that the interaction with the environment in the course was interesting (only 3% answered strictly negative). However, it is interesting to investigate the reasons why a proportion of more than 50% of students found the environment not at all, a little or a lot, but not very interesting. In fact, according to the students' answers to the previous questions, the reason is not only the fact that the comparative learning environment is unfamiliar to them (**Figure 5**).

From the evaluation by the students it becomes evident that the students would consider the ASSISTments environment to create quizzes, namely with a percentage of 87% (**Figure 6**).

From the evaluation by the students it becomes clear that the students would like the ASSISTments environment to be used in the immediate future as an integral part of the teaching process. Specifically, 94% would consider this. However, even in this case a significant percentage of students who answer positively, i.e., 38% of the respondents, have specific doubts, which are not identified in this survey (**Figure 7**).

From the answers of the students it can be seen that 85% would consider delving deeper in the ASSISTments environment (**Figure 8**).

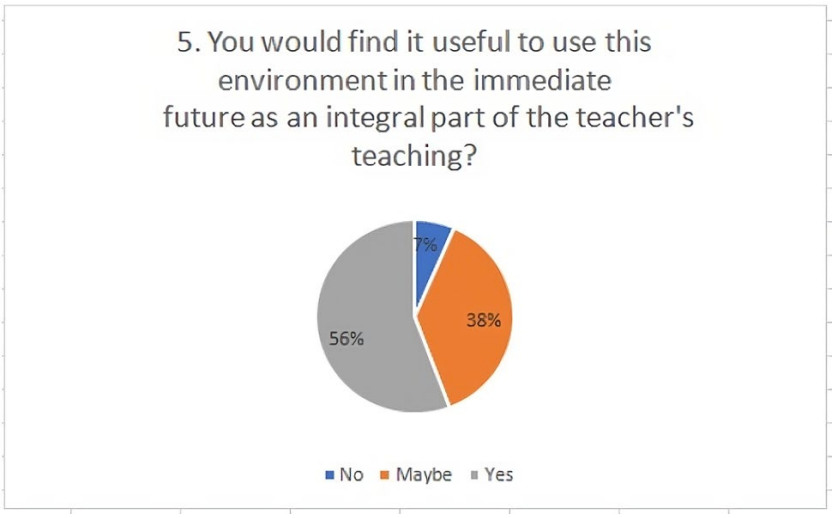

Figure 7. Question 5 (Source: Authors)

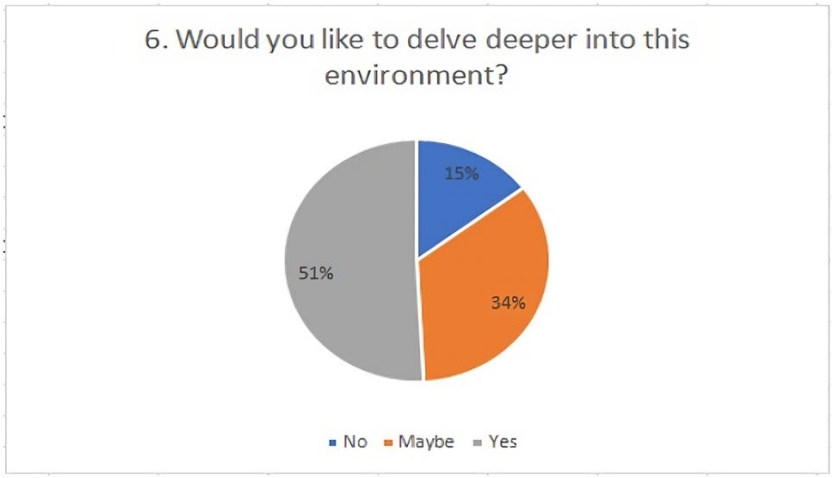

Figure 8. Question 6 (Source: Authors)

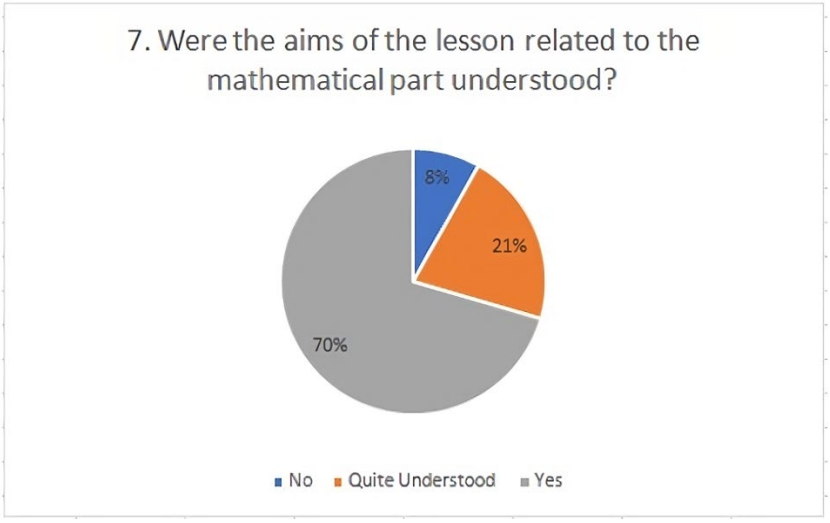

Figure 9. Question 7 (Source: Authors)

From the answers of the students, it is evident that the aims of the lesson, related to the mathematical part were clear. The result from these answers also confirms the findings of the research conducted so far, according to which the use of AI tools in teaching contributes to the very good planning of teaching (**Figure 9**).

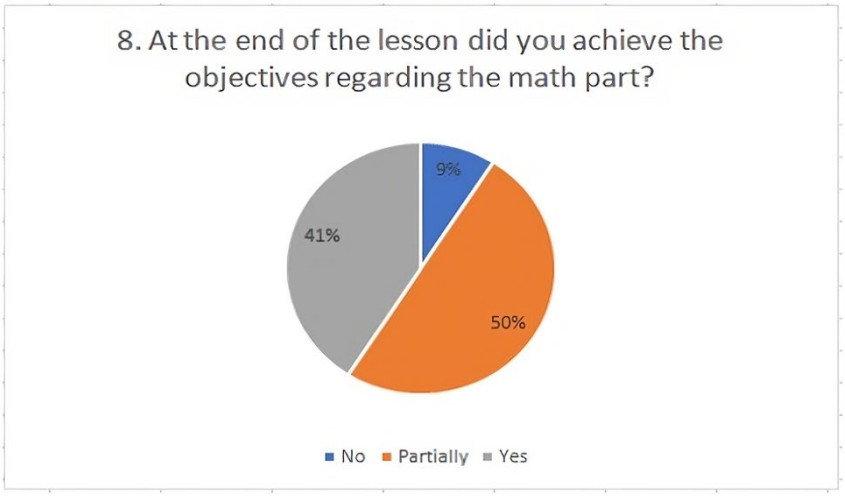

Figure 10. Question 8 (Source: Authors)

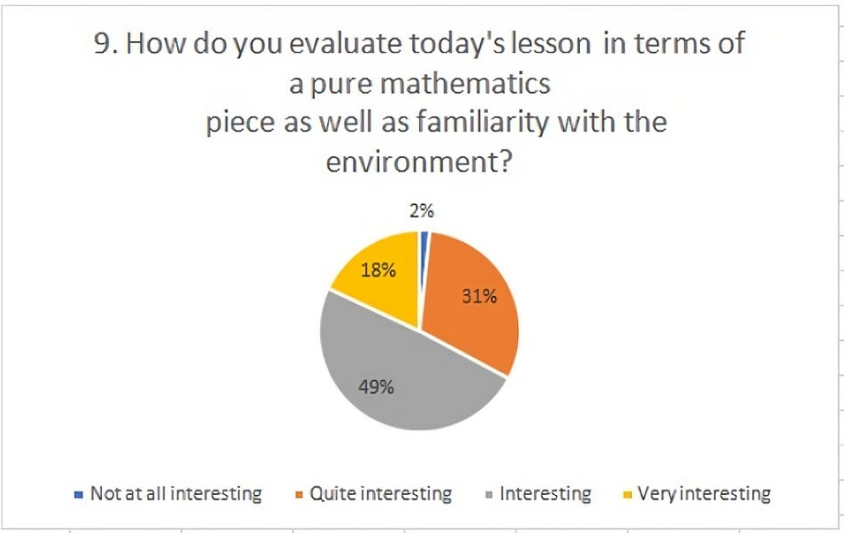

Figure 11. Question 9 (Source: Authors)

From the answers of the students it can be seen that the majority only partially or not at all achieved the objectives regarding the mathematical part. Students' answers to this question highlight the value of AI tools in the quality and effectiveness of teaching. However, this type of evaluation does not capture the results of teaching in terms of the social and metacognitive skills developed by students (**Figure 10**).

From the answers of the students it becomes evident, that the students found the lesson in terms of a pure mathematics piece, as well as how familiar they became with the environment at least as quite interesting (**Figure 11**).

From the answers of the students it is clear that the lesson with ASSISTments only satisfactorily help to better understand the material that was taught in a conventional lesson (**Figure 12**).

It is obvious that the students would consider the integration of ASSISTments in the teaching of mathematics in a large majority (**Figure 13**).

From the answers of the students, it becomes evident, that, in their opinion the hints in the questions did not help to a large extent or only enough (**Figure 14**).

The assessment caused anxiety for about half of the students interviewed. From this response, the educational need to redefine the purpose of educational assessment also emerges. The perception that assessment is an obstacle that students have to overcome should be replaced with the perception that assessment is a necessary educational tool through which students identify and understand their knowledge deficits (**Figure 15**).

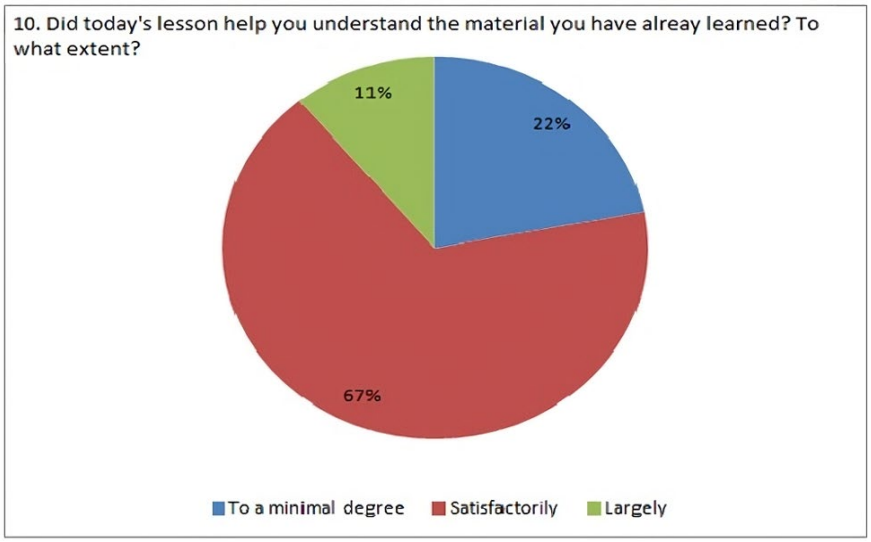

Figure 12. Question 10 (Source: Authors)

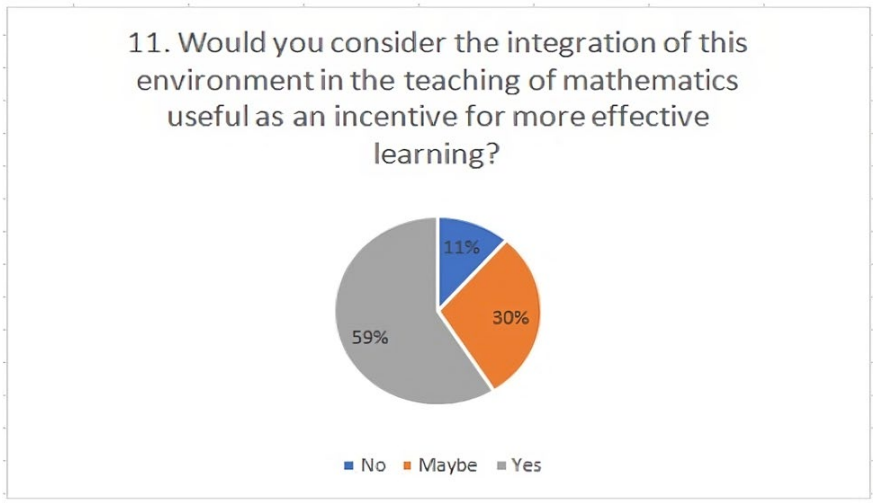

Figure 13. Question 11 (Source: Authors)

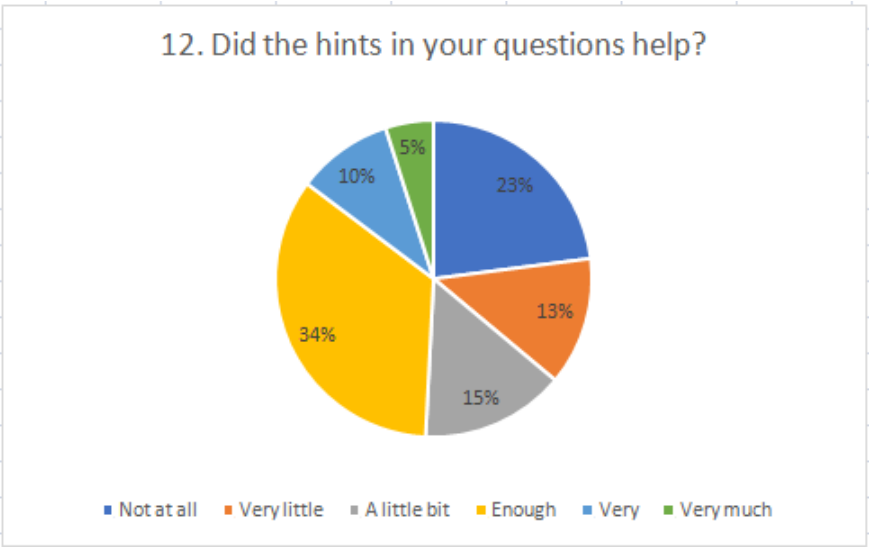

Figure 14. Question 12 (Source: Authors)

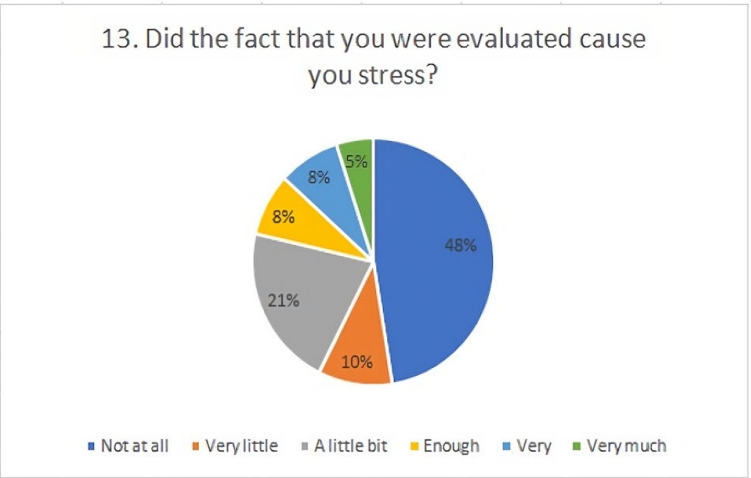

Figure 15. Question 13 (Source: Authors)

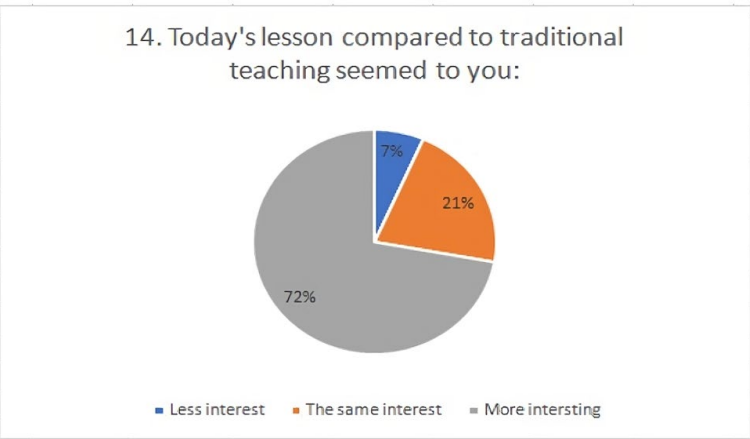

Figure 16. Question 14 (Source: Authors)

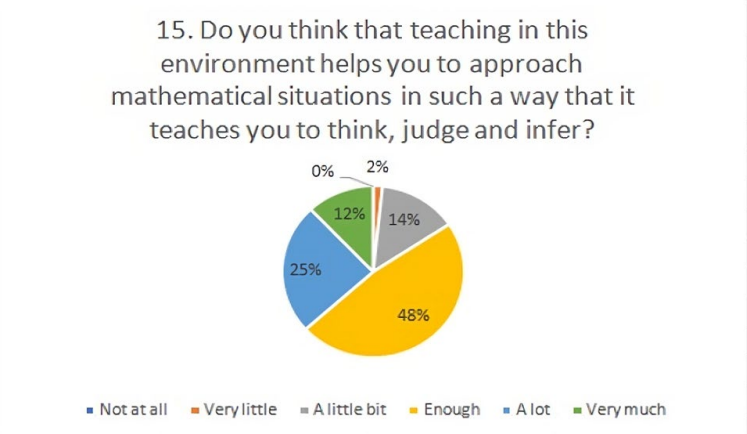

Figure 17. Question 15 (Source: Authors)

The large majority of the students found the lesson with ASSISTments more interesting (**Figure 16**).

Teaching with ASSISTments helps to approach mathematical situations enough according to almost half of the students, while 25% think that it does not help at all. The percentage of students who consider that this environment did not help at all towards the development of the above skills should be further investigated. However, according to the students' responses to the preceding questions, one of the main reasons for the negative response is the lack of digital literacy among students (**Figure 17**).

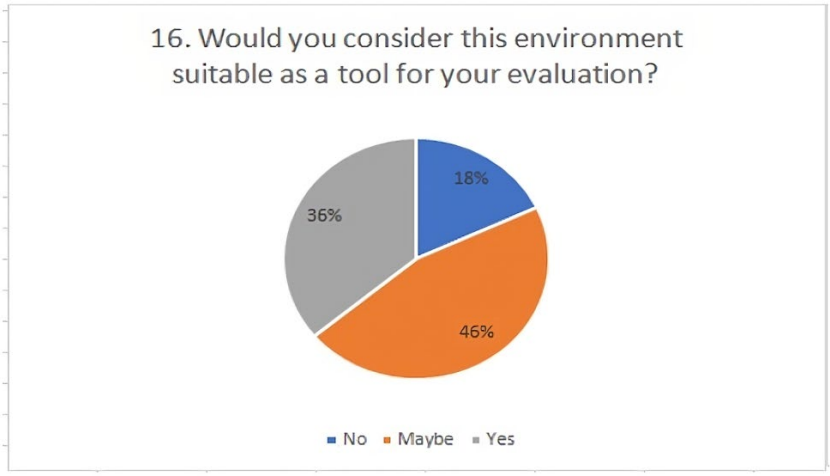

Figure 18. Question 16 (Source: Authors)

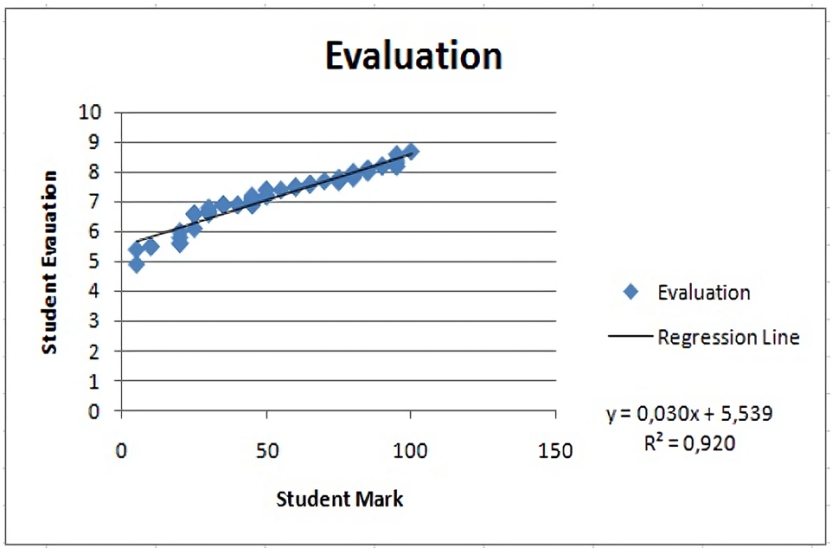

Figure 19. Linear regression to find the relation between the student marks and their evaluation of ASSISTments (Source: Authors)

The students would probably consider ASSISTments as a tool for their evaluation, but we can say that the opinions are divided, since 18% answer with a strict "No", and the majority (namely 46%) answered that they maybe would consider ASSISTments as an evaluation tool. The response rates to this question are of particular interest, as there is a large percentage of students, i.e., 46%, who are not sure that this digital tool is suitable as an assessment tool. If we add to this percentage the 18% of students who are certain that this particular tool is inappropriate, it shows that 64% of the students questioned have strong doubts or are absolutely certain that the digital tool is completely inappropriate. Students were not asked why they answered positively or negatively. In a subsequent survey, it would be interesting to ask students whether their doubt or refusal is due, among other things, to the fact that they do not consider objective an assessment that measures only the performance of students, without evaluating other factors related to human nature, its cultivation and maturation achieved even through failed attempts to solve mathematical problems (**Figure 18**).

The questionnaires that were given to the students were anonymous. However, we can assume that the students that got the lower marks gave a negative evaluation to ASSISTments. By making this assumption and taking the average of the evaluation marks for each student, we can assume a linear relationship between the marks taken and the evaluation by the students. So, we performed a linear regression. The results are given in **Figure 19**.

It can be seen that a linear relationship indeed holds, taking also into account that the R^2 value is very close to one (0.920). Additionally, we can see that the intercept with the y-axis is 5.339 which is above the score basis (5). However, some outliers indeed exist, such as the 4.9 evaluation value. Additionally, we can note that the regression line, does not have a high slope.

CONCLUSIONS AND FUTURE WORK

We have evaluated ASSISTments as an AIEd tool for teaching mathematics in 12th grade. We applied ASSISTments as a case study with 71 students answering a related questionnaire. Results show that the students liked the interaction with ASSISTments to learn mathematics. Additionally, the students' interest in this tool seemed to be related to how well they performed in the simulation test. These results are similar to the ones presented by Feng et al. (2023b); however we have implemented the same strategy on a different curriculum. Specifically, they have applied the experiments in 7th grade mathematics, while we investigated the application of ASSISTments to 12th grade calculus.

A new, promising approach to AIEd are generative AI systems. A critique of these systems in teaching is presented in (UNESCO, 2023c). We have evaluated a specialized tool for mathematics education, namely MathGPT (2023) but it does not find the correct solution to a first order linear ordinary non-autonomous differential equation while the Bing AI chat in the creative mode does. However, there exist some basic ethical issues, such as regulations, copyright infringement, offensive and unethical materials and undermining the development of plural opinions and plural expressions. Moreover, these tools assume that the formulas in the prompts are included as LaTeX expressions, with which most high-school students are not acquainted with. Finally, sometimes generative AI systems reveal hallucinations, which means that they present some statements as correct, while they are incorrect and insist on supporting them. To our knowledge, up to now there does not exist any generative AI large language model (LLM) that mitigates hallucinations. The adoption of generative AI in the classroom is an open research question related to how much willing are the teachers to lose control over the students in favor of differentiated learning as well as whether they will adapt mechanisms in class that sometimes make mistakes.

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Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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