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TECH8 intelligent and adaptive e-learning system: Integration into Technology and Science classrooms in lower secondary schools

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A R T I C L E I N F O

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A B S T R A C T

E-materials and various e-learning systems have become regular features in lower secondary schools in Slovenia and around the world. Many different systems and materials have been created for students, but only a few offer the same amount of individualisation that is present in traditional one to one teaching (one teacher to one student). The purpose of this research is to demonstrate the design and evaluation of an adaptive, intelligent and, most important, an individualised intelligent tutoring system (ITS) based on the cognitive characteristics of the individual learner. The TECH8 model presented is designed modularly, based on a system for collecting a range of metadata and variables that are vital for the teaching process. Prepared in such a way, the proposed system supports individualization and differentiation; because of this, it can be adapted to each individual's level of knowledge and understanding of the subject matter. This TECH8 system was evaluated in a real learning environment. The evaluation sample of the study consists of 117 students from five schools (suburban and urban). Qualitative and quantitative data was gathered with a system for collecting metadata and variables. The assembled data was analysed and statistically processed using descriptive analysis. This data was also compared to data from national assessments of knowledge, which encompassed the entire student population (approx. 5000) in the years 2008, 2010 and 2013. The study and the comparisons indicated that appropriately created TECH8 e-learning material, yields results that are better than those from traditional teaching but not better than one to one teaching. With the help of the collected metadata, optimisation, evaluation and an upgrade of the TECH8 itself will be carried out. In addition, such individualized e-learning systems can reinforce knowledge gained through traditional classroom education.

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1. Introduction

Much has been said about the potential of new technologies to transform education and training, but only a handful of these statements have been supported by research or even tested by thorough scientific research (Lowe & Schnotz, 2008; Mayer, 2009; O'Neil & Perez, 2003, 2006; Pytllik Zillig, Bodvarsson, & Bruning, 2005; Reiser & Dempsey, 2007; Rouet, Levonen, & Biardeau, 2001; Spector, Merrill, Van Merrienboer, & Driscoll, 2008). With initial testing of programmed instructions, Skinner believed that Learning machines could be an excellent means to save teachers' time and facilitate their work. If a teacher relegates to the machine those learning tasks that can be mechanized, then he is free to perform the irreplaceable human tasks in the learning process (Skinner, 1963). This paper will focus on what research tells us about different ways of learning with technology (the science of learning) and different ways of using technology as an aid in teaching (the science of teaching).

Learning with technology refers mostly to situations when technology is used with the purpose of encouraging learning. Today's term "learning with technology" mostly reflects what Lowyck (Lowyck, 2008, p. xiii) calls "*a common impulse to (try to) use available technology for schooling purposes*". The explosion of personal computers with the potential for internet connection in the second half of the 20th century revolutionized the way we communicate and has therefore profoundly influenced learning and teaching. At this stage we need to

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distinguish between two different directions: *technology oriented* and *learning oriented* approaches to teaching (Dumont, Istance, & Benavides, 2010). In the *technology oriented approach*, the use of technology is at the centre of education, enabling access to the latest technology.

What is therefore wrong with the technology oriented approach? The major problem with this approach is that in the 20th century it underwent numerous important cycles of inflated promises, and some introductions in to schools, followed by failures. Cuban (Cuban, 2001, p. 195) states: "*The introduction of information technology in schools in the last two decades of the 20th century has not brought about the transformation of teaching and learning nor increased the performance, for what executive directors of IT companies, public official, parents and educators strived for*". We need to be aware that each system is characterised by *structure* and *function*. One without the other is incomplete and cannot be conceived. Thus, it seems that the primary problem of the technology oriented approach is that it remains inconceivable, that technology remains self-serving, mostly because it considers neither the teacher nor the student; it is not concerned with its actual purpose or the goals of education, and it "demands" that students and teachers adjust to this technology instead of the technology adjusting to their needs.

On the other side, in the *learning oriented* approach, we focus first on how people learn, and we perceive technology merely as an aid, as a tool for learning. Therefore, it seems that *technology needs to be adapted* to the needs of the students and teachers to create suitable methods for working with it and a suitable pedagogical approach (innovative one to one pedagogy) (Aberšek, Borstner, & Bregant, 2014). In short, the majority of yesterday's optimistic forecasts about the influence of educational technology on education have not come true. Taking into account these previous disappointments, in teaching with technology *we must strive for an approach aimed towards the students*; moreover, the student and his experience need to be placed at the centre of the educational process (Dumont et al., 2010).

In short, we can agree that in traditional methods of e-learning (in the technology oriented approach), the individuality of the student is omitted (Berge, 2002; Dolenc & Aberšek, 2012). The majority of traditional e-material does not consider the varied parameters that influence the learning and learning habits of the individual; because of this, students cannot influence the course of their own learning (Picciano, 2001; Saba, 2002). Intelligent tutoring systems (ITS) are a generation of new learning systems that include the individuality of the student in the learning process, similar to what happens in a traditional individualised lesson with one teacher and one student. This traditional human tutoring process has proven successful and has represented the most efficient method of learning and teaching since the beginning of teaching. It should be enough to mention Plato and his teacher Socrates, and then Socrates and Aristotle, Aristotle and Alexander the Great, etc. (B. S Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Cohen, Kulik, & Kulik, 1982).

Developing ITS is connected to varied fields, because a correct and therefore successful implementation of a human teacher, needs to link fields from the cognitive sciences, artificial intelligence, functional literacy and many different fields connected to education. Knowledge is the basis of intelligent behaviour; that is why each ITS, in order to be called a knowledge-based ITS (Stankov, Rosic, Zitko, & Grubisic, 2008), needs to have: domain knowledge, knowledge about teaching principles and methods, and knowledge about the methods and techniques for student modelling. Computer systems such as ITS should provide the same instructional advantages as a human tutor (teacher), which certainly implies the interdisciplinary of these fields (Anderson, Boyle, & Reiser, 1985).

1.1. Previous research

Recently, many researchers have attempted to create and develop diverse individualized ITS. These ITS classify students according to several elements. The authors of ITS UZWEBMAT (Ozyurt, Ozyurt, Baki, & Guven, 2013) advocate classifying students according to their learning styles, and their courses are in line with the constructivist approach. Their ITS is intended for learning mathematics in secondary schools. Similar individualised learning environments based on learning styles (VAK – Visual, Auditory Kinaesthetic) are as follows: DEUS (Brown, Brailsford, Fisher, & Moore, 2009), eTeacher (Schiaffino, Garcia, & Amandi, 2008), Iweaver (Wolf, 2003) and AEHS-LS (Mustafa & Sharif, 2011). The authors of ITS ZOSMAT (Keles, Ocak, & Gulu, 2009) advocate learning with the help of gradual problem solving. Their ITS is intended for teaching and learning mathematics in higher education. Similar individualised learning environments based on a problem solving environment are the ELM-ART – an intelligent textbook created in the programming language Lisp (Weber, 1999), and COMET for teaching in medical schools (Suebnukarn, 2010).

A major problem that occurs with analysing the data in published literature is that of evaluating and grading the achievements of an individual ITS. Because of the difficulty with the range of tasks and the small sample size, for objective evaluation it is usually insufficient to merely compare a control group (lessons without the use of ITS) and an experimental group that is using a suitable ITS. Fletcher's study has provided some reference points for all future research that deals with evaluating the effectiveness of e-learning systems (Fletcher, 2003). On the basis of meta-analysis of research from this field, he classified and calculated effect size for different e-learning systems. For calculating an e-learning system's effectiveness, he used the distribution theory of the Glass estimator of effect size (Hedges, 1981). The results of Fletcher's research show that modern ITS are around 1.05 sigma better than conventional classroom teaching, which however is still less than 2 sigma, the difference that Bloom measured between tutorial instruction (one-to-one tutoring) and conventional classroom teaching (Bloom, 1984). This difference of 2 sigma (2 standard deviations) was the foundation for all subsequent research in the field of e-learning. An important study in this field was done by VanLehn (VanLehn, 2011), who compared a human tutor, his ITS and conventional classroom teaching. For calculating effect sizes, he used Cohen's estimator of effect size (J. Cohen, 1988). VanLehn's study did not confirm such a difference between human tutoring and conventional classroom teaching as did the Bloom study. The effect size of human tutoring compared to conventional classroom teaching was only $d = 0.79$, and his ITS achieved an effect size of $d = 0.76$ which is almost as effective as human teaching.

Because of the deviations in the research carried out, the results should also be compared to national achievements (or at least with the results of a large target group). In Slovenia, with the overhaul of the primary school system and the transition from an 8 to a 9 - year primary school programme, a National Assessment of Knowledge (NAK) has been defined and established. The fundamental objectives of NAK are to improve the knowledge of students, improve the quality of teaching and learning, and gather additional information concerning students' knowledge. The indirect goals, which originate from the fundamental ones, are as follows: developing students' capacity for critical analysis of their own accomplishments, ensuring equal educational attainment and unified criteria for teacher assessment, assistance with evaluating lessons plan, and long term efforts towards better quality of knowledge. The main purpose of NAK is therefore to improve the quality of

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learning and teaching, and by doing so, to ensure better quality knowledge and skills for the students. With the help of the information gathered from NAK, additional feedback is ensured concerning how the school system is functioning. The data from NAK is intended for students, their parents, teachers, schools and the creators of the educational system at the national level. The use of accomplishment in NAK in order to rank schools by achievement is not allowed and is against the principles of NAK (DKNPZ, 2005).

NAK is mandatory for students in the 6th and 9th grades. Knowledge from three different subject areas is tested. The first subject is Slovene; in ethnically mixed schools, Italian and Hungarian are also tested. The second subject is mathematics, and the third subject is chosen from the remaining subjects from the primary school programme. The third subject is chosen by the Minister of Education, Science and Sport, who, from among all subjects in the primary school programme, chooses not more than four subjects that will be tested and at the same time decides which one of these subjects will be tested at a certain school. The statistical results of NAK testing are published on the National Examination Centre's internet site (RIC, 2013, 2014). The percentage of tasks in the NAK tests is the same for all subjects and is defined in the NAK guidelines in primary school. It is recommended that each test include at least three types of task and that the percentage of these is in the following ratio:

- 30% tasks from level I of Bloom's Taxonomy (Bloom et al., 1956) (knowledge),
- 35% tasks from level II of Bloom's Taxonomy (understanding and use),
- 35% tasks from level III of Bloom's Taxonomy (analysis, synthesis and evaluation).

The examination and evaluation for each individual subject course is prepared by a subject commission appointed for that subject. The subject Technology and Science, was the third NAK subject in 2008, 2010 and 2013.

1.2. Challenges of education

The previously mentioned international and national comparisons demonstrate the challenges confronting education, but also illustrate the success of efforts to meet such challenges. In this process, education and skills will be of the utmost importance. What influences a student's experience is briefly shown in Fig. 1 (Aberšek, 2013).

One of the basic questions facing educators has always been, *Where do we begin in seeking to improve the teaching/learning process*? Undoubtedly, modern lessons are based on a modern learning environment. However, merely introducing modern ICT, such as ITS, is not enough. Additionally from that, we certainly need at least two elements in the process of education, if we disregard teacher qualification, and these are as follows:

- Modern, innovative teaching and learning methods and a pedagogy that supports and guides the use of ICT (Bocconi, Kampylis, & Punie, 2013) and
- Modern learning materials (Course/subject curriculum), to give content to the ICT, and therefore function and concomitant its true value.

Without mutual and integral interaction of all three elements, improved results cannot be expected, because with such an integral approach we must do the following:

- First, start from how individuals learn; answers to this can be found in modern cognitive science and neuroscience (Mathews, Badia, & Verschure, 2010) and
- Secondly, establish how to implement these findings in the form of e-materials (Kurilovas, Zilinskiene, & Dagiene, 2014; Ozyurt et al., 2013).

The article will present a model of a *learning oriented approach* and that stresses *individualisation* (the path suited an individual student) and *differentiation* (the pace of work adjusted to the needs of an individual student), which puts the student at the focal point of the ICT events.

2. Cognitive science and e-learning material

Cognitive scientists are trying to transfer their findings into practice – especially in the fields of teaching and learning, cooperation, machine learning and decision-making. Before showing how the learning process can be formalised, without disregarding the differences between psychological and pedagogical features of mental functioning, on the one hand and the characteristics of technical systems on the

Fig. 1. 4 Pillars of the education system.

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other, a *cognitive theory of learning*, which today is one of the most important paradigms of modern learning and teaching, must be taken into account. If we wish to overcome the accusation of disregarding the differences between psychological and pedagogical features of mental functioning, on the one hand and the characteristics of technical systems on the other, and when modelling higher cognitive processes also include the special characteristics of the educational field, where a student is not merely a research object but also a subject of their own guidance in change, we have to substitute structuralism as a basis with modern *cognitive science*, with a dynamic system and artificial intelligence (Aberšek et al., 2014).

So, when developing and planning e-material, one needs to include students' varying cognitive abilities. The majority of researchers (Ackerman & Goldsmith, 2011; DeStefano & LeFevre, 2007; Eklundh, 1992; Mangen, Walgermo, & Brønnick, 2013; Wastlund, Reinikka, Norlander, & Archer, 2005) agree that above average students have the fewest problems with reading and understanding e-material; however, several problems occur with average and below average students. Reading strategies and functional literacy are the main fields that should be included when developing e-material. Researchers (Mangen et al., 2013) assumed that students comprehend shorter texts better than longer ones. Researchers (Baccino, 2004; Eklundh, 1992) believe that this could be related to the issue of navigation between documents. Scrolling is known to hamper the process of reading. Organisation and structure of the text can also be hampered by limited access to the text (Piolat, Roussey, & Thunin, 1997). Ackerman and Goldsmith (Ackerman & Goldsmith, 2011) in their study suggested that people comprehend print media as being more suitable for effective learning and electronic media as a tool for fast, shallow reading of short texts, such as e-mail, news and notes. To overcome such problems, it is crucial then to individualise e-materials and adjust them to each student's capabilities.

3. An intelligent, adaptive and individualised e-learning environment

The basic system and content architecture of the modular system and a pilot model of the TECH8 e-learning material are explained in the following section.

3.1. Basic architecture of the modular system

A cognitive learning approach was taken as a foundation in creating the content of a pilot model of the TECH8 e-learning material which is an individualized, intelligent, student-oriented learning environment. Some innovations and characteristics that distinguish it from other systems can be listed as follows:

- *The content is in accordance with the cognitive approach*: Content is prepared in such a way that it guides the user according to his or her current knowledge and current learning capacity. TECH8 is designed so that learning proceeds from easier to harder, from simple to complex.
- *Intelligence and adaptivity:* Because TECH8 follows the user, it can, with the help of metadata, automatically adjust the difficulty of the learning content to the user. The user also has at his or her disposal a range of content and help, which can be chosen when needed.
- *System for collecting metadata and variables (SCAMV)*: Collecting metadata and variables allows direct analysis and evaluation within TECH8 itself and outside of it. TECH8 also allows the exporting and sending of metadata to developers and teachers, who can use the assembled data to evaluate the students and for "external" optimisation of TECH8, for example at the end of a school year (Fig. 2).

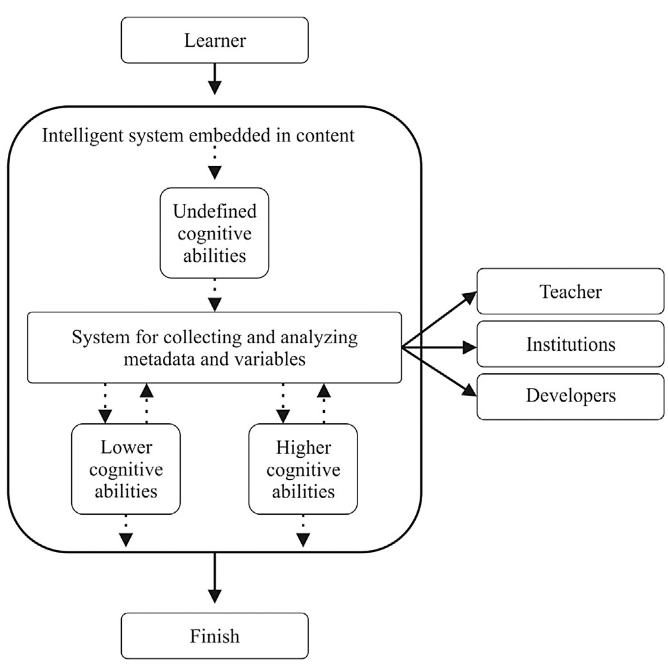

Fig. 2. Architecture of the TECH8 pilot system.

- *Modular architecture of the system*: TECH8 is built modularly; thus, a random part of the content can be changed and supplemented with new content or learning pathways and not interfere with the regular functioning of the whole system (Fig. 3).

As seen in Fig. 3, the learning whole represents the curriculum of a desired course. The learning whole consists of separate learning units, which include different content sections for an individual course. Learning units comprise separate building blocks, which include material that suits individual operating content and curriculum goals. With each building block, certain knowledge standards that are required by the specific subject curriculum can be achieved (Fakin, Kocijančič, Hostnik, & Florjančič, 2011). A component part of each building block is summative assessment (Fig. 4). The smallest module and component part of a building block is the learning step, which includes material needed for acquiring the desired standard of knowledge. If we wish to enable the highest level of individualisation and adaptivity in the system, the learning steps must have an appropriately branched structure, as can be seen in Fig. 3. The learning step is also the most important part of TECH8 because its structure decisively influences the individualisation process of teaching. Learning steps should not be fragmented but connected to the previous and the following learning steps. These steps should not include long texts, but include material in concentrated form, which stresses the essence of the specific material that the user needs to learn. They are adjusted to the individual requirements, level of knowledge and ability of each student. Each learning step includes formative assessment, with feedback that guides students from the beginning to the end (Fig. 4).

A system that is built according to such a modularly structured principle allows more than a simple replacement or substitution of individual modules but also permits vertical and horizontal interconnection of content within an individual curriculum and among separate curricula.

3.2. Content and structure of TECH8

For a pilot TECH8 ITS model, the Gears unit was chosen, which is the last unit of the Technology and Science class in the 8th grade of primary school in Slovenia. In the classroom, two lessons are assigned to cover this unit, and they are also the last two lessons in this subject

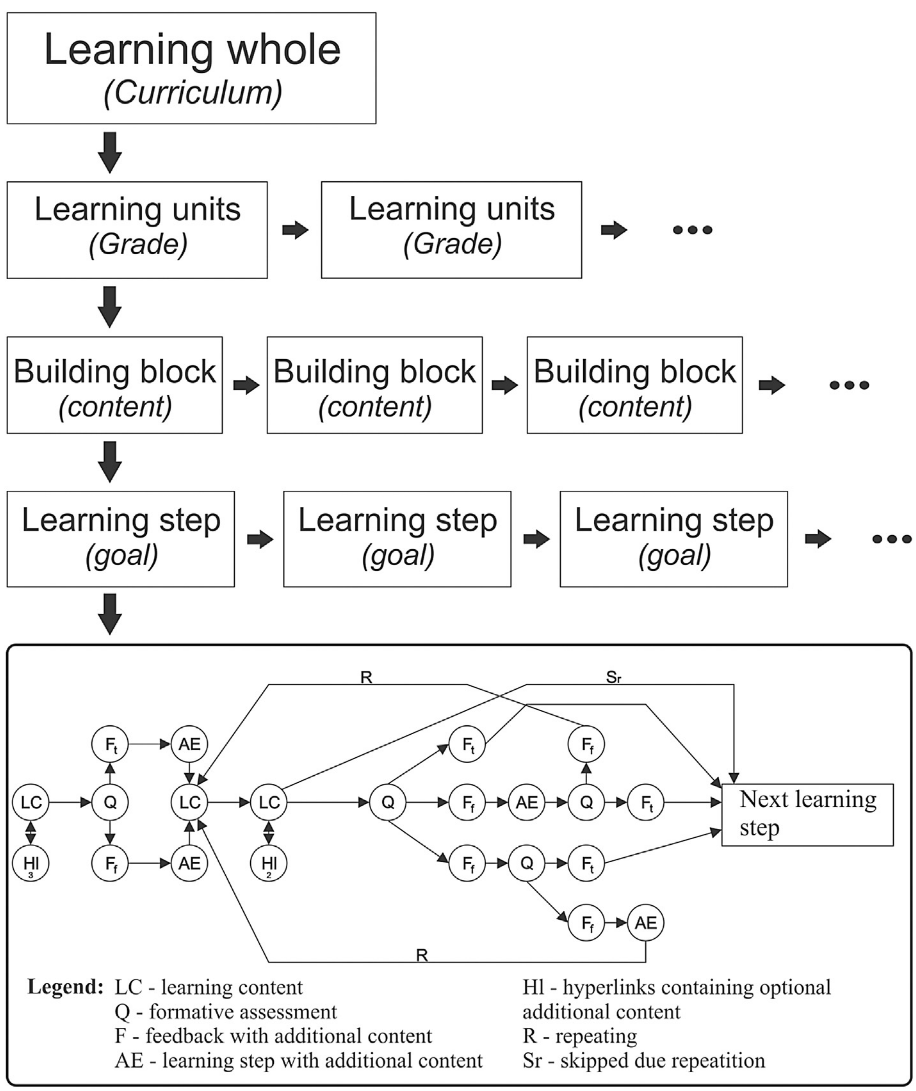

Fig. 3. Basic architecture of a TECH8 intelligent tutoring modular system.

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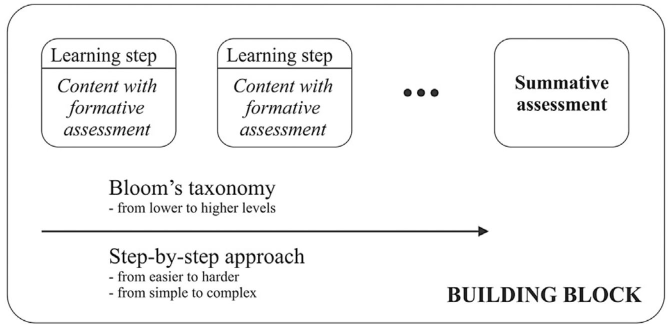

Fig. 4. Basic architecture of a building block and learning steps.

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in 8th grade. These units have been chosen because they traditionally yield the lowest grades according to the national assessment of knowledge on Technology and Science.

Six learning steps and an assessment comprise the Gears building block. Each of the six learning steps has a branched structure, with multiple formative assessments. The formative assessments are didactically designed in such a way that, with the help of the answers provided, TECH8 can figure out the exact gap in knowledge, and on that basis can provide the student with additional content/knowledge. Special attention was given to the introduction of content, which is followed by pictures, animations and a range of interactive elements. The content is prepared in such a way that the user can increase his or her knowledge, eliminate gaps in knowledge and progress from simpler subjects to more complex ones.

The initial learning step includes elements of diagnostic assessment, the majority of the formative assessment and part of the summative assessment. In this first learning step, all students begin with the same subject matter, which adjusts to their needs as learning progresses. SCAMV in TECH8 regularly assesses and analyses their achievements and prepares the best selection of subject matter and learning path for subsequent units. Simultaneously at this stage, the student's cognitive abilities are determined, according to which all future learning paths are adjusted (early differentiation). If a student is placed into a lower group at this unit (classified as a student with lower cognitive capabilities), additional content with additional explanation is automatically switched on in the following steps, for better understanding. Despite this, the student is constantly encouraged and guided towards understanding the content even at the highest cognitive levels. Thus, the student's initial classification can change in the course of the study material.

After the first unit, an intelligent agent was added on the basis of the results from preliminary research; through the metadata and variables obtained, this agent alerts the student to any mistakes. At the same time, it gives the student recommendations on how to improve learning. This agent is important, mostly because it can automatically analyse the student's learning path and warn him of the most frequent mistakes that occur during learning with TECH8. These could be as follows:

1. Skipping additional subject matter: when it has been ascertained that a student has studied a certain part of the course superficially (too fast – if the actual time differs significantly from the average time calculated for total assimilation of the material),
2. Finishing the formative assessment too fast or too superficially, when it is assessed on the basis of answers to questions that the student did not even read properly,
3. Useless additional material and help when the student has not used the help provided despite worse results, etc.

With this agent, the required level of TECH8 intelligence adaptivity was achieved. This intelligent agent is followed by other learning steps and at the end by a summative assessment, which assesses the content of the whole TECH8 course. The assessment comprised of 17 tasks, with which the achieved standards of knowledge are tested (Bloom et al., 1956):

- Four tasks that test the minimum standards of knowledge achieved (taxonomic level I),
- Five tasks that test the basic standards of knowledge achieved (taxonomic level II),
- Eight tasks that test the higher standards of knowledge achieved (taxonomic level III)

After the students finish the assessment, they can check their answers and the results achieved. SCAMV saves the acquired metadata and transfers it to TECH8 developers. Throughout the whole TECH8 course, between 300 and 400 different items of metadata are created, through which an individual's complete learning path can be constructed.

3.3. *A sample of a learning step used in the pilot model*

In this section, screen shots and the architecture of the 'Gear Ratio' learning step are given. Gear Ratio is the 4th learning step in the TECH8 pilot model. In the curriculum for Technology and Science for this subject matter, one basic standard of knowledge that is required involve: "determining the gear ratio". After this learning step, students must be able to calculate the gear ratios of two teeth from a given number of teeth or a given number of revolutions. In order to achieve the highest level of knowledge they must also be able to calculate the gear ratio of a gear assembly. Fig. 5 shows the architecture of this part of the learning step.

At the first level, all users, regardless of predefined cognitive abilities, are introduced to learning content with basic theory (LC – BT) and learning content with graphic illustration (LC – GD) of that basic theory (Fig. 6).

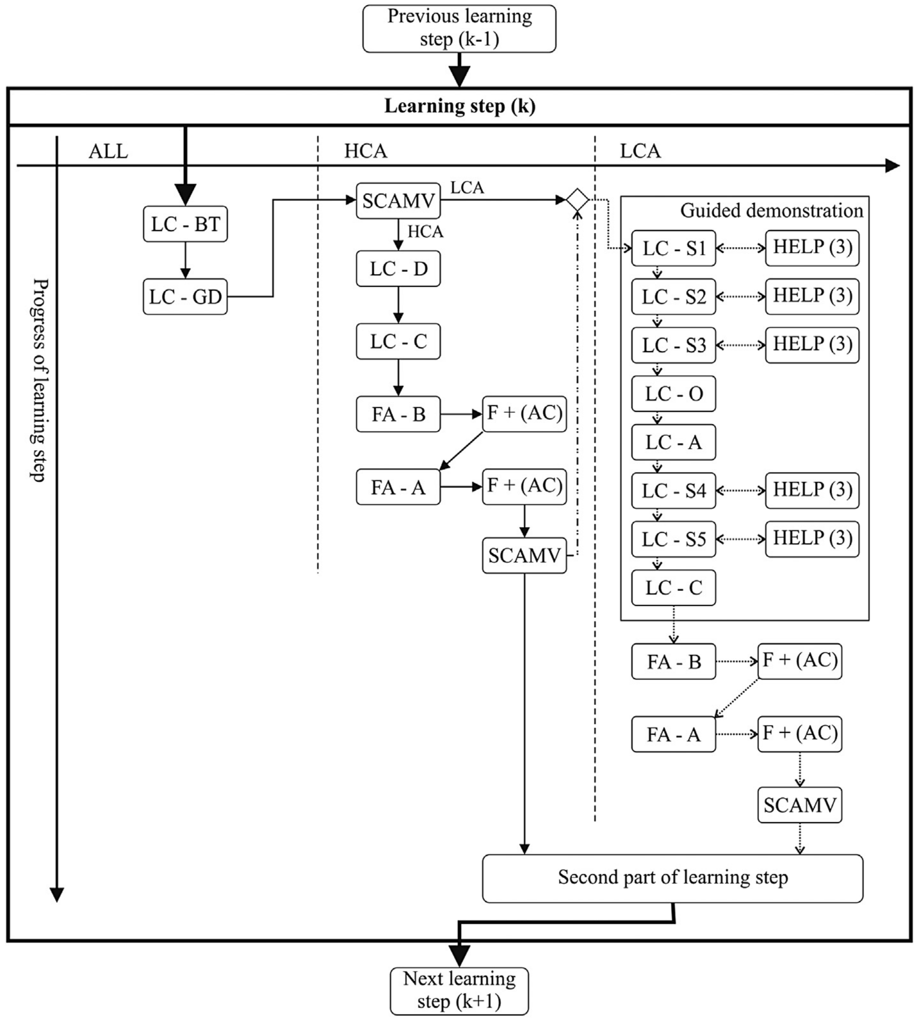

Fig. 5. Architecture of the Gear Ratio learning step.

In the next step, the system for collecting and analysing metadata and variables (SCAMV), through analysis of data from the previous learning steps, classifies students into higher (HCA) and lower learning levels (LCA). The students in the higher level advance to the learning content, where they are presented with examples of tasks and formulas for calculating gear ratio (LC − D), and in the following modules, also with examples of calculating and solving these tasks (LC − C). After finishing these modules, they advance to formative assessment, which is composed of two tasks. First, the formative assessment (FA − B) tests arithmetical knowledge of gear ratios from the number of teeth, and second (FA − A) from the number of axle rotations. In both tasks the students always receive feedback (F + (AC)), where an explanation is given of how to solve the specific problem, along with its solution, no matter if the answer given was correct or not. If the answer was correct, the feedback serves as knowledge confirmation and, if not, it serves as clarification of the mistake. After the feedback is given, SCAMV calculates the success of the formative assessment. If the results fulfil the conditions for advancement, the user progresses to the second part of the learning step. If the student does not fulfil the requirements for advancement, he or she is directed towards a guided demonstration. Guided demonstration is adjusted for students at a lower level. It comprises various learning units, fragmented into smaller steps, which function on a step-by-step didactic principle through which the student progresses from easier to more difficult subject matter (LC − S). In the first step (LC − S1), additional instructions are given for solving the task along with instructions for using the help that is at their disposal. At each step, a three-stage help feature (HELP (3)) is available; this appears automatically with every incorrect entry or can be activated by the user when needed. In the case of the first learning step (LC − S1), the functioning of the three-stage help process is as follows: In this step (LC − S1) the students must use the text of the given task to transcribe the number of teeth of the first sprocket. Following an incorrect entry or a click on the help button, the student receives initial help, which alerts him that he needs to enter the number of teeth of the first sprocket in the input field and confirm the entry by pushing the ENTER button (Fig. 7).

After a second incorrect entry or a click on help button, the student is again alerted that the required data can be found within the text itself. With the third and last stage of help, the sentence containing the information for solving the task is highlighted.

The steps from 1 to 3 include the subject matter for calculating a gear ratio with a given number of teeth. Then follows the overview of calculations and the results obtained (LC − O), and after that, an animation of the rotation of two sprockets of different sized (LC − A). This continues with steps 4 and 5, which include calculating gear ratio from the given speeds of the axles. After all the steps, there follows the analysis of the processes involved in solving the task and transfer of the results (LC − C). After that, the formative assessment follows, which

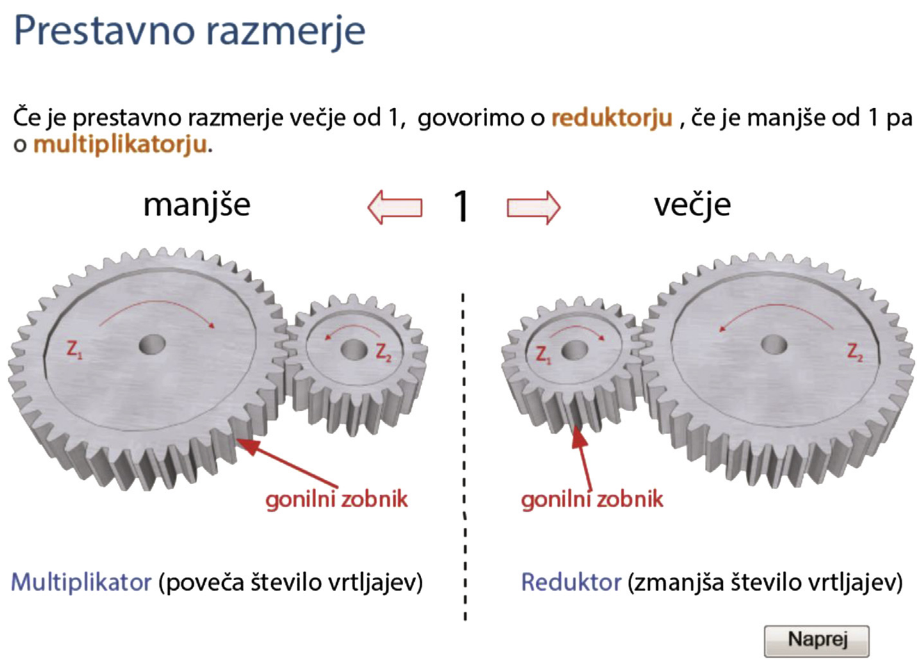

Fig. 6. Sample screen shot of learning content with graphic illustration of basic theory – the text in the picture is in Slovene.

is designed in the same way as for students at a higher level. Following the formative assessment feedback, SCAMV calculates the student's performance.

After completing the first part of the learning step, for classification in the second part SCAMV determines four states which the students can achieve:

- State 1: Students with a higher level of cognitive ability who have met the requirements for advancement at their level;
- State 2: Students with a lower level of cognitive ability who have met the requirements for advancement at their level;

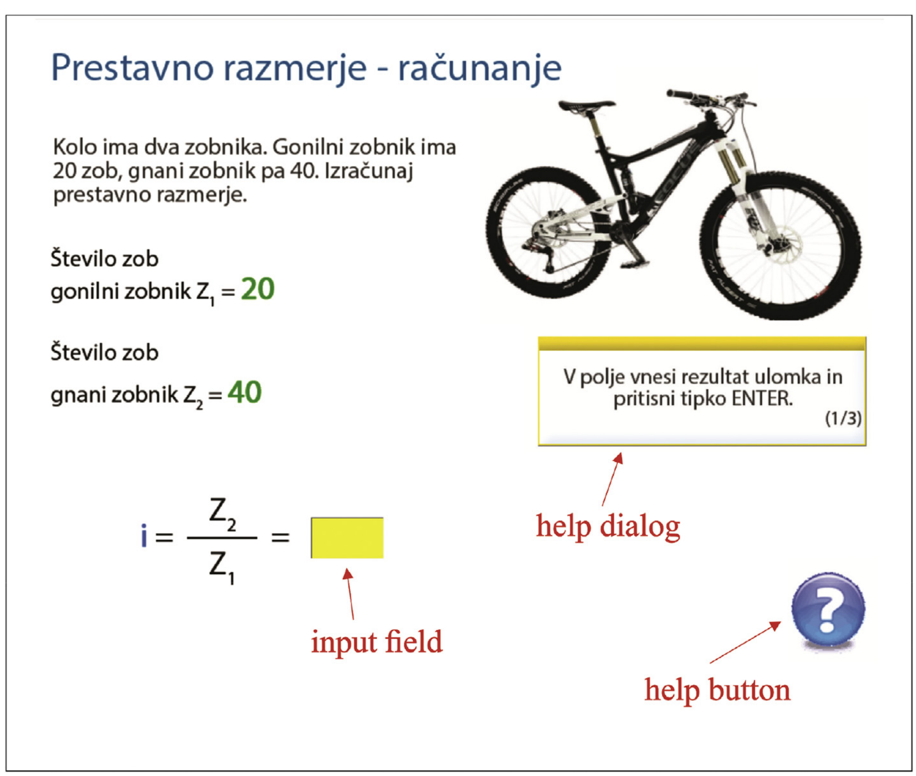

Fig. 7. Sample screenshot of a learning content step one (LC –S1) – the text in the picture is in Slovene.

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- State 3: Students with a higher level of cognitive ability who have not met the requirements for advancement at their level and have revised the subject matter;
- State 4: Students with a lower level of cognitive ability who have not met the requirements for advancement at their level.

The second part of the learning step includes the topic of calculations involving a gear assembly, where a higher standard of knowledge is required. The architecture of the second part of the learning step is the same as for the first part. On the basis of the student's state after the first part of the learning step and the level of cognitive ability defined before the learning step (k), at state 1 the student can advance on the path for students with greater cognitive ability. A student at state 3 can advance on the path for students with less cognitive ability. Although the second part of the learning step requires higher standards of knowledge, a student at state 2 or 4 can continue on the path for a student with less cognitive ability. At the end of the Gear Ratio learning step, SCAMV recalculates the results of the formative assessment and the effectiveness of task solving and, if necessary, adjusts the student's level.

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4. Research methods and procedures

The aim of the empirical research is the implementation, evaluation and optimisation of TECH8, which is based on adaptive and, most importantly, on individual e-learning with ITS. The research was divided into two steps:

- Preliminary research: testing and evaluation;
- Full scale research: optimization, implementation and re-evaluation.

Firstly, TECH8 was designed and developed. Individualised content, which is comprises a various topics suitable for different levels of knowledge together with the SCAMV system were integrated into TECH8. The primary part of the designed ITS was subjected to preliminary testing and evaluated as part of the preparations for NAK (National Assessment of Knowledge) in the field of Technology and Science. In this case the teacher was merely a spectator. The main research questions in this part of the research mostly concerned technical and technological fields. The main research questions of the preliminary research were whether the SCAMV system for classification worked, and how the acquired metadata could be used to improve TECH8's intelligence, increase the knowledge level of individuals, and to analyse and evaluate TECH8's intelligence. After the acquired data was evaluated, TECH8 was optimised and implemented in full scale research in a real class environment. For the topic of Gears two 45 min lessons are prescribed in the curriculum. Each school selected in the project participated with two classes arranged as follows:

- One class represented *the control group*, where conventional lessons were carried out (teacher, use of learning puzzles, sets of building blocks with gears, disassembly of several machines and examination of the gears)
- The second class represented *the experimental group*, in which students independently used TECH8 (independent work by students, the teacher as merely a spectator)

The performance data for the control group and the experimental group was acquired via summative assessment. In the control group, after the lessons were finished, a written summative assessment took place. The assessment was identical to that for the experimental group, with one exception; it was not in electronic form. In the experimental group, the data was collected with the SCAMV system throughout the TECH8 process. At the end of the individualised learning process, a summative assessment in electronic form was carried out.

The main research questions for this part of the research were mostly connected with problems in the field of pedagogy. The primary research question of the preliminary study concerned the deviation between levels of students' knowledge using TECH8 (individualised learning) and students' knowledge level when using traditional teaching, and the suitability of the students' initial cognitive level classification according to the end result of the summative assessment. The results of the TECH8 summative assessment were also compared to the results of the national assessment of knowledge from 2008, 2010 and 2013. The tasks compared were of the same difficulty level and required the same goals to be achieved.

4.1. Participants and sample selection

In the preliminary research, the TECH8 was tested in the 9th grade in two randomly chosen lower secondary schools (suburban and urban), which had already studied the chosen subject matter in the 8th grade. 33 students participated in the study.

In the full scale research, the TECH8 was tested in the 8th grade in five randomly chosen lower secondary schools (suburban and urban) that had not already studied the chosen subject matter. 117 students participated in the research. The group was fairly gender homogeneous and was composed of 52 girls and 65 boys. TECH8 was tested in a real classroom environment.

In the national assessment of knowledge, there were:

- in 2008, 4747 students from 121 schools;
- in 2010, 4762 students from 121 schools;
- in 2013, 4135 students from 119 schools.

4.2. Data analysis

Quantitative data in the experimental group was collected via the SCAMV system for collecting metadata and variables developed for evaluating students and for adapting and evaluating TECH8. SCAMV collected over 300 - 400 separate items of metadata per student.

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Table 1
Results of the NAK from the subject course Technology and Science.

Year	Mean of total score	No. students	Max. Points	Mean of total score in %	Standard deviation in %	Mean (of gears content) in %
2008	18.4	4841	33	55.8	17.4	33.3
2010	17.56	4762	33	53.2	17.73	27
2013	17.49	4135	30	58.33	16.03	69.66

Table 2
Students' achievements in the summative assessment.

Group	Mean of total score	No. students	Mean of total score in %	Max. Points	Standard deviation in %	Skewness
Experimental group	20.71	59	55.70%	39	20.78	−0.236
Control group	16.72	58	44.30%	39	25.11	0.657

Quantitative data in the control group was collected, reviewed and rated by a group of experts in the field of technology and science. Quantitative data collected in the experimental and the control groups was analysed according to the following phases, or by: encoding, defining and organizing the data and interpreting the results.

Data from NAK was collected, evaluated and statistically processed by the national curriculum committee for the Technology and Science course and published in the yearly report of the National Assessment of Knowledge.

5. Results and discussion

The results from the Gears module are traditionally the worst (with the exception of 2013[2]) in the national assessment of knowledge, which is apparent from Table 1.

In 2008, 4841 students participated in NAK, where the maximum possible number of points was 33. The average achievement of students on NAK as a whole was 18.4 points, which represents 55.8%. In the Gears module this percentage was only 33.3%. For the Gears topic there were six tasks, two of which belonged to the 1st taxonomic level and four to the 3rd taxonomic level. In 2010, 4762 students participated in NAK, where the maximum possible number of points was 33. The average achievement of students on NAK as a whole was 17.56 points, which represents 53.2%. In the Gears module this percentage was 27%. For the Gears topic there were four tasks, one of which belonged to the 1st taxonomic level and three to the 3rd taxonomic level. In 2013, 4135 students participated in NAK, where the maximum possible number of points was 30. The average achievement of students on NAK as a whole was 17.49 points, which represents 58.33%. In the Gears module this percentage was higher, being 69.66%. For the Gears topic there were three tasks, all three of which belonged to the 3rd taxonomic level, which is also why the results were (seemingly) better. Standard deviation is very high in all the years, which confirms that there are great differences in the students' levels of knowledge.

The acquired TECH8 results were analysed via descriptive statistical techniques. With the preliminary research, it was possible to successfully test TECH8's technical functioning. It was established that the SCAMV system functioned successfully and that it collected metadata. A problem was identified in the stability of the system that sends metadata. Because of the amount of data (300–400 items per student) certain data was lost that was intended for the evaluation of the content itself. The metadata and variables intended for adapting TECH8 to students functioned as intended.

In the full scale research, the main research question was the deviation between levels of knowledge in the TECH8 groups (students' individualised-learning) and traditional teaching groups (Table 2).

The control group, composed of 58 students, achieved an average of 16.72 points in the summative assessment, which is 44.3%. The experimental group, composed of 59 students, achieved an average of 20.71 points in the summative assessment, which is 55.7%. The standard deviation in both groups is very high, which confirms that as with NAK there are great differences in the students' levels of knowledge. The skewness value for the experimental group is negative, which indicates that the mass of distribution is concentrated on the left. The skewness value for the control group is positive, which indicates that the mass of distribution is concentrated on the right. Skewness values for both groups indicate that, in the experimental group, the majority of students achieved better results, and that the majority of students in the control achieved worse results, as indicated in Fig. 8.

The results of the experimental group with TECH8 were more than 10% better than those from the control group, which was to be expected. The progress of the experimental group in comparison to the control group and the results from NAK is also obvious from the cognitive level of students measured at the start of using TECH8 and the cognitive level achieved from the summative assessment at the end of using TECH8. The cognitive level represents the student's ability to comprehend and solve various tasks, especially those at a higher taxonomic level. At the start of using TECH8, it was established that 30.5% of students fall within the lower cognitive level and 69.5% within the higher cognitive level. After the summative assessment and renewed classification, the percentage of students in the lower cognitive level was only 16.9%. The percentage of students who advanced to the higher cognitive level was 23.7%. 10.2% of students, however, regressed from the higher level to the lower. After a detailed analysis and evaluation of data acquired with the SCAMV system, it was established that all the students who regressed to a lower cognitive level were borderline cases, which means that the students' values measured at the start of using TECH8 were on the boundary line between the lower and higher cognitive levels but were classified in the higher cognitive level. 66.1% of students kept the same cognitive level as was measured at the start.

[2] See explanation of causes below.

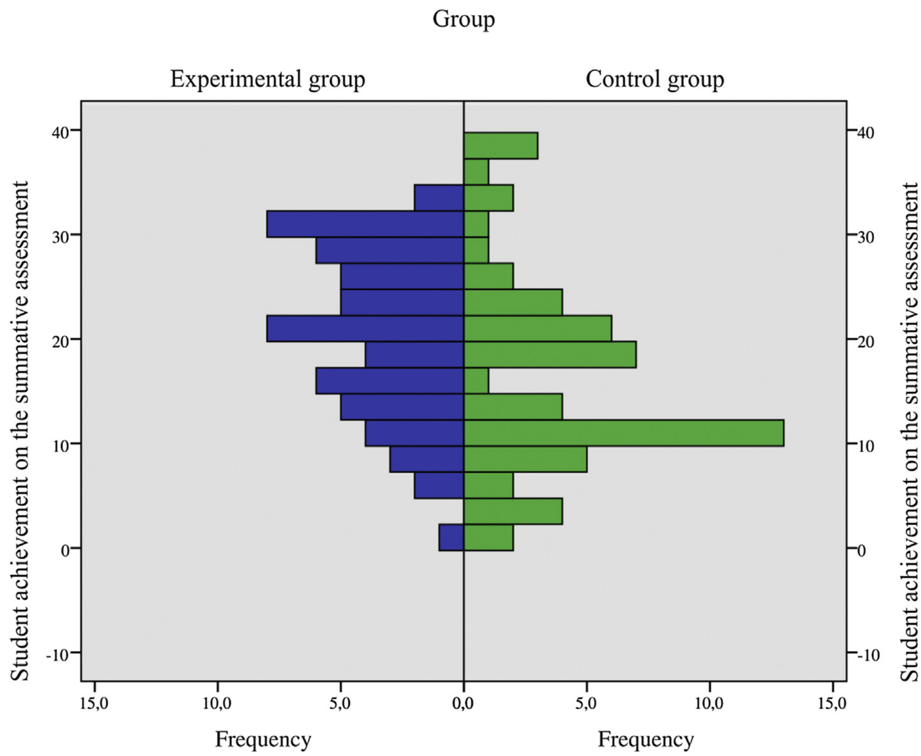

Fig. 8. The frequency of results for the control and the experimental group.

6. Conclusion and future work

Information-communication technology (ICT) is already an integral part of all school systems, while e-education and e-material are notions without which we cannot imagine schools today. This is why it is even more important that electronic learning material be prepared in a high-quality manner and that it be intended for active education without the direct presence of a teacher or with only limited teacher input; moreover, it should not be perceived as an end in itself, as is often the case today. Modern research in educational processes shows that the highest educational goals cannot be achieved without the active participation of the student. In order to follow the appropriate development of the student's potential, it is therefore of the utmost importance that we continuously follow and evaluate the educational process, and implement corrections when needed. This way of working is largely enabled by modern (intelligent) electronic learning material, but only if it is correctly designed (from the viewpoint of pedagogy and didactics) and technologically implemented. Such material must also evaluate the user and in the case of poor results, change the path towards achieving the planned goals.

The results of the evaluation clearly show that, with the use of TECH8, the achieved results are more than 10% better when compared to traditional lessons, which was expected. Nevertheless, the control group, according to the results of NAK in the Gears subject module, also achieved a high result, which can be attributed mostly to the highly qualified work of the teachers who took part in the research. These teachers regularly collaborate with the university, and it can be assumed that by cooperating with the researchers they transfer modern methods and theories of teaching into their own classrooms. At the start of using TECH8, it was calculated that 30.5% of students fall within the lower cognitive level and 69.5% within the higher. However, the measurements at the end of training showed that only 16.9% of students were within the lower cognitive level, which clearly indicates the advance in student knowledge levels that was achieved with the help of the individualised ITS. The progress that was achieved is only the first part of the optimisation of TECH8. With the help of all the data collected with the SCAMV system, it is now clear which parts still need to be upgraded and where various new paths and elements need to be added as a motivation for students to learn. This is also the biggest challenge for both schools and modern intelligent tutoring systems. It turned out that, despite individualised e-learning and adjusted content, the motivational element or the capacity for learning by oneself plays the key role in working and learning with the help of ITS. Following the student's every step, which is made possible by TECH8, yields better insight into the student's motivation and his or her ability at self-learning. This will be a challenge for future research and advance in this TECH8 system (and certainly all others).

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