INTERACTIVE E-LEARNING MATERIALS IN THE MATHEMATICS CLASSROOM IN SLOVENIA

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Abstract

This article presents the current development of e-learning in Slovenia, with an emphasis on the domestic E-um web portal (URL: www.e-um.si) for teaching mathematics in primary and secondary schools. Based on findings from recent scientific research, the strengths and weaknesses of e-learning materials in education, particularly in mathematics classes, are analyzed. We are particularly interested in the advantages and disadvantages of interactive e-learning materials in comparison to traditional learning materials as well as in the quality of the E-um web portal in comparison to similar educational web portals at home and abroad. Theoretical findings are tightly interwoven with examples of teaching practice using the E-um interactive materials.
Key words: *blended learning, e-learning, E-um, interactive e-learning materials, mathematics classes.*

Introduction

Schools and teachers are constantly challenged to modify old practices and to incorporate new pedagogical, psychological and didactic knowledge into teaching practice. School work at the end of the 20th and the beginning of the 21st Century is particularly marked by constructivism (e.g. Vygotsky's Social Constructivist Theory), as well as with the development of information and communication technologies (ICT). Teachers should be able to adopt new educational media and more effective teaching approaches, while evaluating the quality of their own work. This evaluation must consider issues such as the following: motivating the current generation of students, including them in the learning process as active members, promoting their responsibility for their own learning, explaining abstract concepts in an understandable way, contributing to a greater sustainability and transferability of skills, encouraging talented students, and planning effective assessment.

This article presents and discusses e-learning with the use of e-learning materials, which is one such educational challenge. Based on findings from recent scientific research, the strengths and weaknesses of e-learning materials in education, in particular in mathematics classes, are analyzed. Theoretical findings are presented together with an example of current e-learning development in Slovenia, while special emphasis is placed on the domestic *E-um* web portal for teaching mathematics in primary and secondary schools. The quality of this web portal is discussed and compared to that of similar domestic and foreign educational web portals.

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Contexts and hypotheses

Slovenia has been in the process of implementing the curricular reforms for vocational, vocational-technical, professional and gymnasium programmes since 2008. The reformed curriculum for mathematics underlines the development of the ability to use ICT in the implementation of mathematical processes and solving mathematical problems as one of the key competences. There are four main purposes of using ICT in mathematics classes: compensating the deficits in knowledge and skills, supporting teaching problem-solving and learning strategies, dealing with complex mathematical problems that are relevant to specific professions and everyday tasks, and implementing mathematical procedures by applying technological tools. Explicitly mentioned among ICT are pocket calculators, graphing calculators and educational software such as spreadsheets, dynamic geometry programs, graph plotting software, etc. (Repolusk and Lipovec, 2007; Rojko et al., 2007a, 2007b).

The curricula for mathematics in vocational-technical and professional programmes also set the ICT challenge for modernizing the curriculum for mathematics in gymnasium, as the intense and functional integration of ICT into school practice was among the highlighted objectives of the gymnasium programme modernization (Žakelj et al., 2008).

Potential integration of ICT into education includes e-learning and the use of e-learning materials. Until recently, e-learning in the narrow sense of online education was substantially more developed and widespread in the world than in Slovenia. A comparison of e-learning prevalence in mathematics classes in Slovenia and in some other countries leads to two observations:

- The use of ICT in Slovenia, particularly calculators, open source mathematics software (e.g. GeoGebra, Z.u.L., Graph, etc.), selected internet content and interactive whiteboards is gradually increasing. In gymnasium math classes in Slovenia – unlike the common practice in the world (cf. Kutzler, 1999; Posamentier, Smith, & Stepelman, 2006) – we skipped the phase of broader systematic introduction and the use of graphing and CAS calculators. Instead, our preference lay in supporting online learning and the use of educational math software on PCs. During reforming of mathematics curriculum in the new nine-year primary school in 1998, a great debate took place whether to permit the use of any pocket calculator at all in Slovenian primary schools (Magajna & Žakelj, 2000).
- Until recently, there were few active web-courses in teaching mathematics (minor projects limited to specific mathematical content and smaller groups of users), mainly due to the lack of sites, dealing with a wider selection of mathematical content in primary or secondary schools. This is, of course, linked to the need for a large initial financial input, mostly possible through the recent e-learning projects financed by the European Social Fund (ESF) and the Ministry of Education and Sport of the Republic of Slovenia (see e.g. *E-gradiva! Pregled novih e-gradiv 2006/2007*). One of the major milestones in online education concerning math classes in Slovenia was the creation of the *E-um* web portal in 2006 (URL: http://www.e-um.si), which was designed for interactive learning of mathematics in primary and secondary schools.

Next we will present some current theoretical and empirical findings concerning the role of computer-assisted teaching, particularly the use of e-learning materials. This will be followed by an analysis of the *E-um* web portal as an example of good practice in computer-assisted learning in math classes. As the authors of the *E-um* web portal, we wanted to support our practical work with theoretical and empirical arguments. Selected results of this study will be presented here.

The following two hypotheses are related to the use of e-learning materials for mathematics classes:

- The first hypothesis: E-learning materials have great educational potential in comparison to printed ones, and owing to their electronic nature and interactive capabilities, they have important advantages, which may increase the quality of education.

- The second hypothesis: In comparison to similar domestic and foreign online portals, the Slovenian *E-um* web portal for teaching and learning mathematics in primary and secondary schools is a high-quality educational portal.

We want to avoid the duality of man vs. media, which is sometimes presented as a threat to the role of the teacher in school (i.e. the question, to what extent will electronic media replace the teacher's role in the classroom and eliminate face-to-face communication). Such personal beliefs and concerns can often be an obstacle to comprehensive critical evaluation of the role of ICT in the modern educational process (Bowers & Doerr, 2001; Da Ponte, Oliveira, & Varandas, 2002; Leder, Pehkonen, & Törner, 2003). One solution was offered by Borba (2005), who developed the concept of *humans-with-media* as a basic educational unit in which the bipolar view of man and media is unnecessary. If the media are defined as mediators in communication between people and the world, then this term includes all forms of mediators – from the primary ones, such as speech and writing, to the complex, technology-supported ones, such as computer and phone (cf. Blažič, Ivanuš Grmek, Kramar, & Strmčnik, 2003). All media serve humans and are in close association with them. Borba's approach is partly based on the work of the Russian psychologist Oleg Tikhomirov, who introduces the idea that the main role of the computer is primarily to reorganize existing human activities and to encourage the creation of new ones, rather than to replace the human role in the process of education (Borba, 2005). Borba continues to support this view with his own as well as foreign research, which may lead to the conclusion that the human-computer unit creates conditions for new forms of teacher-student interaction and for designing new ways of reasoning and arguing in the educational process.

Methodology of Research

Having examined the professional and scientific literature (primary and secondary sources) dealing with the role of e-learning materials in education and the possible positioning of the *E-um* web portal in a broader context of similar web portals in the world, we have decided to use the descriptive method, the comparative method, the classification method, and the method of analysis and synthesis.

Basic terminology

There were some terminology problems in describing the concepts of e-learning. Therefore, we first outlined some basic definitions chosen on the basis of a wider review of professional and scientific sources.

We define the concept of media according to Blažič et al. (2003): *media* are providers and/or deliverers of information. The media in the broadest sense constitute persons, beings, objects and symbolic expressive forms that convey information between humans and the world. However, the term media is frequently used in its narrowest sense; i.e. to denote the material media made by humans. To address the importance of media in education, we are particularly interested in *learning media* – those that provide a specific didactic function in the educational process. Under the concept of *e-learning media*, we will understand every electronic educational technology that is based on computer technology in potential combination with telecommunication networks – such media are also known as *digital media*. In this paper, the phrase information and communication technologies (ICT) is used as a synonym for e-learning media.

E-learning is defined as education where computer-assisted technology in potential combination with the telecommunication networks is used as the learning media (cf. Ando, Górczyński, & Wierzbicki, 2007; Suanpang et al., 2003, as cited in Engelbrecht & Harding, 2005a; Uzunboylu, 2006). In a narrower sense, e-learning is strictly used for *online education* (Anderson & Elloumi, 2004; Ando et al., 2007). When combining traditional forms and methods of learning with e-learning, we talk about *blended learning* (Bielawski & Metcalf, 2005).

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E-learning material (object) is learning material that is used and presented by computer technology and/or telecommunication networks (i.e. digital media). This includes, for example, educational software, digital video-and audio recordings, online encyclopaedias, e-books and e-workbooks, digital slides (presentations), interactive web resources, interactive diagrams (applets), etc. All these are available either on portable memory storage media or on the internet.

In the following chapter, we present recent results about opportunities for e-learning that can help us in planning and designing e-learning materials.

Results of Research

Advantages and limitations of e-learning and e-learning materials

Let us summarize current research findings about the role of e-learning in teaching mathematics (and beyond):

Advantages of e-learning:

- spatial and temporal flexibility of the educational process for all participants (Descamps, Bass, Evia, Seiler, & Seppälä, 2006; Engelbrecht & Harding, 2005a, 2005b);
- the possibility of individualized learning and progress monitoring for each student (Orton, 2004; Posamentier et al., 2006);
- simple, quick accessibility to comprehensive collections of information and educational materials on memory storage media or internet (Ameis, 2006);
- increased frequency and facilitation of new forms of communication between participants in the educational process (Ameis, 2006; Engelbrecht & Harding, 2005b);
- provision of and demand for greater student responsibility for their own knowledge (Engelbrecht & Harding, 2005a, 2005b; Orton, 2004);
- visualization and multimedia capabilities of digital media have great potential didactic value in the educational process (Ameis, 2006; Engelbrecht & Harding, 2005a);
- digital media permit new methods for detection and investigation of (mathematical) problems (Ameis, 2006; Krantz, 1998; Orton, 2004).

Limitations of e-learning:

- asynchronous forms of e-learning neglect the intuitive and emotional aspects of learning, of interpersonal contact and of confrontation of different ideas (Ando et al., 2007; Engelbrecht & Harding, 2005b; Gagne, Wager, Golas, & Keller, 2005; Orton, 2004);
- students cannot formulate and ask questions appropriately (Krantz, 1998; Orton, 2004);
- the quality of mathematical knowledge improves only through use of the computer to develop mental strategies of a higher order (applets and laboratory work, i.e. programming, may play an important role here) (Krantz, 1998; Wenglinsky, 1998, as cited in Blažič et al., 2003);

Mason's conjecture:

- "Animated images in particular may decrease the time needed to encounter an idea, but there may be a corresponding increase in the time needed for construal. In other words, electronic screens may enhance learning, but may not make it less time consuming" (Mason, 1995, as cited in Povey & Ransom, 2000, p. 55);
- there is a danger of information overload and an issue of content authenticity – it is necessary to simultaneously develop competence in critical selection and evaluation of information (Gagne et al., 2005; Stiles, 2000; Engelbrecht & Harding, 2005b);
- the sense of a loss of control over modern e-learning media appears to be an issue for some participants in the educational process (Hendricks, 2000, as cited in Blažič et al., 2003; Povey & Ransom, 2000);

- technical familiarity with ICT is a basic prerequisite for effective e-learning (Vale & Leder, 2004);
- eacher and student beliefs, their attitudes towards e-learning and previous experience with e-media have an important impact on the effectiveness of the learning process (Da Ponte et al., 2002; Forgasz, 2006; Leder et al., 2003; Povey & Ransom, 2000);
- enormous financial resources are required to start e-learning, not to mention hundreds of hours for technical and didactic planning as well as for the creation of e-learning materials.

There are also some interesting and important research findings about the strengths and weaknesses of e-learning materials in (mathematics) education:

The advantages of e-learning materials are the following:

- interactive knowledge objects (applets, quizzes, etc.) encourage internal motivation and enable an independent investigation of the effects of various parameter changes (Anderson & Elloumi, 2004; Engelbrecht & Harding, 2005a; Orton, 2004; Yerushalmy, 2005);
- diverse presentation of concepts and procedures (multimedia) activates student senses more completely and thus increases the possibility of accessing and understanding the learning content (Descampes et al., 2006);
- interactive e-materials allow multiple repetitions of individual learning activities (Ameis, 2006; Blažič et al., 2003);
- with dynamically generated exercises, understanding is easy to check, motivation increases and individualized learning is promoted (Prnaver, Pesek, & Repolusk, 2009);
- e-learning materials are quickly and easily accessed and updated in comparison to printed materials.

The limitations of e-learning materials are as follows:

- the existence of interactive material does not alone guarantee the effectiveness of e-learning, neither does the lack of interactive knowledge objects suggest its inefficiency: e.g. applets *"require work and must be changed, not merely viewed"* (Yerushalmy, 2005, p. 244);
- digital interfaces are a must for the presentation of e-learning materials;
- reading the text from the display is up to 50% more burdensome for the eyes than reading from a printed book (Bielawski & Metcalf, 2005);
- the average reading speed from the screen is 25% lower than that from a printed book (Bielawski & Metcalf, 2005);
- interactive e-learning materials face a significant problem with anticipating student behaviour and response; therefore, developing adequate feedback is difficult (Krantz, 1998; Orton, 2004);
- planning and creating of e-learning materials is relatively demanding and complex from the didactic, technical, temporal and financial point of view.

According to Bonk and Reynolds (1997, as cited in Anderson & Elloumi, 2004), web-learning encourages higher mental processes only if it allows implementation of activities in which students connect new and existing knowledge, acquire meaningful knowledge and develop metacognitive skills. Therefore, the quality of learning is primarily influenced by the pedagogical approach (didactic methods, motivation, communication, etc.) and not by the technology itself. In other words, it is not the computer and internet that contribute to increased learning efficiency but well-designed and well-presented learning materials and activities transmitted via the computer or internet. Since computers and the internet (or other digital media), on the other hand, enable the design of rich interactive and multimedia-based learning materials, they affect learning indirectly (Anderson & Elloumi, 2004). Rosset (2002, as cited in Anderson & Elloumi, 2004) pointed out that e-learning materials should be designed to focus on students and learning, while e-learning

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should also provide additional technical and pedagogical support. Ring and Mathieux (2002, as cited in Anderson & Elloumi, 2004) additionally stress that e-learning should be as authentic (i.e. contextual learning) as possible, while it should enable cooperative learning among the participants.

Furthermore, Slavit and Yeidel (1999) reveal that, if web-based activities are incompatible with the teacher's usual pedagogical approach, short, intensive teacher training for such a form of education is insufficient to overcome the discrepancy. Computer aided teaching is much more learner-centred, investigation-based and visually oriented; therefore, teachers who fail to develop such pedagogical approaches in traditional classes (i.e., without the use of digital media) have difficulty in introducing digital media into any form of teaching.

E-learning materials have, therefore, great pedagogical potential, but the key lies in wise planning and effective use of these materials, not just in their interactive or multimedia capability. The above results are well summarized by Ameis (2006):

"Technology such as the Internet is not a panacea for the challenges inherent in teaching mathematics or a cure for ineffective teaching practice. Nor is the Internet a replacement for basic mathematical understandings and skills that students need to acquire. Rather, the Internet can be used to foster those understandings and skills and enrich students' learning of mathematics. (...) The Internet offers teachers for teaching important areas of mathematics and offers students opportunities to engage the interrelated processes of investigation, reflection, communication, problem solving, and reasoning" (Ameis, 2006, p. 18).

In the following chapter, we introduce the example of the first comprehensive web portal for teaching and learning mathematics in Slovenian primary and secondary schools and analyze it in the light of previously described findings.

An example of a modern teaching approach with the E-um e-learning materials

Over the last decade, many seminars were held in Slovenia where teachers were trained to use specific educational software for the mathematics curriculum; additionally, some learning materials were published on CD's. However, the teacher had to spend a considerable amount of his working (or even free) time to discover the learning potential of this software. The main drawback of such practice was the fact that the seminars and software covered only a limited amount of mathematical content that could only be used occasionally in math classes (e.g. dynamic geometry software, or software for symbolic algebraic manipulation). For a relatively short period of classroom time using such software, the teacher had to invest a large share of his/her time and enthusiasm, an investment that was not always justified by the results. This was probably a major reason for the lower popularity and use of ICT in mathematics classes than some educators in Slovenia wanted or expected. An additional problem in Slovenia was the relatively underdeveloped field of didactics of ICT use, so many teachers had no wider didactic support in planning and teaching with ICT, despite their good technical knowledge (Repolusk & Lipovec, 2007).

We have already mentioned the *E-um* web portal, which was developed between 2006 and 2009, and was financially supported by the European Social Fund (ESF) and the Ministry of Education and Sport of the Republic of Slovenia. The project involved about 50 primary and secondary school mathematics teachers, mathematics teachers from Gymnasium Ptuj, and university professors and assistants from three Slovenian universities (Hvala, Kobal, & Zmazek, 2007, Kobal, Hvala, Zmazek, Šenveter, & Zmazek, 2007; Lipovec, Kobal, & Repolusk, 2007, Pesek & Regvat, 2007; Zmazek, Hvala, & Kobal, 2007).

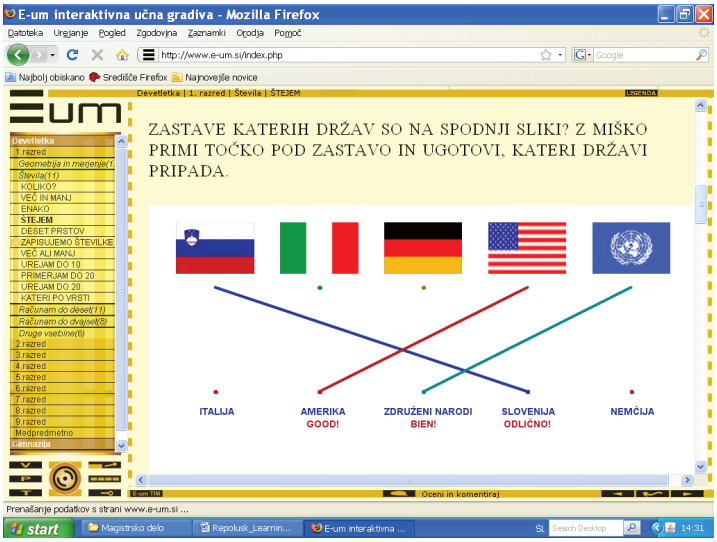

Figure 1. Example from E-um e-learning folder for 1st year of primary school (source: E-um web portal, URL: http://www.e-um.si/).

Participants in the *E-um* project tried to overcome the two previously mentioned major obstacles for teachers. Firstly, the designed *E-um* e-learning materials cover the mathematical content from the 1st year of primary school to the 4th year of gymnasium (i.e. 9+4 years). Secondly, for the use of *E-um* e-learning materials, the teacher needs no special training or advanced technical knowledge on the use of ICT (the only technical knowledge needed is how to switch on the PC and connect to the internet). Owing to such technical simplicity, more time is left for the teacher to spend on the key aspects of e-learning: planning for and implementation of the e-learning materials into the lessons.

By 2008, over 1200 e-learning folders (i.e. e-learning materials for mathematics lessons) had been published on the *E-um* web portal, and their number is still increasing through upgrading projects in 2008 and 2009. The folders cover the entire mathematical content of nine-year primary school and four-year gymnasium, as well as many cross-curricular themes (Kobal et al., 2007).

The *E-um* e-learning folders contain several interesting elements (e.g. knowledge objects) that can be used as learning support for teachers and students in either online or blended learning (Repolusk & Lipovec, 2007):

- interactive questions, quizzes and tests promote ongoing student activity (knowledge is constructed through student learning activities) and help in verifying their understanding of new (and old) learning content (function of assessment);
- applets, images, animation, movie clips and interactive dynamic constructions provide effective visual representations of mathematical concepts and procedures (including real-life context examples);
- applets and other applications in e-learning materials run on open-source software (e.g. Java, eXe, Z.u.L., GeoGebra, etc.);
- dynamically generated exercises and additional exercises attached (as pdf-files) at the end of every e-learning folder provide a source of interesting tasks for in-class work or homework and could be easily printed on paper or saved;
- summaries help students jointly repeat the objectives and the main concepts of each thematic chapter (e.g. Set theory, Linear function, Fractions, etc.) as preparation for assessment or final external examination;
- the cross-curricular themes could be used as the initial source for planning cross-curricular lessons or project days;

- e-learning materials are intended primarily for students; therefore, the language is informal (user adapted), and the presented proofs are not rigorously detailed, while at the same time they try to develop student reasoning, argumentation and understanding of definitions and key connections between objects (theorems, procedures, etc.);
- the *E-um* e-learning folders could be an appropriate reference for student project work (portfolio), for self-study or simply for satisfying curiosity.

Many e-learning courses designers agree (Anderson & Elloumi, 2004; Bryceson, 2006, Nunes & McPherson, 2007) that before, during and after each e-learning process it is necessary to rethink the theoretical platform on which the design of and pedagogical guidelines for creating e-learning materials are based. Lipovec et al. (2007) conducted a comprehensive analysis of the *E-um* e-learning materials in the light of learning theories, which led to the conclusion that many important elements of various learning theories are reflected in the *E-um* e-learning materials:

- behaviourism: step-by-step achievement of learning objectives, knowledge upgrading, complex and potentially difficult or interesting but unnecessary information hidden under buttons, instant feedback in applets (either positive following a correct student action or encouraging in the case of an incorrect one), feedback and verification of understanding with the help of interactive questions, quizzes, applets and attached exercises;
- cognitivism: content and learning activities adapted to student's cognitive maturity, "axioms of continuous thread" (i.e. guidelines for engaging attention and internal motivation during the whole lesson), reference to previous knowledge, short blocks of text, highlighted key information, questions with tips (predicting "gaps" in knowledge), different representations of concepts and procedures, learning and problem solving strategies, meaningful learning with examples of everyday situations and cross-curricular themes (i.e. contextual learning);
- constructivism: interactive knowledge objects (for active participation by students), applets for investigative activities or visual representations;
- instructional theories: instructional steps (attracting attention, informing about the objectives, recalling prior knowledge, presenting new content, scaffolding, managing student responses, providing appropriate feedback, evaluating responses, enhancing long-term memory retention).

Hvala et al. (2007) presented the guidelines for production of the *E-um* e-learning folders in more detail: the guidelines were divided into three groups of axioms:

Axioms of continuous thread: the materials should attract and keep attention (learning tension) and internal motivation with permanent activities and interesting content design from the beginning to the end of the lesson:

- material: friendly, encouraging, visually attractive, uncluttered, should promote curiosity from the first sentence; language: friendly and personal;
- communication: continuous, abundant in interactive knowledge objects, buttons with funny inscriptions, multimedia objects should not be cheap fun, but a tool for increasing motivation, curiosity and understanding;
- material should not be too long and complex: content divided into smaller units; difficult or interesting but unnecessary information hidden under buttons;
- there should be no hyperlinks (to external or internal information) to preserve student concentration on essential learning activities;
- applets, quizzes, video- and audio-clips should be technically simple and manageable by any student without specific technical knowledge (i.e., the student should be able to focus on the content and not on technology).

Axioms of deepening: the material must allow for the acquisition of depth learning experiences:

- applets allow independent monitoring, investigation, experimentation and problem solving; instructions and questions should guide the applet-using learner to new insights;
- new concepts should be learned from concrete examples – formalization and generalization come later (i.e., from the concrete-to-abstract and the specific-to-general approach).

Axiom of uniform design: e-learning folders should have uniform visual appearance:

- text should be colour highlighted according to its role in the material: normal text on default background, summaries and relevant information emphasized on different backgrounds;
- long and complex learning themes are divided into smaller units (with subchapters, etc.);
- fonts: larger font size in e-learning folders for the first three years of nine-year primary school ("prva triada"), and capital letters for the first year; mathematical text should be written in accordance with the usual standards for writing mathematical texts (LaTeX, etc.);
- at the end of each *E-um* e-learning folder, a special pdf-file with additional exercises (and solutions) is attached;
- each e-learning folder is equipped with metadata (title, keywords, related items, etc.).

After presenting the main guidelines for developing *E-um* e-learning materials, it is important to stress an interesting feature of the development process: while many developers of e-learning materials share the idea of distributed roles in pedagogical and technical design of e-learning materials (Anderson & Elloumi, 2004; Clark & Mayer, 2008), the *E-um* group decided on a policy where a single author creates each item of e-learning material (from pedagogical planning to technical implementation). There were at least two reasons for this decision:

- greater coherence between the content-didactic template and the actual technical implementation of the material;
- rational use of time in designing the process and consequently a wider range of prepared learning materials.

The authors of the *E-um* e-learning materials were carefully selected teachers-practitioners, who had been trained for the use of specific software (eXe e-um, Java, Z.u.L., GeoGebra, etc.) at *E-um* seminars. At the same time, the *E-um* community conducted over 40 seminars at Slovenian schools that showed interest, where teachers were trained to use ICT in the classroom (creating simple e-learning materials and using different mathematical programs in the classroom). The project has thus contributed to the development of digital literacy and the ability to use ICT in teaching practice in the wider Slovenian school area, which represents a significant added value to the project.

A brief evaluation of the E-um web portal

Nowadays, many online courses and much e-learning material can be found on the internet, so it is important to evaluate and choose the most appropriate ones for our educational purposes. Therefore, an appropriate classification according to selected criteria is needed. Here we present two models for the classification of online courses and an evaluation of the E-*um* web portal that can help to compare *E-um* with similar internet portals.

Two-dimensional classification of online mathematics courses

Engelbrecht and Harding (2005a) introduced the two-dimensional quadrant model,

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where they focused on two aspects: the amount of content presented online and the amount of interactivity required from the student (see Figure 2). The quadrants are named after the main action involved: there is the DO-quadrant with high interaction and little content; there is the SEE-quadrant, containing mainly notable information; there is the READ-quadrant with reading for understanding as the main action, and there is the LEARN-quadrant, where both reading the content and displaying understanding through action are needed. Engelbrecht and Harding also noted that most online courses fit into the bottom-right and the top-left quadrants (Engelbrecht & Harding, 2005a, p. 243).

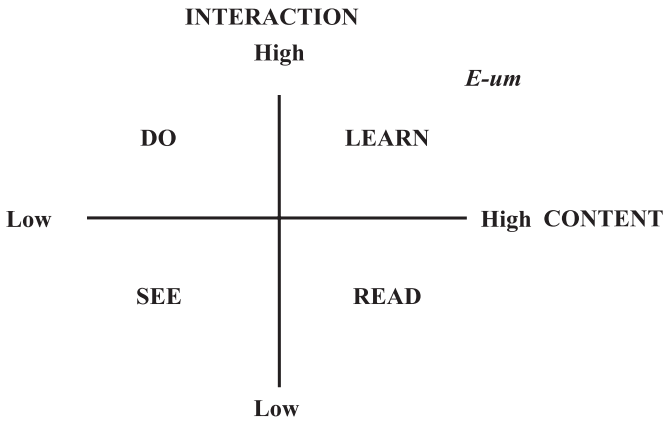

Figure 2. Positioning of the E-um web portal in the two-dimensional quadrant model
(according to Engelbrecht & Harding, 2005a).

According to previously described features, the *E-um* web portal could, therefore, be placed in the LEARN-quadrant (see Figure 2): it covers the entire primary and secondary school mathematics content, and the e-learning folders contain many interactive knowledge objects (from simple gap filling to highly interactive Java applets).

Radar chart classification of online mathematics courses

Another possible classification of online courses is represented by the radar chart (see Figure 3), also introduced by Engelbrecht and Harding (2005a). It allows the evaluation of six online course characteristics with a numeric scale (values from 1 to 5).

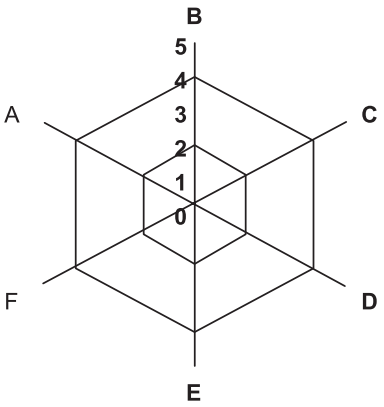

Figure 3. Radar chart classification of online mathematics courses
(according to Engelbrecht & Harding, 2005a).

Explanation of individual characteristics of the radar chart:

A. *Dynamics and Access:* What is the expected frequency of access for success in the course? 1 - once per term, 2 - once per month, 3 - once per week, 4 - two to three times a week, 5 - daily
B. *Assessment:* How much of the assessment is done on the site? 1 - little, 2 - almost half of it, 3 - more than half of it, 4 - most of it, 5 - all of it
C. *Communication:* How much of the communication happens online? 1 - little, 2 - almost half of it, 3 - more than half of it, 4 - most of it, 5 - all of it
D. *Content:* How much of the course content is on the site? From 1 to 5 points for next items: the entire course content (book), course information, course administration, lecture notes, study objectives.
E. *Richness:* How many enriching components does the site have? From 1 to 5 points for next items, which represent more than text communication: CAS system, graphics, Java applets, slide presentations or animations, video clips, sound clips, other (eg. mathematical text and LaTeX printout - this item is added by author of the article).
F. *Independence:* How independent is success in the course from face-toface contact? 1 - Fully contact lecture and tutorial-driven, website an add-on, 2 - Contact lectures but web-based tutorials or assessment, 3 - Limited regular contact, 4 - Sporadic contact, 5 - No face-to-face contact.

The area of the radial diagram indicates to what extent the internet is included in the educational process. However, a larger area does not automatically mean higher quality in the online course: in many instances the objectives of the course design do not include all categorized aspects. However, the shape of the diagram enables us to categorise a particular course. The first three categories, Dynamics and access, Assessment and Communication, could be grouped under "interaction" (the possibility of interaction between the participants in the online course). In the chart, these are located on the upper half (top). If a diagram is top-heavy, it indicates rich interaction. The second three categories, Content, Richness and Independence, could be grouped under "material". Courses focused on the content and rich interactive knowledge objects will be "heavier" on the bottom half (Engelbrecht & Harding, 2005a, p. 245).

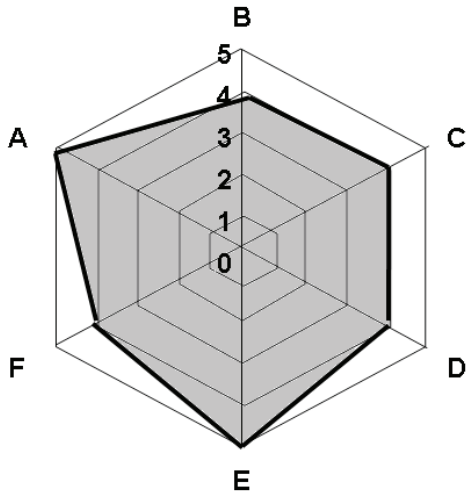

Figure 4. Positioning of the E-um web portal on the radar chart (according to Engelbrecht & Harding, 2005a).

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Using the radar chart, we can classify the *E-um* web portal: the diagram in Figure 4 shows a relatively good coverage of all categories (n. b.: the C and F properties are evaluated with the presumption that the web portal is integrated into LMS, e.g. Moodle). The *E-um* web portal can, therefore, be used in e-learning as well as in blended learning.

Detailed comparison of the *E-um* web portal with the online courses presented by Engelbrecht and Harding (2005a) indicates that the *E-um* web portal is among the highest quality and most holistic online courses worldwide. With the *E-um* e-learning materials, we have finally compensated for the deficit in the development of effective online courses in Slovenia compared to countries with a longer e-learning tradition.

Conclusions

The analysis of the advantages and limitations of e-learning materials, presentation of design guidelines and classification of the *E-um* web portal lead us to confirmation of both hypotheses.

- E-learning materials have great educational potential in comparison to printed educational materials, and – owing to their electronic nature and interactive capabilities – some important advantages that may contribute to the quality of education.
  A good teacher will be able to use e-learning materials to enrich the common educational experience, but for the uninteresting and passive teacher who has difficulty establishing genuine personal contact with his/her students, even quality e-learning materials will not contribute to a positive teaching experience in the classroom (however, such materials could, at least, help his students in self-study).
- The Slovenian *E-um* web portal for teaching and learning mathematics in primary and secondary schools is a high-quality educational portal compared to similar online portals at home and abroad.
  A quality criterion of major importance for the *E-um* web portal is strongly positive feedback from its users (students and teachers). According to the Ministry of Education and Sport of the Republic of Slovenia, the *E-um* web portal was the most often visited and used educational web portal in Slovenia in the "E-Learning Promotion Month" in Slovenian primary and secondary schools (November 2008). (Čampelj, Kreuh, & Šavli, 2009).

Let us conclude this research on e-learning materials in the mathematics classroom and the importance of school reform for the quality of education with critical thoughts from the article "The courage to teach with personal style" by Hvala (2007):

"Many projects advertising modern and effective methods were forgotten somewhere on the desks of school officials. Much money and time has been spent on such things. However, this is not the most serious damage that has occurred. Worse than that was aggressive advertising of the only acceptable methods for those teachers, whose work was already focused and successful. The single educational panacea that can be applied equally to all does not exist. Therefore, introducing any modern method that a teacher experiences as a heavy imposition and as interference with his/her personal style is a mistake – a particularly serious one if the teacher is deprived of confidence, which is essential to work in education" (Hvala, 2007 p. 244, 246–247).

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