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Systematic Review of Web-based Learning Environments in High School Mathematics Education: Attitude, Achievement, Challenges, and Possible Solutions

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Abstract

Web-based learning environments (WBLE) are widely adopted in the context of higher education. Comparatively, little is known about how they are used in high school mathematics curricula. Therefore, this systematic review investigates how WBLEs are applied in high school education and which outcomes this instructional approach has resulted in up to now. 14 related journal publications on high school WBLE are identified and analysed in terms of their WBLE activities, student achievement, attitude, and challenges encountered. The findings suggest that several activities are used in WBLE. WBLE application in high school mathematics education produced a neutral or positive effect on student achievement when compared to traditional classroom-based learning. Students' attitudes toward WBLE approach are varied. WBLE implementation challenges are classified as student-associated, faculty-associated, and operational. We proposed seven possible solutions to address these challenges based on previous studies. Also, recommendations for future research are discussed.

Keywords: *High school; mathematics education; student-centred learning; Web-based learning environments.*

Introduction

The web-based learning environments method facilitates multiple forms of interactions between instructors and students, as well as multiple forms of access to learning materials. It includes various applications such as administration and monitoring, tutorials and assessment, and asynchronous and synchronous communication. These applications support the delivery of instruction, improve the quality of learning and the evaluation of individual student learning, and track the progress of learning to enhance students' achievement (Mioduser et al., 2000).

In the last three decades, WBLE have become a very important aspect of educational technology in higher education. They provide students access to sources of information and knowledge that are essential for different kinds of learning, such as distance, collaborative, student-centred learning, and learning by problem-solving (Aparicio, Bacao, & Oliveira, 2016; Dabbagh & Kitsantas, 2012; Papadakis, Dovros, Paschalis, & Rossiou, 2012).

The need to improve the instructional delivery in mathematics education, particularly in high school mathematics, has been stressed in previous studies (see Baron, 2015; Star, 2016). Many high school mathematics teachers have called for a change from the teacher-centred learning approach to a student-centred and collaborative learning environment (Watson, Mong, & Harris, 2011; Zhu, 2012). This systematic review investigates the application of WBLE in high school mathematics education and its related effect on students' achievement.

Background of this study

In the 21st century, high schools have recognized that students' mathematics learning requires a collaborative and problem-solving approach. In a collaborative learning environment, students are challenged to attain understanding through discussion and engagement in problem-solving activities that improve their creativity and thinking skills, which are essential in a real-life demand (Avcu & Avcu, 2010; Lazakidou & Retalis, 2010).

Despite the introduction of a collaborative, student-centred, and problem-solving learning environment, many mathematics instructions depend on a traditional strategy whereby the teacher is the one transmitting knowledge to students. The limitations are that students become inactive in the learning process and do not acquire sufficient understanding of the matter (Reece & Walker, 2016). Students receiving such traditional instruction are treated as empty vessels actively gripping knowledge from teachers (Lage, Platt, & Treglia, 2000). Such a perception of the learning process has reduced many students' interest in mathematics. Several educators have advocated instructional reform in mathematics education by stressing the need for a learning environment that encourages active learning and critical thinking (Suherman et al., 2011; Firmender, Gavin, & McCoach, 2014; Lau, 2015). The development of students' analytical skills in alignment with higher-order learning of the revised Bloom taxonomy is regarded as important in high school education.

In order to overcome the limitations of the traditional method of teaching, there should be a significant move towards student-oriented learning experiences such as student-centred and collaborative learning (Faria, Almeida, Martins, & Gonçalves, 2015; Olsen, Aleven, & Rummel, 2015; Jacobs, Renandya, & Power, 2016). The advancement of WBLE is consistent with the student-centred, collaborative, and problem-solving approach in learning, and has transformed instructional delivery in higher education (Clark & Mayer, 2016).

The benefits of student-centred, collaborative, and problem-solving learning include increased higher-order thinking, greater engagement, and higher self-esteem, which may lead to students' higher academic achievement and motivation (Jacobs et al., 2016). Research indicates that personal participation, intrinsic motivation, and self-confidence encourage further learning, which results in higher test scores in school (Murphy & Alexander, 2000).

The move toward student-centred, collaborative, and problem-based learning has happened along with the use of WBLE in higher education (Dupuis, Coutu, & Laneuville, 2013; Lamb, 2016). Despite the ability of the WBLE-approach to improve the quality of high school education, at the time of this review no empirical review has been done to ascertain the success and application of WBLE in high school mathematics education. Therefore, a systematic review is necessary to examine the implementation of WBLE in high school mathematics education. In this study, we included elementary (grade), middle, junior high, secondary schools and K-12 as high school education, since the names vary in different countries. The purpose of the current systematic review is to investigate the application of WBLE in high school mathematics education and the outcomes related to this instructional approach.

Research Question

The present review is guided by the following questions:

RQ1: What are the WBLE learning activities used in high school mathematics education?

RQ2: What is the effect of the WBLE approach on high school students' achievement?

RQ3: What is high school students' attitude toward WBLE in math education?

RQ4: What are the main challenges of WBLE implementation in high school mathematics education?

RQ5: How can we address the challenges in (4)?

Methodology

Search Strategy

In order to perform a comprehensive and systematic selection, the following nine electronic databases were searched: (1) CABdirect, (2) Elton B. Stephens Co. (EBSCOhost), (3) Scopus, (4) Institute of Electrical and Electronics Engineers (IEEE), (5) JSTOR, (6) Springer Link, (7) Science Direct, (8) Educational Resources Information Center

(ERIC), and (9) Web of Science. The following search terms were used in the systematic review: ("web-based*" OR "online*" OR "e-learning*" OR "the Internet* OR "LMS*") AND ("learn*" OR "environment*" "mathematics*") AND ("high school" OR "middle school" OR "secondary" OR "basic" OR "elementary school"). The search included some terms related to WBLE (e.g., Internet learning, e-learning, LMS, online learning) and high school education (e.g., middle school, secondary education, K-12 education).

Exclusion and Inclusion Criteria

The exclusion and inclusion criteria for article selection were developed as shown in Table 2. For a study to be included in the current review, it had to be published in a peer-review publication, in the English language. The studies chosen for this review were published between January 1999 and July 2017. Studies published before January 1999 were not likely to discuss the application of WBLE in schools (Ahamer, 1999). Furthermore, the current review focused on empirical studies discussing the application of WBLE in any segment of high school mathematics education.

Table 1

Inclusion and exclusion criteria for selection

Criterion	Inclusion	Exclusion
Definition of WBLE	The WBLE should at least include the following six attributes: (1) hypermedia with various forms of space, (2) decentralized control, (3) interaction of several types, (4) globalization, (5) asynchronous communication, and (6) active and real-time information.	All studies in which the web-based learning environment lacks any of the six attributes and which were not designed for the purpose of teaching and learning.
Participants	Students in high school education settings (e.g., elementary schools, secondary school, middle school)	All other students outside of high school education (e.g., higher education, graduate or postgraduate education students)
Subject Matter	High school mathematics content	All other subjects apart from high school mathematics
Time duration	Studies from January 1999 to August 2017	Studies published before January 1999 and after August 2017
Type of studies	The studies must be experimental research issued in peer-reviewed journals	The studies that were not experimental or peer-reviewed
Language	English	Studies published in a language other than English

The WBLE use in the study must meet the Dabbagh and Bannan-Ritland (2005) definition of WBLE's six attributes. Thus, it must include (1) hypermedia with various forms of space (2) decentralized control, (3) interaction of several types, (4) globalization, (5) asynchronous communication, and (6) active and real-time information. As a result, we excluded any study in which the web-based learning environment lacks any of the six attributes and which was not designed for the purpose of teaching and learning. Finally, the subject matter of the study should be in the context of mathematics as indicated in Table 1.

Search outcome

After using the search terms, a sum of 100 studies was obtained by 17th August 2017. However, a total number of 89 studies remained after removing duplicates across databases. Furthermore, after reviewing the title and abstract, 50 studies were deemed irrelevant and excluded from the study because they did not represent empirical research or did not fall within the high school context. The remaining 39 studies were examined for subject content, whereupon 23 studies were rejected as they were outside of the scope of mathematics. Finally, the remaining 16 studies were checked for the application of the six attributes of WBLE as suggested by Dabbagh and Bannan-Ritland (2005). In this process, three studies did not satisfy the criterion. As a result, a total of 14 studies were included in the current systematic review. The outline of the selection process is shown in Figure 2.

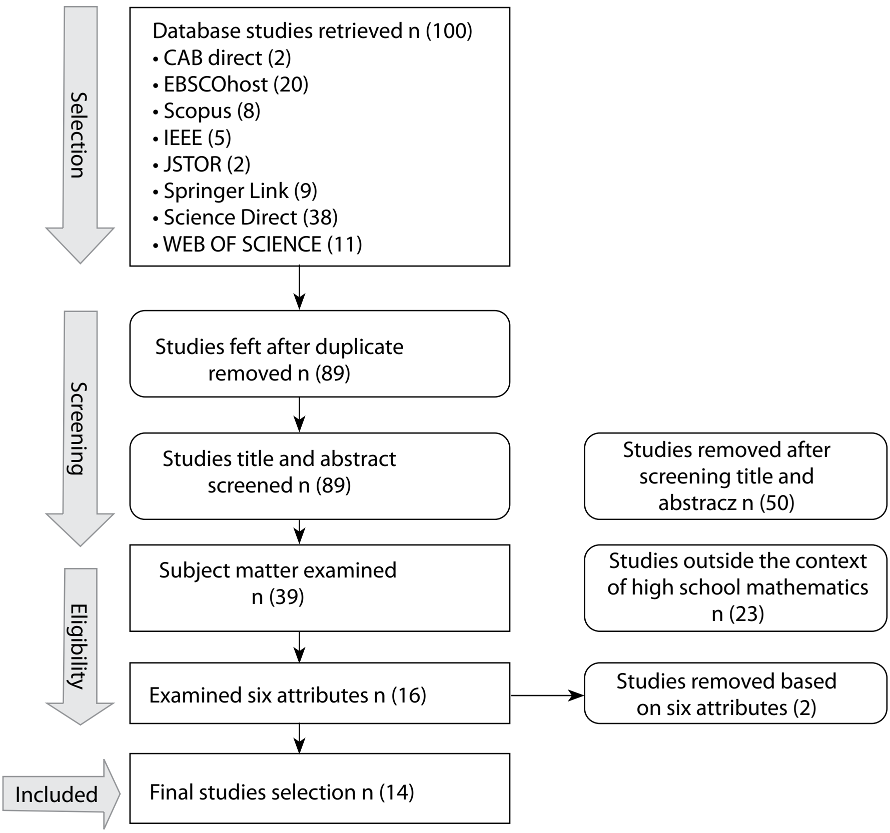

Figure 1. Data screening and selection process flow

Data extraction and analysis

The authors extracted and categorized the data in folders according to the database used for easy identification. Specific data used for the review were author(s), year, context and country of publication, study purpose, study design, research design and duration, sample size, and application of WBLE (Instructional Strategy of the application). In addition, students' achievement and satisfaction with the implementation of WBLE were summarized and systematically shown in Table 2. In the event of authors' differing views regarding data extraction and analysis, data were extracted, reassessed, and the selected studies were analysed again.

Results

14 studies were included in this systematic review of WBLE application in high school mathematics education. The majority of the studies were conducted between 2008 and 2017 in the USA (n = 7), followed by Taiwan (n=2), Turkey (n=2), Germany (n=1), Croatia (n=1), and North Cyprus (n=1). The reported period of instruction lasted between 0.4 and 156 weeks. However, not all studies reported instruction during the entire period of research. Various research designs were employed in the studies: mixed-method design (n = 4), quasi-experimental design (n=5), counterbalanced experimental design (n=2), randomized experimental design (n=1), complex cross-over, blocking design (n=1), and longitudinal design (n=1). The studies encompassed a total number of 2817 participants, with a sample size ranging from 59 to 703. The following mathematics content was taught using WBLE: (1) decimals, (2) the concept of function, (3) geometry, (4) arithmetic operations, (5) number sense and mixed problem sets, and (6) numbers and their operation.

8 out of 14 studies were conducted in elementary and middle school, while six were conducted in lower secondary, junior high, and primary school. Thus, five studies were conducted in elementary schools (Dijanić and Trupčević, 2017; Craig et al., 2013; Güzeller and Akın, 2012; Tsuei, 2012; Mendicino, Razzaq, and Heffernan, 2009), three in middle schools (Ocumpaugh et al., 2016; Adams et al., 2014; Arroyo et al., 2010), two studies involved secondary schools (Baki and Güveli, 2008; Graff et al., 2008), three studies were conducted in junior high school (Wang, 2011; Pane, 2010; Beal et al., 2007) and one was conducted in primary school (Pilli & Aksu, 201), as displayed in Table 2.

In the sections below the findings were structured based on our research purpose (the application of WBLE in high school mathematics education), the effects of WBLE approach on high school students' achievement and their satisfaction with this learning approach.

RQ1. What are the WBLE learning activities used in high school mathematics education?

Fourteen different types of WBLE applications in high school mathematics education were identified in the systematic review. These were: (1) web-based tutoring system with erroneous examples, (2) Wayang Outpost web-based interactive tutoring system, (3) Wayang tutoring system and Mathematics Fact Retrieval (MFR) training software, (4) Web-based mathematics teaching (WBMT), (5) Assessment and Learning in Knowledge Spaces (ALEKS), an Intelligent Tutoring System for mathematics, (6) Dynamic geometry software and GeoGebra interactive applets, (7) eFit (adaptive web-based intelligent tutoring system), (8) Web-based mathematics instruction (WBMI), (9) Web-based homework ASSISTment System (intelligent tutoring systems), (10) Cognitive Tutor Geometry curriculum with two components (classroom instruction and individualized, computer-guided instruction using Carnegie Learning's tutorial software), (11) Frizbi Mathematics 4, (12) ASSISTments, a free web-based mathematics tutoring system, (13) G-Math system with mathematics curriculum, and (14) Graduated Prompting Assessment Module, WATA system (GPAM-WATA). In the following, we discussed the purpose and instructional strategy for each WBLE application in high school mathematics education based on the selected studies as shown in Table 2:

Web-based tutoring system with erroneous examples*:* Web-based tutoring system with erroneous examples is an intelligent tutor authoring software that allows students to critique wrong solutions of decimal problems based on fundamental misunderstandings. Thus, students are provided with incorrect solutions of decimal questions solved by their colleagues. It is believed that students' understanding and learning of mathematics increased when they identified, explained, and corrected the errors in their colleague incorrect solutions (Adams et al., 2014). In addition, students were asked to solve problems on their own, whereupon they received feedback on correctness and were then prompted to give an explanation of their solution using the web-based tutoring system (Adams et al., 2014).

Wayang tutoring system and MFR training software*:* Wayang tutoring system is a multimedia-based tutoring system that teaches students how to solve geometry, statistics, and algebra problems frequently included in standardized tests. The purpose of using the Wayang tutoring system is to improve middle school students' mathematics learning (Arroyo et al., 2010). Students solve the mathematical problem in the Wayang tutoring system and then choose a solution that matches their answer from a list of multiple options. The Wayang system provides immediate feedback after the selected option. Moreover, during the process of solving a problem, students can request hints from tutoring system about the solution to the problem (Arroyo et al., 2010).

The MFR software provides training and assessment to students. For the purpose of training, students learn the mathematical operations such as addition, subtraction and multiplication through digital pages (Arroyo et al., 2010). In the assessment section students are examined for accuracy and speed by speaking out their answer to the system. This answer, whether correct or incorrect, is then coded into the system. Upon completion of the assessment session, the system provides a line chart to indicate the progress of student speed and accuracy (Arroyo et al., 2010).

Web-based mathematics teaching (WBMT): WBMT is an Internet web-based mathematics assisted instruction with basic explanations, examples and interactive exercises on functions. WBMT was designed to improve secondary school students' basic concepts of functions and their attitude toward them (Baki & Güveli, 2008). Furthermore, WBMT covers the general concepts of linear, quadratic and multiple functions, and simultaneous equation. The system offers students a short tutorial lesson on each concept of functions, then allows them to go through some interactive exercises and assessment to practice as much as they like with immediate feedback (Baki & Güveli, 2008).

Wayang Outpost web-based interactive tutoring system: the Wayang Outpost web-based interactive tutoring system is designed to provide students with personalized multi-media tutoring to address the SAT-Math questions involving geometry skills and additional algebraic concepts in high schools (Beal et al., 2007). When first logging into the system, the tutoring system server would randomly assign the user (student) to use either visual interactive or algorithmic hints. The system includes several mathematical problems in the form of figures, graphics, and an equation to be solved. Students are allowed to click on the correct answer by choosing between five options. The system would send feedback to students indicating correct or incorrect. In addition, the system has the "help" option, which provides hints leading to the solution of a problem (Beal et al.,).

Assessment and Learning in Knowledge Spaces (ALEKS): ALEKS is a mathematics-based intelligent tutoring system with the artificial intelligence component employed as a method of an intervention strategy to improve elementary students' mathematical skills (Craig et al., 2013). It is designed to support students' learning in the following ways: (1) learning the material used in the lesson, (2) evaluating with multiple choice and similar tasks, (3) receiving feedback on test performance, (4) learning the material again if the performance is below expectation, and (5) progressing to a new concept if performance exceeds expectations (Craig et al., 2013).

Dynamic geometry software and GeoGebra Interactive Applet: GeoGebra interactive applet is a tool for acquiring and discovering new mathematical knowledge associated with conceptual knowledge. Interactive applets are organized in a digital textbook with several chapters for separate units of teaching. The applets include one of the following functions: (1) Motivation applet: used at the beginning of each instruction for the presentation of content to students and motivation for further work, (2) Exploration applet: enables teachers to perform a mathematical experiment for students in order to discover new knowledge in mathematics. In the process of the experiment, a problem-solving strategy (i.e. problem understanding, developing a plan, carrying out of the plan and looking back) is employed; (3) Training applet: enables students to solve lesson-related mathematical problems. The training applet includes a game component with scoring points to motivate and encourage learners to progress in the learning;

(4) Additional contents: applets have other interesting elements such as mathematics content for gifted students, a daily life mathematics application, a section on the history of mathematics, activities for students with weak mathematical thinking, and quizzes (Dijanić & Trupčević, 2017).

Dynamic geometry software is a computer-guided discovery learning program with dynamic geometry, consisting of three basic components: (1) learning objects, (2) students' activities, and (3) learning results (Dijanić & Trupčević, 2017). The purpose of designing computer-guided discovery software using dynamic geometry and GeoGebra interactive applets was to investigate the impact on elementary students' procedural and conceptual knowledge in mathematics (Dijanić & Trupčević, 2017).

eFit (adaptive web-based intelligent tutoring system): eFit is designed as a web-based intelligent tutoring system which provides students with a teaching and learning environment adapted to their learning competency and knowledge. The goal is to provide user-tailored, individualized instruction similar to one-to-one tutoring. The aim of designing eFit is to alleviate secondary students' mathematics difficulties (Graff et al., 2008).

For eFit's instructions, students use the school computer laboratory or their personal computers with Internet access which the eFit system is launched on. The eFit program starts by examining secondary school students' performance on a standardized test of basic math operations such as addition, subtraction, multiplication, and division. The eFit assessment test includes the Heidelberger Rechentest (HRT) subscale, which measures students' arithmetic skills and competency in basic mathematical operations (Graff et al., 2008).

Web-based mathematics instruction *(WBMI):* WBMI is also known as online environment empowering students to interact with their peers or others and enabling them access to several learning materials, immediate feedback, and self-directed learning (Pilli, O., & Aksu, 2013; Nguyen, Hsieh, & Allen, 2006; Kim MacGregor & Lou, 2004; Morgan & O'Reilly, 2001). The purpose of designing the WBMI for elementary school students is to improve their mathematics achievement, attitudes, anxiety, and self-efficacy (Güzeller & Akın, 2012).

Web-based homework ASSISTment System*:* The ASSISTment System is a web-based system which includes assistance and assessment. The system provides instructions to students while offering comprehensive assessment of their competency to instructors. The ASSISTment system has an inbuilt component enabling teachers to assess students' abilities and identify their main problems and conceptual weaknesses which need to be resolved, or skills which need to be improved in the classroom. The purpose of the system is to assist elementary students in learning more by doing their mathematics homework (Mendicino, Razzaq, & Heffernan, 2009).

Mathematics problems are presented to students when logging into the ASSISTment system. The system consists of two types of tutoring assistance: scaffolds, and hints.

Students using scaffolds tutoring assistance receive the message "Hmm, no. Let me break this down for you," whenever they answer the questions incorrectly. This is followed by scaffolds questions that would lead the students to work toward the correct answer before proceeding to the next question. In addition, students are prompted to answer the breakdown scaffolding question before considering the main question. The hint aspect of the tutoring assistance leads the learner to the correct answer to the question (Mendicino, Razzaq, & Heffernan, 2009).

***Cognitive Tutor Geometry curriculum**:* The Cognitive Tutor Geometry curriculum is purposely designed to enhance junior high school students' knowledge in geometric concepts, principles, and spatial reasoning skills as well as to provide personalized instruction to address their specific needs (Pane et al., 2010). The Cognitive Tutor software provides the students with challenging questions in the form of multiple steps, which reflect practical situations. Students can solve mathematics problems individually and request a hint from the system if they have difficulties. Afterwards, the tutoring software generates the next questions based on student performance. The students are then provided with a progress report of their content ability by an on-screen progress meter (a component of the software). Moreover, the software provides detailed feedback on individual students' progress rate to the teacher. The tutoring software includes a model which directs students toward the correct answer when solving a problem (Mendicino, Razzaq, & Heffernan, 2009).

***Educational software: Frizbi Mathematics** 4:* Frizbi Mathematics 4 is an educational tool intended to assist with mathematics teaching and promote student learning in primary school (Pilli & Aksu, 2013). This instructional software enables students to discover and understand mathematical content in different ways, which are challenging for the traditional mathematics classroom. The software consists of 1) an enjoyable animation-story, with video clips, creativity tools and games related to daily life activities, 2) general problem-solving strategies, 3) interactive exercises on mathematics problems, and 4) solutions based on the given mathematics problems. Moreover, the system directs students to the content explanation whenever they have difficulty with a specific task. In addition, the software provides exercises and feedback at the end of every lesson, which enables them to assess their own mathematics knowledge (Pilli & Aksu, 2013).

***Web-based mathematics ASSISTments system**:* The ASSISTments system is a free web-based tutoring system, designed specifically for teaching and learning in middle school mathematics (Ocumpaugh et al., 2016). The system evaluates the knowledge of students while supporting them in learning and providing teachers with information about each student's content skills. The system enables students to proceed to the next problem after giving the correct answer to the previous question. On the other hand, whenever the student answers incorrectly, the system breaks down instruction into smaller components, thus guiding the learner systematically before coming back to the original question (Mendicino, Razzaq, & Heffernan, 2009; Razzaq et al., 2005). The ASSISTments system is widely utilized by 50,000 students in the USA every year (Ocumpaugh et al., 2016).

G-Math system with a mathematics curriculum: G-Math is an asynchronous peer tutoring system designed to assist students and teachers in the elementary school mathematics classroom. G-Math has two main features: (1) the aspect of managing peer tutoring activities by the teachers, and (2) the peer tutoring system which permits students to perform peer learning activities such as "game-like" (Tsuei, 2012). G-Math has an item bank with mathematics problems in the Mathematics Tutoring Activities Module assigned by the teacher. The system randomly allocates the problems to the students and provides real-time information on each student group. Moreover, G-Math has a peer rating system for judging performance in the process of solving mathematical problems. The system also provides the correct answer to each problem in the end. This approach enables students to reflect on their solutions, which encourages metacognitive thinking (Tsuei, 2012). The G-Math peer tutoring system provides several forms of scaffolding and interaction tools to facilitate a peer face-to-face mathematics discussion. The system provides categories of mathematical concepts such as the numbers line, geometry, integers, fractions, place value, and others (Tsuei, 2012).

Web-based dynamic assessment system - GPAM-WATA: According to Wang (2010), the Web-based dynamic assessment system is also known as the Graduated Prompting Assessment Module of the WATA system (GPAM-WATA). It is used to assist in remedial mathematics learning and teaching in junior high school and is intended as an addition to traditional mathematics instruction (Wang, 2011). Students participating in this system receive personal remedial mathematics teaching. As a result, the students are exposed to several learning situations, which leads to their improved understanding of mathematical concepts.

Furthermore, the GPAM WATA includes a component called IP, which provides students with timely feedback when faced with difficulties in solving the problems in the system. The system contains instructional messages which provide learning guidance and enable students to solve mathematical questions (Wang, 2011).

We discover that WBLEs as educational tools offer students access to well-ordered and simply-updatable learning materials, problem-based activities, online resources, and tutorial support. Some aspects of WBLE examine students' mathematical knowledge and provide information on each student's content skills to the instructor. Since students' problem-solving performance has proven to be at a very low level for a number of examined years (Lester, 1994), problem-solving activity was the major observed aspect of all the WBLE application instances among the reviewed papers. The WBLE activities included in the studies are helpful in reducing students' problem-solving difficulties.

Table 2

An overview of the reviewed studies of WBLE in high school mathematics education

Author(s) and publication year	Context and country	Mathematical content	Purpose	Research design (duration)	Sample size	Application of WBLE
Adams et al. (2014)	Middle school USA	Decimals	Examining students' corrections of incorrect solutions and common misconceptions in decimal problems	Mixed methods (Not specified)	TC (n = 108) and WBLE (n=100). Total (n=208)	Web-based tutoring system with erroneous examples
Arroyo et al. (2010)	Middle school USA	Not specified	Improving middle school students' learning of mathematics through intelligent tutoring and Basic Skills Training	Counterbalance experiment (3 days)	MBLE (n=250)	Wayang Tutoring System and Mathematics Fact Retrieval (MFR) Training Software
Baki and Güveli (2008)	Secondary school Turkey	Concept of Function	Developing a web-based mathematics teaching (WBMT) system and evaluating its effectiveness for 9th-grade students	Mixed methods (5 weeks)	TC (n = 40) and WBLE (n=40). Total (n=80)	Web-based mathematics teaching (WBMT)
Beal et al., (2007)	High school USA	Geometry and Algebra	Evaluating the effect of an online tutoring system on solving high-stakes mathematics problems in high school	Quasi-experimental (not specified)	TC (n = 49) and WBLE (n =153). Total (n = 202)	Wayang Outpost web-based interactive tutoring system
Craig et al. (2013)	Elementary school USA	Not specified	Helping 6th-grade students from a west Tennessee school district improve their achievement in mathematics	Randomized experimental (25week)	Two TC groups and Two WBLE. Total (n=253)	Assessment and Learning in Knowledge Spaces (ALEKS), an Intelligent Tutoring System for mathematics
Dijanić and Trupčević (2017)	Elementary school Croatia	Geometry	Examining the impact of utilizing the proposed computer-guided discovery learning model on students' procedural and conceptual knowledge in mathematics	Mixed-Method (Not specified)	TC and WBLE. Total (n = 703)	Dynamic geometry software and GeoGebra interactive applets
Graff et al. (2008)	Secondary school Germany	Arithmetic operations	Investigating whether eFit constitutes an effective intervention at the lower secondary level	Quasi-experimental (36 weeks)	TC (n =136) and WBLE (n= 58). Total (n=194)	eFit (adaptive web-based intelligent tutoring system)

Author(s) and publication year	Context and country	Mathematical content	Purpose	Research design (duration)	Sample size	Application of WBLE
Güzeller and Akın (2012)	Elementary school Turkey	Not specified	Examining the effects of web-based mathematics instruction on 6th-grade students' mathematics achievement, attitudes, anxiety, and mathematical self-efficacy	Mixed method (Not specified)	TC (n = 50) and WBLE (n = 12). Total (n = 62)	Web-based mathematics instruction (WBMI)
Mendicino, Razzaq and Heffernan (2009)	Elementary school USA	Number Sense and problem sets	Determining if elementary students can learn more using by doing their math homework in the ASSISTment web-based system	Counterbalance experiment (Not specified)	TC (n = 28) and WBLE (n = 28). Total (n = 59)	Web-based homework ASSISTment System (intelligent tutoring systems)
Pane et al. (2010)	Junior high schools USA	Geometry	Investigating the impact of using technology-based geometry curriculum on their geometry achievement, attitudes toward mathematics and technology	Complex cross-over blocking design (156 weeks)	TC and WBLE. Total (n = 699)	Cognitive Tutor Geometry curriculum with Carnegie Learning's tutorial software
Pilli and Aksu (2013)	Elementary school North Cyprus	Natural Numbers and Fractions	Investigating the implication of the educational software (Frizbi Mathematics 4) on primary school students' mathematics achievement	Quasi-experimental (Not specified)	TC (n = 26) and WBLE (n = 29) Total (55)	Frizbi Mathematics 4
Ocumpaugh et al., (2016)	Middle school (USA)	Not specified	Measuring middle school student engagement and performance by analyzing the log file data of students' interactions with ASSISTments.	Longitudinal Study (Not specified)	WBLE (n=76)	ASSISTments, a free web-based mathematics tutoring system
Tsuei (2012)	Elementary school Taiwan	Not specified	Finding out the effects of the synchronous peer tutoring system on student mathematics outcome	Quasi-experimental (3 weeks)	WBLE (n=88)	G-Math system with mathematics curriculum.
Wang (2011)	Junior high school Taiwan	Numbers and its operation	Investigating the effect of GPAM- WATA on the teaching remedial mathematics against the paper and pencil test (PPT) and normal Web-based test (N-WBT)	Quasi-experimental (Not stated)	TC (n = 34) and Two WBLE (n = 62) GPAM Total (n = 96)	Graduated Prompting Assessment Module, WATA system (GPAM-WATA)

RQ2: What is the effect of the WBLE approach on high school students' achievement?

12 studies compared students' academic performance of learning with WBLE application against the traditional and other methods of teaching. Two of them, Baki and Güveli (2008) and Craig et al. (2013) reported no significant difference between the performance of students' learning with WBLEs applications and the traditional method. On the other hand, 10 studies (Adams et al., 2014; Pilli & Aksu, 2013; Güzeller & Akın, 2012; Tsuei, 2012; Wang, 2011; Arroyo et al., 2010; Pane et al., 2010; Graff et al., 2008; Mendicino, Razzaq, & Heffernan, 2009; Beal et al., 2007;) found that students using WBLE approach achieved significantly higher test scores than those taught in other methods. Surprisingly, one study (Dijanić & Trupčević, 2017) indicated that students using WBLE in sixth and eighth grade perform better than their peers in the Traditional Classroom (TC), whereas students in the seventh grade had a higher score than their WBLE-using counterparts. Only one study, Ocumpaugh et al. (2016) did not investigate students' performance. None of the studies indicated a negative performance of students using WBLE against other methods accept a section of WBL seventh grade students (Dijanić & Trupčević, 2017) as shown in Figure 3 and Table 4. Adams et al. (2014) suggested that when students are familiar with the web-based mathematics platform, they gain confidence in learning and have enormous opportunities to access a large amount of knowledge and information.

Table 3

Results of WBLE on students' academic achievement

Study	Student Achievement
Adams et al. (2014)	WBLE students perform better than TC in the test score
Arroyo et al. (2010)	WBLE students perform better than TC in the test score
Baki and Güveli (2008)	No significant difference in students' performance
Beal et al., (2007)	WBLE students perform better than TC in the test score
Craig et al. (2013)	No significant difference in students' performance
Dijanić and Trupčević (2017)	WBLE students perform better than TC except for 7th-grade students, who perform better in TC than in WBLE
Graff et al. (2008)	WBLE students perform better than TC in test score
Güzeller and Akın (2012)	WBLE students perform better than TC in test score
Mendicino, Razzaq, and Heffernan (2009)	WBLE students perform better than TC in test score
Pane et al. (2010)	WBLE students perform better than TC in test score
Pilli and Aksu (2013)	WBLE students perform better than TC in test score
Ocumpaugh et al., (2016)	Not measured
Tsuei (2012)	WBLE students perform better than TC in test score
Wang (2011)	WBLE students perform better in test score

Furthermore, students who use web-based intelligent tutoring systems encountered very high individual instruction apart from the instruction they experience in the traditional-based mathematics classroom (Graff et al., 2008). In addition, Tsuei (2012) asserted that synchronous peer tutoring system is an effective learning environment for elementary schools to improve students' mathematics learning and encourages their confidence in concepts.

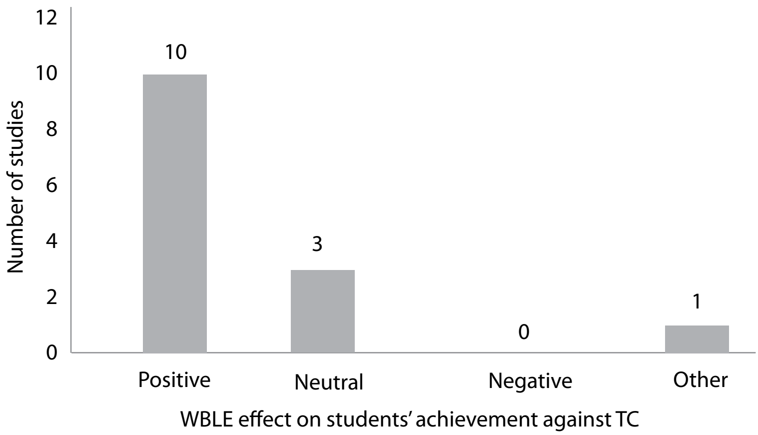

Figure 2. The outcomes of WBLE on students' performance

RQ3: What is the high school mathematics students' attitude toward WBLE?

In this current study, attitude is defined as students' feeling toward using the WBLE to learn mathematics. To examine high school students' attitude toward WBLE approach, we investigated the reported data of the students (interview, surveys), teacher' thoughts and the observation of the researchers which is reported in the studies under review. In general, it was found that high school students show a higher level of satisfaction with using WBLE in learning mathematics (e.g., Ocumpaugh et al., 2016; Craig et al., 2013; Güzeller & Akın, 2012; Pilli & Aksu, 2013; Tsuei, 2012; Baki & Güveli, 2008). To be more specific, the following qualitative remarks indicated the benefits of WBLE approach which added to students' satisfaction of learning mathematics with WBLE.

First, students indicated that as they become more conversant with mathematical procedure and online process, their confidence and motivation in learning mathematics increased (Tsuei, 2012; Baki & Güveli, 2008; Beal et al., 2007) and more practice with mathematics activities included in WBLE provided them with the opportunity to improve their mathematics performance, self-efficacy, and to reduce their mathematics anxiety (Güzeller & Akın, 2012). In particular, one student reported that WBLE "improved students' confidence in mathematics problem solving and increased a positive attitude towards learning" (Güzeller & Akın, 2012, p. 51). Another stated that

"I am confident I can do an excellent job on the assignment and tests in this math class" (Tsuei, 2012, p. 1178).

Second, WBLE approach provided immediate and timely feedback when students have difficulties in answering problems in the system (Dijanić & Trupčević, 2017; Tsuei, 2012; Pane, et al.,2010). For instance, they received feedback on the correctness of their answer when solving a mathematics problem and then were given to the solution (Adams et al., 2014). WBLE enables students to understand the mathematics content and provide them with a clear direction on how to enhance their learning (Craig et al., 2013). More specifically, a student responded during the interview, "I like to practice quizzes with instant feedback" (Baki & Güveli, 2008, p. 860). In support, one student stressed that "I like the way the computer responded to my input" (Adams et al., 2014, p. 404).

Third, the "help" feature of the system provides the students with a step-by-step learning process including presentation of the concept, appropriate examples, hints and interactive exercise to improve their mathematics knowledge (Baki & Güveli, 2008). In addition, WBLE offers a peer learning process, which constitutes an interesting and different way of learning mathematics (Tsuei, 2012). Baki and Güveli (2008) point out that the WBLE system hints enable students to complete tasks and solve mathematics problems individually and thereby build a lasting understanding of mathematics content (Adams et al., 2014).

Contrary to positive attitudes towards WBLE, Adams et al. (2014) discovered that some students perceived difficulty of the lesson because learning materials used in the system are hard to understand. More precisely, a student stated that "I worked hard on understanding the material in this lesson" (Adams et al., 2014, p. 404).

RQ4: What are the main challenges of WBLE implementation in high school mathematics education?

Based on Betihavas et al. (2016), the current review identifies the main challenges of WBLE implementation in high school mathematics education into three main categories, namely student-associated challenges, faculty-associated challenges, and operational challenges.

Student-associated challenges: Güzeller and Akın (2012) asserted that students lacked quality access to a computer and the Internet in schools and home, which denied them the enjoyment of WBLE interactive features. Student remarks were focused on their struggle to adjust to this new learning environment, difficulty to understand WBLE instruction, and the feeling that they were left to themselves (Dijanić & Trupčević, 2017). In consequence, they rushed through the WBLE learning activities without proper understanding (Dijanić & Trupčević, 2017). Moreover, Baki and Güveli (2008) suggested that time was important for extra-curricular activities and that student motivation and satisfaction level were negatively affected by grading.

Teacher-associated challenges: Baki and Güveli (2008) reported that teachers' unfamiliarity or inexperience with WBLE could affect the students' learning outcomes.

However, learning and managing instruction of WBLE to enhance student learning outcomes means added burden on the teachers. In addition, Pilli and Aksu (2013) expressed concern that WBLE instruction mostly took longer to deliver than the traditional mathematics lessons. They also suggested that during problem-solving in WBLE teachers could not prevent students from copying answers from their peers. Furthermore, there is the added burden on faculty members to learn the technology before implementing it.

Operational challenges: Baki and Güveli (2008) identify the infrastructure, laboratory conditions, a lack of quality internet access in rural schools as some challenges of implementing WBLE. In addition, a problem related to training programs on using educational technology as well as teacher readiness for applying modern technology hinders the use of WBLE (Dijanić & Trupčević, 2017). Despite these challenges, none of the studies specifically outline solutions to these but rather recommended the use of WBLE in high school.

RQ5: How can we address the above challenges in (RQ4)?

Addressing student-associated challenges

Proposed solution 1: Ensuring that high schools have the quality of Internet and computers which support WBLE is a challenging task. This is because it requires a high investment from the government and private sectors. High schools can partner with a district education service or a non-profit organization to support students with quality Internet accessibility both in schools and homes. For example, they can partner with E-rate and non-profit Education Super Highway, providers of high-speed, high-capacity Internet for schools to assist with funding to reduce the cost of high-speed internet access (Bleiberg, 2016).

Moreover, a high school can open up to one-to-one laptop program to ensure ongoing access to a computer for WBLE learning approach. For instance, the schools could associate with the PC industry to develop lower-cost, educational technology-oriented PCs to support this initiative. Depending on the commercial market support only might not help to achieve this project (Kraemer, Dedrick, & Sharma, 2009). Schools can ask for assistance from the government to support these one-to-one laptop projects. This would enable enhancement of participation in WBLE learning, particularly for students in poor rural areas.

Proposed solution 2: Adapting to a new learning environment and understanding instruction content at the same time is challenging and requires much effort (Clark, 2015). WBLE should include features to encourage regular interaction or open communication of students with teachers and make them feel important. The presence of teachers and peers can reduce student anxiety and enable them to adjust to this new learning environment. They may not feel rejected but rather focus on the learning activities assigned by the system. Furthermore, students should be given intensive orientation about WBLE on how the system works and what is expected from them. This encourages students' confidence and helps them familiarize with WBLE faster (Clark, 2015).

Proposed solution 3: Motivated students learn effectively, retain mathematical knowledge, participate in the learning process and become disciplined. If students feel that their work is recognized and valued, they are more likely to be excited about the learning activities. WBLE should praise students' work often and enable recognition of their contributions when solving a mathematical problem. Praise should be in the form of supportive statements such as "Good job, keep it up!" when getting the correct answer, or "You can do better than this!" when they get an incorrect answer. Praise can motivate elementary school students to display behaviours that will increase their performance (Hodgman, 2014). If the system exhibits friendliness and makes students feel appreciated, they will be eager to do more activities. Furthermore, providing students incentives encourages and motivates them to learn (Bishop, 2004). Incentives such as additional awarding of marks in the WBLE activities would encourage them to work with a goal in mind and continue to work more. Furthermore, WBLE with a gamification aspect could be an incentive for students to improve their performance.

Addressing teacher-associated challenges

Proposed solution 4: Few high schools have such management which commits time and resources to organize formal mentoring programs in educational technology for their teachers. Providing these mentorship programs to teachers can empower them to progress in the implementation of WBLE. Also, there should be more WBLE in-service training for teachers. In-service training is important for teachers to eliminate deficiencies and keep them abreast to integrate technology-based instructional strategies for teaching and learning.

Proposed solution 5: One of the easiest ways to avoid the instruction delay of using WBLE is to spend a little bit of time with WBLE before actual implementation. This would reduce the potential hindrances that may cause the delay and enable the teacher to reduce the time spent when using WBLE as compared to face-to-face instruction. Teachers should be aware that using WBLE instead of traditional teaching is not time-wasting. For instance, a study conducted by Andersen and Avery (2008) revealed that web-based and face-to-face instructions required a similar time on average for a credit course. They explained that more time is spent in the preparation of face-to-face instruction (39%) than in updates for web-based instruction (12%).

Proposed solution 6: teachers should remind students of the academic integrity code when solving a mathematical problem with WBLE. Let the students know and warn them of the consequences of cheating. In addition, the WBLE should have question pools where different questions are generated whenever a student logs in, to answer any mathematical problem. Also, the system should allow teachers to add more questions whenever they feel that students have completed almost all the tasks in the pool. On the other hand, they should be able to remove existing questions. These strategies could enable teachers to prevent students from cheating when using WBLE to answer mathematical problems.

Addressing operational challenges

Proposed solution 7: As we discussed under the possible solution to student-associated challenges, high schools should solicit support from non-governmental organizations, district education offices and computer industries for quality Internet and one-to-one laptop per child program. They should improve the infrastructure by enabling computers in the laboratory and quality Internet access, particularly in rural high schools. Moreover, high schools can partner with educational technology faculties to provide educational technology training programs for teachers in order to improve their readiness for WBLE application.

Conclusions and recommendations for future studies

The current paper reviewed the empirical studies of WBLE in high school mathematics education. Based on the selected papers, we presented an overview of WBLE activities, the results of the impact of WBLE on students' achievement, the attitude of students toward WBLE, and the challenges related to its implementation as well as possible solutions. Though we recognized that WBLE approach is not a remedy for all high school mathematics education problems, it appears to support student-centred learning which calls for learning through problem-based activities, tutorial support, as well as using online resources and real-time study materials. In the present review, there is no confirmation that WBLE application in high school negatively affects student mathematics learning. In particular, WBLE approach enables students to perform significantly better than their counterparts in traditional classrooms. Only two reviewed papers indicated neutral or insignificant difference (Craig et al., 2013; Baki & Güveli, 2008).

Our findings regarding the attitude of students toward WBLE approach are varied. Students' negative feedback revealed the importance of improving this instructional method. The challenges facing the use of WBLE are classified into three themes, specifically student-associated challenges, teacher-associated challenges, and operational challenges. Based on relevant literature and the experimental findings, seven possible solutions were outlined to address these challenges.

In addition, the findings from this present review were limited to 14 empirical studies on WBLE in high school mathematics education. While the application of WBLE approach has been increasing (Hui et al., 2015), it seems that there is no sufficient study on WBLE in high school mathematics education in literature. For instance, only two WBLE studies were conducted in junior high schools (Pane et al., 2010; Wang, 2011). Moreover, these two did not identify or report any challenges. We recommend more empirical studies examining the WBLE effect and challenges in high school mathematics education, particularly in junior high schools.

Further studies should address the most important limitations of some previous empirical studies on WBLE. For instance, researchers should conduct assessment such as pre-tests for experimental and control groups to examine the homogeneity among the groups, rather than just assuming that students in the two groups are similar in terms of prior mathematics knowledge.

The major pedagogy behind the designing of WBLE is to enhance students search and discover knowledge for themselves through interactions, flexible, interesting, and several activities. Regrettably, most of the previous studies in developing WBLE did not evaluate students' mathematics needs and therefore provided little support for these activities. Future studies should investigate and incorporate learning theories during the design of WBLE to address students' mathematics needs.

Limitations

The major significant limitation of this study is that some potential papers that fell within the criteria of inclusion may not have been selected due to the restrictions of the search strategy. In order to mitigate these limitations, the authors reviewed the references of the fourteen papers to find out whether or not other possible inclusion papers were missed during the search strategy.

Conflict of interests

No conflict of interest in the study.

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Sustavan pregled mrežnih okruženja učenja u nastavi Matematike na sekundarnoj razini obrazovanja: stavovi, postignuća, izazovi i moguća rješenja

Sažetak

Mrežna okruženja za učenje (WBLE) široko su prihvaćena u kontekstu visokoga obrazovanja. S druge strane, malo se zna o tome kako se ona koriste u programima matematike u višim razredima osnovnih te u srednjim školama. Stoga se u ovome sustavnom pregledu istražuje kako se WBLE primjenjuje na sekundarnoj razini obrazovanja i koji su dosdašnji rezultati primjene ovog nastavnoga pristupa. Odabrano je 14 relevantnih časopisa o WBLE-u na sekundarnoj razini obrazovanja te analizirano u smislu njihovih WBLE aktivnosti, postignuća učenika, stavova i izazova s kojima se susreću. Rezultati pokazuju da se u WBLE-u koristi nekoliko aktivnosti. Primjena WBLE-a u matematičkom obrazovanju na srednjoškolskoj razini proizvela je neutralan ili pozitivan učinak na učenička postignuća u usporedbi s tradicionalnim učenjem u učionici. Stavovi učenika o WBLE pristupu su različiti. Izazovi primjene WBLE-a javljaju se na razini učenika, nastavnika i organizacije. Na temelju prethodnih studija predložili smo sedam mogućih rješenja kao odgovor na njih. Također, u raspravi dajemo preporuke za buduća istraživanja.

Ključne riječi: *srednja škola; matematičko obrazovanje; učenje usmjereno na učenika; mrežna okruženja za učenje (WBLE)*

Uvod

WBLE metoda omogućava više oblika interakcije između nastavnika i učenika, kao i višestruki oblik pristupa materijalima za učenje. Sadrži različite aplikacije kao što su administracija i nadzor, priručnici i procjena te asinkrona i sinkrona komunikacija. Ove aplikacije podržavaju nastavu, poboljšavaju kvalitetu i vrednovanje učenja svakog pojedinog učenika te prate napredak u učenja kako bi se poboljšala učenička postignuća (Mioduser i dr., 2000).

U posljednja tri desetljeća WBLE-i postali su vrlo važan aspekt obrazovne tehnologije u visokom obrazovanju. Omogućuju učenicima pristup izvorima informacija i znanja koje je neophodno za različite vrste učenja, poput učenja na daljinu, suradnje, učenja usmjerenoga na učenike i učenja rješavanjem problema (Aparicio, Bacao, & Oliveira, 2016; Dabbagh & Kitsantas, 2012; Papadakis, Dovros, Paschalis, & Rossiou, 2012).

U prethodnim studijama naglašena je potreba za poboljšanjem poučavanja u nastavi Matematike, posebno u nastavi matematike na sekundarnoj razini obrazovanja (v. Baron, 2015; Star, 2016). Mnogi nastavnici matematike na srednjoškolskoj razini prihvatili su promjenu nastavnoga pristupa od onoga usredotočenog na nastavnika, na onaj usmjeren na učenika i okruženje učenja kroz suradnju (Watson, Mong, & Harris, 2011; Zhu, 2012). Ovaj sustavni pregled istražuje primjenu WBLE-a u nastavi Matematike u srednjoj školi i s njom povezan učinak na učenička postignuća.

Temelj istraživanja

U 21. stoljeću u srednjim školama sekundarne razine prepoznata je potreba suradničkoga i problemskoga pristupa nastavi Matematike. U suradničkom okruženju za učenje, učenici se susreću s izazovom svladavanja gradiva kroz raspravu i uključivanje u aktivnosti rješavanja problema koje poboljšavaju njihovu kreativnost i vještine razmišljanja, a koje su ključne u stvarnom životu (Avcu i Avcu, 2010; Lazakidou i Retalis, 2010).

Unatoč uvođenju suradničkoga okruženja za učenje usmjerenog na učenike i rješavanje problema, u mnogim slučajevima nastava Matematike oslanja se na tradicionalnu strategiju koja podrazumijeva prenošenje znanja s nastavnika na učenika. Ograničenja su u tome što učenici postaju neaktivni u procesu učenja i ne stječu dovoljno razumijevanja gradiva (Reece & Walker, 2016). Učenicima se u okviru takve tradicionalne nastave pristupa kao prema praznim posudama koje od nastavnika aktivno preuzimaju znanje (Lage, Platt, & Treglia, 2000). Takva percepcija procesa učenja smanjila je zanimanje mnogih učenika za matematiku. Nekoliko nastavnika zagovaralo je nastavnu reformu matematičkoga obrazovanja naglašavajući potrebu za aktivnim učenjem i kritičkimm razmišljanjem (Suherman i dr., 2011; Firmender, Gavin, & McCoach, 2014; Lau, 2015). Razvoj analitičkih vještina učenika u skladu s učenjem višega reda revidirane Bloomove taksonomije smatra se važnim na na srednjoškolskoj razini obrazovanja.

Kako bi se prevladala ograničenja tradicionalne metode poučavanja trebalo bi poduzeti značajan pomak prema nastavi usmjerenoj na učenika i suradničkom učenju (Faria, Almeida, Martins, & Gonçalves, 2015; Olsen, Aleven, & Rummel, 2015; Jacobs, Renandya, & Power, 2016). Napredovanje WBLE-a u skladu je s pristupom učenja usmjerenog na učenike, suradnju i rješavanje problema te je transformirao nastavu u visokom obrazovanju (Clark & Mayer, 2016).

Prednosti učenja usmjerenog na učenike, suradnju i rješavanje problema uključuju pojačano mišljenje višega reda, veću angažiranost i veće samopoštovanje, što može dovesti do boljih akademskih postignuća i motivacije učenika (Jacobs i dr., 2016). Istraživanje pokazuje da osobno sudjelovanje, intrinzična motivacija i samopouzdanje potiču daljnje učenje, što rezultira boljim uspjehom na školskim testovima (Murphy i Alexander, 2000).

Pomak prema nastavi usmjerenoj na učenike, suradnju i problemski pristup dogodio se uz primjenu WBLE-a u visokom obrazovanju (Dupuis, Coutu, & Laneuville, 2013; Lamb, 2016). Unatoč tome što WBLE-pristup može poboljšati kvalitetu srednjoškolskoga obrazovanja, u vrijeme provedbe ove studije nije identificiran ni jedan empirijski pregled koji bi utvrdio uspješnost i primjenu WBLE-a u učenju i poučavanju matematike na sekundarnoj razini. Stoga je potreban sustavan pregled kako bi se ispitala primjena WBLE-a u učenju i poučavanju matematike na srednjoškolskoj razini obrazovanja. U ovu smo studiju uključili škole na razini osnovnoškolskoga i srednjoškolskoga obrazovanja u različitim oblicima organizacije ovisno o pojedinoj zemlji. Tako su uključene osnovne škole, škole na nižoj sekundarnoj razini obrazovanja (engl. *junior high school*), srednje škole te sustav objedinjene škole od vrtića do 12. razreda i gimnazije. Svrha je ovoga sustavnog pregleda istražiti primjenu WBLE-a u nastavi Matematike na srednjoškolskoj razini i rezultate vezane uz ovakav nastavni pristup.

Pitanja obuhvaćena istraživanjem

Ovaj rad usmjeren je na sljedeća pitanja:

P1: Koje se WBLE-aktivnosti učenja koriste u nastavi Matematike na srednjoškolskoj razini obrazovanja?

P2: Kakav je učinak WBLE-pristupa na učenička postignuća u srednjoškolskoj razini obrazovanja?

P3: Kakav je stav učenika srednjoškolske razine obrazovanja o WBLE-u u matematici?

P4: Koji su glavni izazovi WBLE-a u učenju i poučavanju matematike na ssrednjoškolskoj razini obrazovanja?

P5: Kako možemo riješiti izazove navedene pod (4)?

Metodologija

Strategija pretraživanja

Kako bi se izvršio sveobuhvatan i sustavan odabir, pretraženo je sljedećih devet elektroničkih baza podataka: (1) CABdirect, (2) Elton B. Stephens Co. (EBSCOhost), (3) Scopus, (4) Institute of Electrical i Electronics Engineers (IEEE), (5) JSTOR, (6) Springer Link, (7) Science Direct, (8) Educational Resources Information Center (ERIC), i (9) Web of Science. U sustavnom pregledu korišteni su sljedeći pojmovi za pretraživanje, na engleskom jeziku: ("web-based*" OR "online*" OR "e-learning*" OR "the Internet* OR "LMS*") I ("learn*" OR "environment*" "mathematics*") I ("high school" OR "middle school" OR "secondary" OR "basic" OR "elementary school"). Pretraživanje je uključivalo neke pojmove koji se odnose na WBLE (npr. internetsko učenje, e-učenje, LMS, mrežno učenje) i sekundarna razina obrazovanja (npr. srednja škola, sekundarno obrazovanje, K-12 obrazovanje).

Kriteriji odabira

Kriteriji za odabir članaka razvijeni su kao što je prikazano u tablici 2. Kako bi studija bila uključena u trenutačni pregled, morala je biti objavljena u *peer-review* publikaciji na engleskom jeziku. Istraživanja odabrana za ovaj pregled objavljena su između siječnja 1999. i srpnja 2017. Studije objavljene prije siječnja 1999. vjerojatno se ne bave primjenom WBLE-a u školama (Ahamer, 1999.). Nadalje, trenutačni je pregled fokusiran na empirijske studije o primjeni WBLE-a u bilo kojem segmentu matematičkoga obrazovanja na srednjoškolskoj razini.

Tablica 1

Upotreba WBLE-a u istraživanju mora zadovoljiti definiciju šest atributa WBLE-a prema Dabbagh i Bannan-Ritland (2005). Dakle, mora uključivati (1) hipermediju s različitim oblicima prostora, (2) decentraliziranu kontrolu, (3) nekoliko vrsta interakcije, (4) globalizaciju, (5) asinkronu komunikaciju te (6) aktivne informacije u stvarnom vremenu. Kao rezultat toga isključili smo sve studije koje tematiziraju mrežno okruženje za učenje, ali bez svih šest atributa i koje nisu usmjerene na nastavni proces. Konačno, predmet istraživanja trebao bi biti u kontekstu matematike kako je naznačeno u tablici 1.

Rezultat pretraživanja

Nakon korištenja pojmova za pretraživanje, prikupljeno je 100 studija do 17. kolovoza 2017. Međutim, nakon uklanjanja duplikata iz svih baza podataka ostalo je ukupno 89 studija. Nadalje, nakon pregleda naslova i sažetaka, 50 studija ocijenjeno je nevažnim i isključeno iz analize jer nisu predstavljale empirijsko istraživanje u kontekstu srednjoškolske razine obrazovanja. Preostalih 39 studija ispitano je za sadržaj predmeta, nakon čega su odbijene 23 studije jer su bile izvan područja matematike. Konačno, preostalih 16 studija provjereno je na primjenu šest svojstava WBLE-a kako je predloženo Dabbagh i Bannan-Ritland (2005). U ovome procesu tri studije nisu zadovoljile kriterij. Kao rezultat toga, u trenutačni sustavni pregled uključeno je ukupno 14 studija. Pregled procesa odabira prikazan je na slici 2.

Slika 2.

Izdvajanje podataka i analiza

Autori su izdvojili i kategorizirali podatke u mape prema bazi podataka koja se koristi za lakšu identifikaciju. Konkretni podatci korišteni za pregled su autor (i), godina, kontekst i zemlja objavljivanja, svrha studije, dizajn studije, dizajn i trajanje istraživanja, veličina uzorka i primjena WBLE-a (uputstvena strategija prijave). Pored toga, postignuća i zadovoljstvo učenika primjenom WBLE-a sažeto su i sustavno prikazani u tablici 2. U slučaju različitih stavova autora u vezi s izdvajanjem i analizom podataka podatci su izdvojeni i ponovno analizirani, a odabrane studije ponovno su analizirane.

Rezultati

14 studija bilo je uključeno u ovaj sustavni pregled primjene WBLE-a u nastavi Matematike na sekundarnoj razini obrazovanja. Većina studija provedena je između 2008. i 2017. u SAD-u (n = 7), a slijede Tajvan (n = 2), Turska (n = 2), Njemačka (n = 1), Hrvatska (n = 1), i Sjeverni Cipar (n = 1). Period poučavanja naveden u studijama iznosio je između 0,4 i 156 tjedana. Međutim, nastava nije u svim studijama provođena tijekom cijeloga istraživačkog perioda. U istraživanjima su korišteni različiti istraživački pristupi: kombinirane metode (n = 4), kvazieksperimentalni dizajn (n = 5), uravnoteženi eksperimentalni dizajn (n = 2), randomizirani eksperimentalni dizajn (n = 1), složeno križanje, blokovi (n = 1) i longitudinalne studije (n = 1). Studije su obuhvatile ukupan broj od 2817 sudionika, s veličinom uzorka od 59 do 703. Sljedeći matematički sadržaji poučavani su korištenjem WBLE-a: (1) decimale, (2) koncept funkcije, (3) geometrija, (4) aritmetičke operacije, (5) brojevi i mješoviti skupovi problema te (6) brojevi i njihove operacije.

Osam od 14 studija provedeno je u osnovnim i srednjim školama, šest je provedeno u višim razredima osnovne škole, srednjim školama i na primarnoj razini obrazovanja. Pet je studija provedeno u osnovnim školama (Dijanić i Trupčević, 2017; Craig i dr., 2013; Güzeller i Akın, 2012; Tsuei, 2012; Mendicino, Razzaq i Heffernan, 2009), tri u srednjim školama (engl. *middle school*), (Ocumpaugh i dr., 2016; Adams i dr., 2014; Arroyo i dr., 2010), dvije studije uključivale su srednje škole gimnazijskoga tipa (Baki i Güveli, 2008; Graff, i dr., 2008), tri su istraživanja provedena u školama gimnazijskoga tipa s višim razredima osnovne škole (engl. *junior high school*) (Wang, 2011; Pane, 2010; Beal i dr., 2007.), a jedna je provedena u osnovnoj školi (Pilli & Aksu, 201), kao što je prikazano u tablici 2.

Dolje prikazani rezultati strukturirani su na temelju naše istraživačke svrhe (primjena WBLE-a u učenju i poučavanju matematike na sekundarnoj razini), učinaka WBLE-pristupa na učenička postignuća i njihova zadovoljstva ovim pristupom učenju.

P1: Koje su WBLE-aktivnosti učenja korištene u nastavi Matematike na srednjoškolskoj razini obrazovanja?

U sustavnom pregledu identificirano je četrnaest različitih vrsta WBLE-aplikacija na srednjoškolskoj razini obrazovanja. To su: (1) mrežni sustav poučavanja s primjerima s greškama, (2) Wayangov Outpost mrežni interaktivni sustav poučavanja, (3) Wayangov sustav poučavanja i softver za učenje Mathematics Fact Retrieval (MFR), (4) Mrežna nastava matematike (WBMT), (5) Ocjenjivanje i učenje u prostorima znanja (ALEKS), Softver za dinamičku geometriju i interaktivni alati GeoGebra, (7) eFit (prilagodljivi mrežni inteligentni sustav poučavanja), (8) Mrežna poduka matematike (WBMI), (9) Mrežni sustav ASSISTment za učenje kod kuće (inteligentni nastavni sustavi), (10) Kognitivni nastavni kurikul geometrije s dvije komponente (učionička i individualizirana nastava, računalna nastava putem softvera za učenje Carnegie Learning) (11) Frizbi Mathematics 4, (12) ASSISTments, besplatni mrežni nastavni sustav matematike, (13) Sustav G-Math s matematičkim kurikulom, i (14) WATA-sustav, modul za ocjenjivanje (GPAM-WATA). U nastavku smo razmotrili svrhu i instruktivnu strategiju za svaku aplikaciju WBLE na sekundarnoj razini učenja i poučavanja matematike na temelju odabranih studija kao što je prikazano u tablici 2:

Mrežni sustav poučavanja s pogrešnim primjerima: Mrežni sustav poučavanja s pogrešnim primjerima inteligentan je program nastavnika koji učenicima omogućuje ispravljanje pogrešnih rješenja decimalnih problema nastalih zbog temeljnih pogrešaka u razumijevanju. Na taj način učenici dobivaju pogrešna rješenja decimalnih pitanja koja su riješili njihovi kolege. Vjeruje se da je razumijevanje i učenje matematike kod učenika bolje kada su identificirali, objasnili i ispravili pogreške u pogrešnim rješenjima svojih kolega (Adams, i dr., 2014). Osim toga, učenici su trebali samostalno riješiti probleme, nakon čega su dobili povratnu informaciju o ispravnosti, a zatim su trebali dati objašnjenje svog rješenja koristeći mrežni sustav poučavanja (Adams, i dr., 2014).

Wayangov sustav poučavanja i softver za vježbanje MFR: Wayangov sustav poučavanja multimedijski je sustav koji učenicima pokazuje kako riješiti probleme geometrije, statistike i algebre, koji se često nalaze na standardiziranim testovima. Svrha korištenja Wayangova sustava poučavanja je poboljšati učenje matematike kod učenika na srednjoškolskoj razini obrazovanja (Arroyo i dr., 2010). Učenici rješavaju matematički problem u Wayangovu sustavu poučavanja, a zatim izaberu rješenje koje odgovara njihovom odgovoru s popisa više mogućnosti. Wayangov sustav pruža neposrednu povratnu informaciju nakon odabrane opcije. Nadalje, učenici tijekom procesa rješavanja problema mogu tražiti savjete od sustava o rješenju problema (Arroyo i dr., 2010).

Softver MFR omogućuje učenje gradiva i ocjenjivanje savladanog. U aspektu gradiva pokrivene su digitalne operacije poput zbrajanja, oduzimanja i množenja putem digitalnih stranica (Arroyo i dr., 2010). Ocjenjuje se točnost i brzina savladanosti gradiva kada učenik svoj odgovor izgovara za sustav. Taj se odgovor kodira u sustav bez obzira je li točan ili ne. Po završetku sesije ocjenjivanja, sustav pruža linijski grafikon koji pokazuje napredak brzine i točnosti kod učenika (Arroyo i dr., 2010).

Mrežna nastava Matematike (WBMT): WBMT je internetska mrežna pomoćna nastava Matematike s osnovnim objašnjenjima, primjerima i interaktivnim vježbama funkcija. WBMT osmišljen je kako bi poboljšao osnovne pojmove funkcija kod učenika na srednjoškolskoj razini obrazovanja (Baki i Güveli, 2008). Nadalje, WBMT pokriva opće koncepte linearne, kvadratne i višekratnih funkcija te jednadžbe. Sustav nudi učenicima kratku lekciju o svakom konceptu funkcija, a zatim im omogućava da prođu kroz neke interaktivne vježbe s ocjenama kako bi mogli vježbati koliko žele, uz neposrednu povratnu informaciju o napretku (Baki i Güveli, 2008).

Wayangov outpost mrežni interaktivni sustav poučavanja: Wayangov outpost mrežni interaktivni sustav poučavanja dizajniran je kako bi učenicima pružio personalizirano multimedijsko poučavanje za rješavanje pitanja SAT-Math koja uključuje geometrijske vještine i dodatne algebarske koncepte na sekundarnoj razini obrazovanja (Beal, et. al., 2007). Prilikom prve prijave u sustav, poslužitelj sustava za poučavanje nasumično dodjeljuje korisniku (učeniku) da koristi pomoć kroz interaktivne vizualne znakove ili algoritme. Sustav uključuje nekoliko matematičkih problema u vidu brojeva, grafikona i jednadžbi koje treba riješiti. Učenici mogu kliknuti na ispravan odgovor odabirom između pet opcija. Sustav će učenicima poslati povratne informacije koje ukazuju na ispravne ili netočne odgovore. Pored toga, sustav ima opciju „pomoć", koja učenicima daje savjete koji vode do rješenja problema (Beal i dr., 2007).

Procjena i učenje u prostorima znanja (ALEKS): ALEKS je inteligentni sustav poučavanja utemeljen na matematici, a komponenta umjetne inteligencije koristi se kao metoda intervencijske strategije za poboljšanje matematičkih vještina učenika osnovne škole (Craig, i dr., 2013.). Osmišljen je kao podrška učenicima na sljedeće načine: (1) učenje gradiva kroz lekcije, (2) vrednovanje s višestrukim izborima i sličnim zadacima, (3) primanje povratnih informacija o izvedbi testa, (4) ponovno učenje gradiva ako je uspješnost ispod očekivanja i (5) prelazak na novi koncept ako uspješnost premaši očekivanja (Craig i dr., 2013).

Softver za dinamičku geometriju i interaktivni program GeoGebra: Interaktivni program GeoGebra alat je za stjecanje i otkrivanje novih matematičkih znanja povezanih s konceptualnim znanjem. Interaktivne aplikacije organizirane su u digitalnom udžbeniku s nekoliko poglavlja za odvojene nastavne jedinice. Aplikacije uključuju jednu od sljedećih funkcija: (1) Motivacijska: koristi se na početku svake upute za predstavljanje sadržaja učenicima i motivaciju za daljnji rad, (2) Aplikacija za istraživanje: omogućava nastavnicima da izvode matematički eksperiment za učenike u cilju otkrivanja novih znanja iz matematike. U procesu eksperimenta koristi se strategija rješavanja problema (tj. razumijevanje problema, izrada plana, provođenje plana i sagledavanje); (3) Aplikacija za usvajanje gradiva: omogućuje učenicima rješavanje matematičkih problema vezanih uz lekciju. Aplikacija za usvajanje gradiva uključuje komponentu igre s bodovanjem za motiviranje i poticanje učenika na napredak u učenju; (4) Dodatni sadržaji: aplikacije imaju i druge zanimljive elemente kao što su sadržaj matematike za nadarene učenike, aplikacija matematike za svakodnevni život, odjeljak o povijesti matematike, aktivnosti za učenike sa slabim matematičkim razmišljanjem i kvizovi (Dijanić i Trupčević, 2017).

Softver za dinamičku geometriju je računalno vođeni program učenja otkrivanjem s dinamičkom geometrijom koji se sastoji od tri osnovne komponente: (1) objekti učenja, (2) aktivnosti učenika i (3) rezultati učenja (Dijanić i Trupčević, 2017). Svrha dizajna računalno vođenoga softvera za otkrivanje pomoću dinamičke geometrije i interaktivnih apleta GeoGebra bila je istražiti utjecaj na procesna i konceptualna znanja učenika u matematici (Dijanić i Trupčević, 2017).

eFit (prilagodljivi mrežni inteligentni sustav poučavanja): eFit je osmišljen kao mrežni inteligentni sustav poučavanja koji učenicima pruža okruženje poučavanja i učenja prilagođeno njihovim kompetencijama i znanju. Cilj je pružiti individualiziranu nastavu prilagođenu korisnicima sličnu poučavanju jedan na jedan. Cilj dizajniranja eFita je ublažiti poteškoće u učenju matematike kod učenika na sekundarnoj razini obrazovanja (Graff i dr., 2008).

Za upute eFits učenici koriste školski računalni laboratorij ili svoja osobna računala s pristupom internetu na kojima je pokrenut sustav eFit. Program eFit započinje ispitivanjem uspješnosti učenika srednjoškolske razine obrazovanja na standardiziranom testu osnovnih matematičkih operacija poput zbrajanja, oduzimanja, množenja i dijeljenja. Procjena eFit-a obuhvaća subskalu Heidelberger Rechentest (HRT), koja mjeri aritmetičke vještine učenika i kompetencije u osnovnim matematičkim operacijama (Graff, i dr., 2008).

Mrežna poduka matematike (WBMI): WBMI je poznata i kao internetsko okruženje koje omogućuje učenicima interakciju s vršnjacima ili drugima i omogućava im pristup nekoliko materijala za učenje, neposrednu povratnu informaciju i samostalno učenje (Pilli, O., i Aksu , 2013; Nguyen, Hsieh, & Allen, 2006; Kim MacGregor & Lou, 2004; Morgan & O'Reilly, 2001). Svrha dizajna WBMI-a za učenike osnovnih škola je poboljšati postignuća iz matematike, stavove, anksioznost i samoefikasnost (Güzeller i Akın, 2012).

Mrežni sustav učenja kod kuće - sustav ASSISTment: Sustav ASSISTment je mrežni sustav koji uključuje pomoć i procjenu. Sustav pruža upute učenicima, a nastavnicima nudi sveobuhvatnu procjenu njihove kompetencije. ASSISTment ima ugrađenu komponentu koja omogućava nastavnicima da procjenjuju sposobnosti učenika i prepoznaju njihove glavne probleme i konceptualne slabosti koje je potrebno riješiti ili vještine koje je potrebno poboljšati u učionici. Svrha sustava je pomoći učenicima osnovnoškolske dobi da nauče više radeći domaću zadaću iz matematike (Mendicino, Razzaq i Heffernan, 2009).

Problemi iz matematike predstavljeni su učenicima prilikom prijave u sustav ASSISTment. Sustav se sastoji od dvije vrste pomoći za poučavanje: segmentiranih uputa i pomoći u rješavanju. Kada koriste segmentirane upute i daju krivi odgovor na pitanje, učenici dobivaju poruke poput „Hmm, ne. Pokazat ću ti dio po dio." Nakon toga slijede pitanja koja korak po korak trebaju navesti učenika prema ispravnom odgovoru prije nego što pređe na sljedeće pitanje. Pored toga, od učenika se traži da odgovore na segmentirana pitanja prije glavnog pitanja. Pomoć u rješavanju navodi učenika na ispravan odgovor (Mendicino, Razzaq i Heffernan, 2009).

Kognitivni kurikul za poučavanje geometrije: Kognitivni kurikul za poučavanje geometrije namijenjen je unaprjeđivanju znanja učenika viših razreda osnovne škole o geometrijskim konceptima, načelima i vještinama prostornoga promišljanja kao i pružanju personalizirane upute za rješavanje njihovih specifičnih potreba (Pane i dr., 2010). Softver Cognitive Tutor daje učenicima zahtjevna pitanja u obliku više koraka, koji odražavaju praktične situacije. Učenici mogu samostalno riješiti matematičke probleme i zatražiti savjet od sustava ako imaju poteškoće. Nakon toga softver za učenje generira daljnja pitanja na temelju uspješnosti učenika. Učenicima se zatim omogućuje izvještaj o napretku njihove sposobnosti sadržaja pomoću zaslonskog mjerača napretka (komponenta softvera). Osim toga, ovaj softver nastavnicima pruža detaljne povratne informacije o brzini napredovanja pojedinih učenika. Program za poučavanje uključuje model koji usmjerava učenike prema točnom odgovoru pri rješavanju problema (Mendicino, Razzaq i Heffernan, 2009).

Obrazovni softver: Frizbi Mathematics 4: Frizbi Mathematics 4 je obrazovni alat namijenjen pružanju pomoći u nastavi Matematike i promicanju učenja učenika u osnovnoj školi (Pilli & Aksu, 2013). Ovaj nastavni softver omogućuje učenicima da otkriju i razumiju matematičke sadržaje na različite načine, što je izazov za tradicionalnu nastavu Matematike. Softver se sastoji od 1) vesele animirane priče s videoisječcima, kreativnim alatima i igrama vezanim za svakodnevne životne aktivnosti, 2) općenitih strategija rješavanja problema, 3) interaktivnih vježbi s matematičkim problemima i 4) rješenja na temelju zadanih matematičkih. Nadalje, sustav usmjerava učenike na objašnjenje sadržaja kad god imaju poteškoća s određenim zadatkom. Osim toga, softver pruža vježbe i povratne informacije na kraju svake lekcije, što učenicima omogućava da procijene vlastito znanje iz matematike (Pilli & Aksu, 2013).

ASSISTments - mrežni sustav za matematiku: ASSISTments je besplatni mrežni program za poučavanje, dizajniran posebno za poučavanje i učenje matematike u školama srednjim školama (Ocumpaugh, i dr., 2016). Sustav ocjenjuje znanja učenika istovremeno ih podržavajući u učenju i pruža nastavnicima informacije o savladanim vještinama svakog učenika. Sustav omogućuje učenicima da prijeđu na sljedeći problem nakon što daju točan odgovor na prethodno pitanje. S druge strane, kad god učenik netočno odgovori, sustav rastavlja predavanje na manje sastavne dijelove te na taj način sustavno usmjerava učenika prije nego što se vrati izvornom pitanju (Mendicino, Razzaq, & Heffernan, 2009; Razzaq, i dr., 2005). Sustav ASSISTments u SAD-u koristi 50 000 učenika godišnje (Ocumpaugh i dr., 2016).

G-Math sustav s matematičkim kurikulom: G-Math je asinkroni sustav poučavanja dizajniran za pomoć učenicima i nastavnicima u učioničkoj nastavi matematike u osnovnoj školi. G-Math ima dvije glavne karakteristike: (1) aspekt upravljanja nastavnim aktivnostima od strane nastavnika i (2) sustav vršnjačkoga mentorstva koji učenicima omogućuje obavljanje aktivnosti vršnjačkoga *učenja poput „game-like*" (Tsuei, 2012). G-Math ima bazu s matematičkim problemima u modulu Aktivnosti poučavanja iz matematike, koji dodjeljuje nastavnik. Sustav nasumično raspoređuje probleme učenicima i pruža informacije u stvarnom vremenu o svakoj učeničkoj grupi. Nadalje, G-Math ima sustav vršnjačkoga ocjenjivanja za ocjenjivanje napretka u procesu rješavanja matematičkih problema. Sustav također na kraju daje točan odgovor na svaki problem. Ovaj pristup omogućuje učenicima da razmisle o svojim rješenjima, što potiče metakognitivno razmišljanje (Tsuei, 2012). G-Math sustav vršnjačkoga poučavanja pruža nekoliko vrsta segmentiranja gradiva i interaktivnih alata radi olakšavanja diskusije o matematici među vršnjacima uživo. Sustav pruža kategorije matematičkih pojmova kao što su linija brojeva, geometrija, cijeli brojevi, razlomci, nepoznanice i drugi (Tsuei, 2012).

Mrežni sustav dinamičkoga ocjenjivanja - GPAM-WATA: Prema Wangu (2010), ovaj mrežni dinamički sustav ocjenjivanja poznat je i pod nazivom Modul stupnjevanog ocjenjivanja WATA sustava (GPAM-WATA). Koristi se kao pomoć u korektivnom učenju i poučavanju matematike u višim razredima osnovne škole te je zamišljen kao dodatak tradicionalnom učenju matematike (Wang, 2011). Učenici koji sudjeluju u ovom sustavu dobivaju osobnu dopunsku nastavu iz matematike. Kao rezultat toga, učenici su izloženi u nekoliko situacija učenja što dovodi do njihova boljeg razumijevanja matematičkih koncepata.

Nadalje, GPAM WATA uključuje komponentu koja se zove IP, koja učenicima pruža pravovremenu povratnu informaciju kada se suoče s poteškoćama u rješavanju problema u sustavu. Sustav sadrži instruktivne poruke koje pružaju upute za učenje i omogućavaju učenicima da rješavaju matematička pitanja (Wang, 2011).

Otkrivamo kako WBLE-ovi kao obrazovni alati nude učenicima pristup uređenim i jednostavno ažuriranim nastavnim materijalima, aktivnostima temeljenim na problemima, mrežnim resursima i podršci za udžbenike. Neki aspekti WBLE-a ispituju učeničko matematičko znanje, a nastavnicima daju informacije o savladanom gradivu svakog učenika. Budući da se uspješnost rješavanja problema kod učenika pokazala tijekom niza ispitnih godina na vrlo niskoj razini (Lester, 1994), aktivnost rješavanja problema bio je glavni promatrani aspekt svih primjera WBLE-aplikacija među pregledanim radovima. Aktivnosti WBLE-a uključene u studije korisne su za smanjenje poteškoća u rješavanju problema kod učenika.

P2: Kakav je učinak WBLE pristupa na postignuće učenika u srednjoškolskoj razini obrazovanja?

12 studija uspoređivalo je akademsku uspješnost učenja putem aplikacije WBLE u odnosu na tradicionalne i druge metode poučavanja. Dvije studije, autora Baki i Güveli (2008) te Craig i dr. (2013) ne bilježe značajnu razliku između uspješnosti učenja pomoću WBLE-a i tradicionalne metode. S druge strane, 10 studija (Adams, i dr., 2014; Pilli & Aksu, 2013; Güzeller & Akın, 2012; Tsuei, 2012; Wang, 2011; Arroyo i dr., 2010; Pane, i dr., 2010; Graff i dr., 2008; Mendicino, Razzaq, & Heffernan, 2009; Beal i dr., 2007;) otkriva da su učenici koji koriste WBLE-pristup postigli znatno bolje rezultate u rješavanju testova od onih koji su poučavani pomoću drugih metoda. Iznenađujuće, jedna studija (Dijanić i Trupčević, 2017) pokazala je da učenici koji koriste WBLE u šestom i osmom razredu imaju bolji uspjeh od svojih vršnjaka u tradicionalnoj nastavi (TN), dok su učenici u sedmom razredu imali višu ocjenu od kolega koji koriste WBLE. Samo jedna studija, Ocumpaugh i dr. (2016) nije istraživala izvedbu učenika. Nijedna studija nije pokazala negativne rezultate kod učenika koji koriste WBLE u odnosu na

druge metode, uz iznimku učenika sedmog razreda (Dijanić i Trupčević, 2017) kao što je prikazano na slici 3 i tablici 4. Adams i dr. (2014) predlažu da, kada se učenici upoznaju s mrežnom platformom za matematiku, steknu povjerenje u učenje i imaju ogromne mogućnosti pristupanja velikoj količini znanja i informacija.

Tablica 3

Nadalje, učenici koji koriste internetske inteligentne sustave poučavanja susreli su se s mnogo individualne poduke pored poduke koju imaju u klasičnoj nastavi Matematike (Graff i dr., 2008). Osim toga, Tsuei (2012) smatra da je sustav sinkronoga poučavanja vršnjaka učinkovito okruženje za učenje u osnovnim školama i poboljšanje učenja matematike te potiče učeničku sigurnost u konceptualno shvaćanje.

Slika 3.

P3: Kakav je stav učenika sekundarne razine obrazovanja prema WBLE-u u matematici?

U ovome istraživanju stav se definira kao osjećaj koji učenici imaju prema korištenju WBLE-a za učenje matematike. Kako bismo ispitali odnos učenika sekundarne razine prema WBLE-u, analizirali smo odgovore učenika (intervjui, ankete), razmišljanja nastavnika i opažanja istraživača koja su iznesena u analiziranim studijama. Općenito, otkriveno je da učenici srednjoškolske razine obrazovanja pokazuju veći stupanj zadovoljstva korištenjem WBLE-a u učenju matematike (npr. Ocumpaugh i dr., 2016; Craig i dr., 2013; Güzeller i Akın, 2012; Pilli & Aksu , 2013; Tsuei, 2012; Baki & Güveli, 2008). Da budemo precizniji, sljedeće kvalitativne napomene ukazale su na prednosti WBLE-pristupa koji je pridonosio zadovoljstvu učenika u nastavi Matematike uz WBLE.

Kao prvo, učenici su pokazali da im samopouzdanje i motivacija za učenje matematike rastu što se bolje upoznaju s matematičkim postupcima i mrežnim procesima (Tsuei, 2012; Baki i Güveli, 2008; Beal i dr., 2007), a više prakse s matematičkim aktivnostima u WBLE-u pružilo im je priliku za poboljšanje svladavanja matematike, samoučinkovitosti i smanjenje straha od matematike (Güzeller i Akın, 2012). Jedan je učenik izjavio da je WBLE „poboljšao učeničko samopouzdanje u rješavanje problema iz matematike i povećao pozitivan stav prema učenju" (Güzeller i Akın, 2012., str. 51). Drugi je izjavio: „Uvjeren sam da u ovoj nastavi matematike mogu postići izvrsne rezultate iz zadataka i na testovima“ (Tsuei, 2012, str. 1178).

Kao drugo, WBLE pristup pružio je učenicima trenutačne i pravovremene povratne informacije pri poteškoćama u rješavanju problema u sustavu (Dijanić i Trupčević, 2017; Tsuei, 2012; Pane i dr., 2010). Primjerice, dobili su povratnu informaciju o ispravnosti svojega odgovora pri rješavanju matematičkoga problema, a zatim su dobili rješenje (Adams, i dr., 2014). WBLE omogućuje učenicima da razumiju matematički sadržaj i pruži im jasan pravac kako mogu unaprijediti svoje učenje (Craig i dr., 2013). Konkretnije, jedan je student tijekom intervjua odgovorio „Volim prolaziti kvizove s trenutnim povratnim informacijama“ (Baki i Güveli, 2008., str. 860). Nadalje, jedan je učenik istaknuo: „Sviđa mi se način na koji je računalo reagiralo na moj unos“ (Adams, i dr., 2014., str. 404).

Treće, funkcija pomoći u sustavu omogućuje učenje korak po korak, uz prezentaciju koncepta, primjerene primjere, savjete i interaktivnu vježbu za poboljšanje znanja iz matematike (Baki i Güveli, 2008). Uz to, WBLE nudi metodu vršnjačkoga učenja koja predstavlja zanimljiv i drugačiji način učenja matematike (Tsuei, 2012). Baki i Güveli (2008) ističu da WBLE sustav savjetima omogućuje učenicima da samostalno riješe zadatke i matematičke probleme te tako trajno ovladaju matematičkim sadržajem (Adams, i dr., 2014).

Nasuprot pozitivnom stavu prema WBLE-u, Adams i dr. (2014) otkrili su da je ta vrsta nastave za neke učenike predstavljala poteškoću jer im je teško razumjeti materijale iz sustava. Točnije, jedan je učenik rekao: „Naprezao sam se kako bih shvatio gradivo u ovoj lekciji." (Adams, i dr., 2014:404).

P4: Koji su glavni izazovi implementacije WBLE-a u nastavi Matematike na srednjoškolskoj razini obrazovanja?

Na temelju Betihavas i dr. (2016), trenuačtni pregled glavne izazove primjene WBLE-a u nastavi matematike u školama sekundarne razine obrazovanja svrstava u tri glavne kategorije, a to su izazovi povezani s učenicima, nastavnicima i operativni izazovi.

Izazovi vezani uz učenike: Güzeller i Akın (2012) kažu da učenicima nedostaje kvalitetan pristup računalu i internetu u školi i kod kuće, stoga su uskraćeni za interaktivne funkcije WBLE-a. Primjedbe učenika bile su usmjerene na njihove poteškoće s prilagođavanjem ovom novom nastavnom okruženju, poteškoće u razumijevanju WBLE-uputa i osjećaj da su prepušteni samima sebi (Dijanić i Trupčević, 2017). Kao rezultat toga kroz WBLE-aktivnosti prošli su žurno i bez odgovarajućega razumijevanja (Dijanić i Trupčević, 2017). Baki i Güveli (2008) dodatno ističu da je vrijeme važan aspekt izvannastavnih aktivnosti te da ocjenjivanje negativno utječe na učeničku motivaciju i zadovoljstvo.

***Izazovi povezani s nastavnim osobljem*:** Prema Baki i Güveli (2008), nastavnikovo nepoznavanje ili neiskustvo s WBLE-om može utjecati na učeničke rezultate učenja. Međutim, učenje i upravljanje poučavanjem WBLE-a radi poboljšanja ishoda učenja predstavlja dodatno opterećenje za nastavnike. Pored toga, Pilli i Aksu (2013) izrazili su zabrinutost da je za poučavanje WBLE-om uglavnom potrebno duže vrijeme od tradicionalne nastave Matematike. Također kažu da tijekom rješavanja problema nastavnici nisu mogli spriječiti učenike da prepisuju odgovore od svojih vršnjaka. Nadalje, nastavnici su dodatno opterećeni svladavanjem tehnologije prije primjene.

Operativni izazovi: Prema Baki i Güveli (2008), neki od izazova primjene WBLE-a u ruralnim sredinama su infrastruktura, laboratorijski uvjeti i nedostatak kvalitetnoga pristupa internetu. Uz to, primjenu WBLE-a ometa i problem vezan uz programe obrazovanja o korištenju tehnologije kao i spremnost nastavnika na primjenu moderne tehnologije (Dijanić i Trupčević, 2017). Unatoč tim izazovima, nijedna od studija posebno ne opisuje rješenja tih problema, već preporučuje upotrebu WBLE-a na srednjoškolskoj razini obrazovanja.

P5: Kako možemo riješiti izazove navedene u (P4)?

Rješavanje izazova povezanih s učenicima

Predloženo rješenje 1: Osigurati da škole na srednjoškolskoj razini obrazovanja imaju kvalitetan pristup internetu i računala koja podržavaju WBLE izazovan je zadatak, jer iziskuje velika ulaganja vlade i privatnoga sektora. Srednje škole mogu u partnerstvu s obrazovnim službama ili neprofitnim organizacijama osigurati učenicima internet u školi i kod kuće. Primjerice, mogu se udružiti s *E-rate* i neprofitnim obrazovanjem *Super Highway* pružateljima brzog interneta velikog kapaciteta za škole kako bi pomogli u financiranju i smanjili troškove brzog pristupa internetu (Bleiberg, 2016).

Nadalje, srednja škola može ući u program prijenosnoga računala za svako dijete i tako osigurati stalan pristup računalima za primjenu WBLE-a. Primjerice, škole bi se mogle povezati s industrijom osobnih računala kako bi se razvila jeftinija računala orijentirana na obrazovne tehnologije radi potpore ovoj inicijativi. Oslanjanje isključivo na podršku komercijalnoga tržišta možda neće pomoći postizanju ovoga (Kraemer, Dedrick, & Sharma, 2009). Škole mogu zatražiti pomoć vlade kako bi podržala ove projekte prijenosnih računala za svako dijete. To bi omogućilo povećanje sudjelovanja u učenju putem WBLE-a, posebno za učenike iz siromašnih ruralnih područja.

Predloženo rješenje 2: Prilagođavanje novom okruženju učenja i razumijevanje sadržaja istovremeno je izazovno i zahtijeva puno napora (Clark, 2015). WBLE bi trebao sadržavati značajke koje potiču redovitu interakciju ili otvorenu komunikaciju učenika s nastavnicima i čine da se osjećaju važnima. Prisutnost nastavnika i vršnjaka može umanjiti učenički strah i omogućiti im da se prilagode ovom novom okruženju učenja. Umjesto da se osjećaju odbačenima, usredotočit će se na aktivnosti učenja koje dodjeljuje sustav. Nadalje, učenike treba detaljno poučiti o WBLE-u, o tome kako sustav funkcionira i što se od njih očekuje. To potiče samopouzdanje učenika i pomaže im brže upoznati WBLE (Clark, 2015).

Predloženo rješenje 3: Motivirani učenici učinkovito uče, zadržavaju matematičko znanje, sudjeluju u procesu učenja i postaju disciplinirani. Ako učenici smatraju da je njihov rad prepoznat i cijenjen, veća je vjerojatnost da će biti uzbuđeni zbog aktivnosti učenja. WBLE bi trebao često hvaliti rad učenika i omogućiti prepoznavanje njihovih doprinosa pri rješavanju matematičkih problema. Pohvale trebaju biti u obliku podržavajućih izjava poput „Jako dobro, samo nastavi!" kod točnog odgovora, ili „Možeš ti to bolje!", za netočan odgovor. Pohvale mogu motivirati učenike osnovnih škola na iskazivanje ponašanja koja će poboljšati njihovu izvedbu (Hodgman, 2014). Ako se sustav prema učenicima ophodi s ljubaznošću i poštivanjem, oni će htjeti nastaviti s aktivnostima. Nadalje, pružanje poticaja učenicima motivira ih da uče (Bishop, 2004). Poticaji poput dodatne dodjele bodova u WBLE aktivnostima ohrabrili bi ih za određeni cilj i nastavak dodatnoga rada. Nadalje, WBLE s aspektom videoigara mogao bi učenicima biti poticaj za bolja postignuća.

Rješavanje izazova povezanih s nastavnicima

Predloženo rješenje 4: Malo srednjih škola ima takvu upravu koja izdvaja vrijeme i resurse za organiziranje formalnih programa mentorstva o obrazovnoj tehnologiji za svoje nastavnike. Organiziranje takvih nastavnih programa može nastavnike osnažiti za napredak u implementaciji WBLE-a. Također bi trebalo osigurati više obuke iz WBLE-a u okviru stručnoga usavršavanja nastavnika. Stručno usavršavanje važno je za nastavnike kako bi uklonili nedostatke i držali korak s ciljem integriranja tehnoloških strategija poučavanja i učenja temeljenoga na tehnologiji.

Predloženo rješenje 5: Jedan od najjednostavnijih načina za izbjegavanje produžavanja nastave zbog korištenja WBLE-a jest taj da se provede malo vremena s WBLE-om prije stvarne primjene sustava. To bi umanjilo potencijalne prepreke koje mogu prouzrokovati kašnjenje i omogućiti nastavniku da smanji vrijeme provedeno pri korištenju WBLE-a u usporedbi s nastavom bez računala. Nastavnici trebaju biti svjesni da upoznavanje s WBLE-om nije gubitak vremena kada koristimo WBLE umjesto tradicionalnoga poučavanja. Tako je studija koju su proveli Andersen i Avery (2008) otkrila je da internetske upute i upute licem u lice u prosjeku zahtijevaju slično vrijeme za jedan predmet koji se ocjenjuje. Objasnili su da se više vremena troši na pripremu nastave uživo (39 %) nego u nadogradnje za internetske upute (12 %).

Predloženo rješenje 6: nastavnici trebaju podsjećati učenike na akademski integritet u rješavanju matematičkih problema s WBLE-om. Učenici trebaju biti upoznati i upozoreni na posljedice varanja. Pored toga, WBLE bi trebao imati skupove različitih pitanja svaki put kada se učenik prijavi kako bi odgovorio na bilo koji matematički problem. Također, sustav bi trebao omogućiti nastavnicima da dodaju više pitanja kad god smatraju da su učenici ispunili gotovo sve zadatke. Također, oni bi trebali moći ukloniti postojeća pitanja. Ove bi strategije mogle omogućiti nastavnicima da spriječe varanje učenika pri korištenju WBLE-a kada rješavaju matematičke probleme.

Rješavanje operativnih izazova

Predloženo rješenje 7: Kao što smo spomenuli, u mogućem rješenju izazova povezanih s učenicima, srednje škole trebaju tražiti podršku nevladinih organizacija, okružnih ureda za obrazovanje i računalne industrije za kvalitetan pristup internetu i program prijenosnoga računala za svako dijete. Trebali bi poboljšati infrastrukturu omogućavanjem računala u laboratorijima i kvalitetnoga pristupa internetu, posebno u ruralnim srednjim školama. Nadalje, srednje škole mogu ostvariti partnerstva s fakultetima obrazovne tehnologije kako bi im oni pružili programe za obuku nastavnika iz obrazovne tehnologije radi njihove bolje pripreme za primjenu WBLE-a.

Zaključci i preporuke za buduća istraživanja

U ovom radu analizirane su empirijske studije o WBLE-u na srednjoškolskoj razini obrazovanja matematike. Na temelju odabranih radova predstavili smo pregled aktivnosti WBLE-a, rezultate utjecaja WBLE-a na postignuća učenika, odnos učenika prema WBLE-u i izazove vezane uz njegovu primjenu, kao i moguća rješenja. Iako

WBLE-pristup nije rješenje za sve probleme u nastavi Matematike na srednjoškolskoj razini obrazovanja, pokazalo se da podržava učenje usmjereno na učenika koje zahtijeva aktivnosti rješavanja problema podršku kroz upute i korištenje mrežnih resursa te nastavno gradivo u stvarnom vremenu. U ovome pregledu nema potvrde da primjena WBLE-a na srednjoškolskoj razini obrazovanja negativno utječe na učeničko savladavanje matematičkih sadržaja. WBLE omogućuje učenicima znatno veći napredak naspram učenika u tradicionalnoj nastavi. Samo dva recenzirana rada pokazala su rezultate prema kojima nije bilo razlike ili ona nije bila značajna (Craig i dr., 2013; Baki i Güveli, 2008).

Naši rezultati u pogledu odnosa učenika prema WBLE-pristupu su različiti. Negativne povratne informacije učenika otkrile su važnost poboljšanja ove nastavne metode. Izazovi primjene WBLE-a razvrstani su u tri kategorije: izazove vezane za učenike, izazove vezane za nastavnike i operativne izazove. Na temelju relevantne literature i eksperimentalnih nalaza izloženo je sedam mogućih rješenja za njihovo nadilaženje.

Nadalje, ovo istraživanje ograničeno je na 14 empirijskih studija o WBLE-u na sekundarnoj razini obrazovanja u nastavi Matematike. Iako se WBLE sve češće koristi (Hui i dr., 2015), čini se da ne postoji dovoljno studija o njegovoj primjeni na sekundarnoj razini obrazovanja u nastavi Matematike. Na primjer, samo dvije studije o WBLE-u provedene su u višim razredima osnovne škole (Pane, i dr., 2010; Wang, 2011). Štoviše, u njima nisu prepoznati nikakvi izazovi. Preporučujemo više empirijskih studija koje ispituju učinak WBLE-a i izazove u obrazovanju iz matematike na sekundarnoj razini, posebno u školama gimnazijskoga tipa i u višim razredima osnovne škole.

Daljnje studije trebaju se baviti najvažnijim ograničenjima nekih prethodnih empirijskih studija o WBLE-u. Na primjer, istraživači bi trebali provesti procjenjivanje poput prethodnih testova za eksperimentalne i kontrolne skupine kako bi ispitali homogenost među skupinama, a ne samo pretpostavljati da su učenici u dvije skupine slični u pogledu prethodnih znanja iz matematike.

Glavna obrazovna ideja koja stoji iza dizajniranja WBLE-a je unaprijediti učeničko znanje u samostalnom traženju i otkrivanju kroz interakciju te više fleksibilnih i zanimljivih aktivnosti. Nažalost, većina dosadašnjih studija o razvoju WBLE-a nije analizirala potrebe učenika i stoga im nije pružila potporu tim aktivnostima. Buduće studije trebale bi istražiti i uključiti teorije učenja tijekom dizajna WBLE-a kako bi se zadovoljile potrebe učenika u području matematike.

Ograničenja

Glavno značajno ograničenje ove studije leži u tome što neki radovi koji su zadovoljavali kriterije za uključivanje u analizu možda nisu odabrani zbog ograničenja strategije pretraživanja. Radi uklanjanja tih ograničenja, autori su pregledali popis literature četrnaest uvrštenih radova kako bi utvrdili jesu li neki radovi propušteni u pretraživanju.

Sukob interesa

U ovom istraživanju nije bilo sukoba interesa.