

# ***Learning and teaching with Moodle-based E-learning environments, combining learning skills and content in the fields of Math and Science & Technology***

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## **Abstract**

E-Learning environments may contribute to the teaching and learning process if the integration is done within the framework of proper pedagogy. Building customized E-learning programs places high demands on design, programming skills, and time. An alternative to this can be deployment of courses within learning management systems. One such system that has been gradually gaining worldwide popularity is Moodle (Modular Object-Oriented Dynamic Learning Environment), a course management system for online learning. Moodle is "open source", allowing developers to tailor the system to individual needs. It also communicates extremely well with many web-based resources (Facebook, YouTube, Wikipedia, JClick, Hot Potatoes, etc.), allowing developers creativity and versatility. The design of Moodle is based on socio-constructivist pedagogy. This means its goal is to provide a set of tools that support an inquiry- and discovery-based approach to online learning. Furthermore, it purports to create an environment that allows for collaborative interaction among students as a standalone, or in addition to, conventional classroom instruction.

In this paper we present an overview of E-learning environments that we have implemented using the Moodle platform. These environments include interactive activities combining simulations, short videos, virtual experiments, games and more, in order to enhance interactive learning based on constructivism theory, and allow for students and teachers to learn skills for intelligent use of information and technological communication. The environments have been developed in partnership with teachers, as an enhancement to face-to-face teaching, for both curricular and extra-curricular learning. One main advantage of these environments is the freedom of teachers to add, change or use them as is, according to their needs; hence, the teachers are equal partners in the development. We will also show how these environments supply teachers with many interesting tools that can be used to improve the teaching– learning process, and the students to reinforce their abilities and knowledge, in a user friendly and stimulating manner engaging them in a fun, familiar and modern environment where much of their daily non-school activities take place.

## **Keywords**

LSS (learning Science Skills), constructivism, Course management system: Moodle platform, computer aided teaching E-learning, innovation, 21 century skills.

## **Introduction**

Nowadays, the computer is a significant part of the learner's daily life. It is, by now, inevitable that methods of teaching and learning should include E-learning components that are based on the computer environment and include proper preparation for the 21st century which requires a "new pedagogy" (Martin and Madigan, 2006). This new pedagogy, in the case of math science teaching and learning, employs:

- High-order thinking and learning skills.
- A constructivistic approach to science teaching and learning.
- Information, communication, and scientific literacy skills using digital means and advanced technologies.

Teaching in an E-Learning environment can contribute to the ability to teach, the ability to learn and most important to bridge between two main components in the classroom, the teacher and the learner. E-learning provides different environments for learners with dynamic, interactive, nonlinear access to a wide range of information (text, graphics, and animation e.g. Jonassen, 1996; Jacobson & Archodidou, 2000) as well as to self-directed learning in online communication (e-mail and forums).

E-learning is based on concepts such as independent learning, active learning, self-directed learning, problem-based education, simulations, and work-based learning (Martens, 2004). Most of these models are based on constructivism in which, according to Reiser (2001), learners become responsible for regulating their own learning process. Self-regulated learners are motivated, independent, and meta-cognitively active learners in their own learning (e.g., Duffy et al. 1993; Wolters 1998; Dalgarno 1998; Pierce & Jones 1998; Bastiaens & Martens 2000; Herrington & Oliver 2000).

All these instructional models hold that it is crucial to generate the learner's motivation (Martens, 2004). For this reason, many of the computer-based learning environments constructed present realistic problems, for example through a simulation or a game. Ryan and Deci (2000) distinguish between extrinsic motivation, which refers to the performance of an activity in order to attain some separable outcome, and intrinsic motivation, which refers to doing an activity for the inherent satisfaction of the activity itself. The effort or motivation on which constructivist e-learning environments try to rely is typically intrinsic motivation, with its associated features such as curiosity, deep level learning (aimed at understanding, not rote learning, Marton & Sa'ljö 1984), explorative behaviour, and self-regulation. Research has shown that intrinsically motivated students show more behaviour that can be described as explorative, self-regulated, aimed at deep level processing, and aimed at exploration and reflection (e.g., Ryan & Deci 2000; Boekaerts & Minnaert 2003). To increase the understanding of the relation between e-learning and motivational processes, it is necessary to gain a better understanding of learning materials that are developed to increase motivation (Martens, 2004).

Moodle allows the integration of a wide range of resources, from chats and forums to online booklets, a variety of questions, collections of problems and exercises, lecture notes; including any kind of text-based or Html-formatted documents, multimedia resources such as graphics, video or audio (e.g., MP3 files), PowerPoint, or Flash-based applications and Java applets (Goodwin-Jones, 2003). Moodle focuses on giving educators the best tools to manage and promote learning and allows teachers to organize, manage and deliver course materials. From a didactic point of view, the usage of multimedia tools to create attractive activities makes the learning process friendlier for students. As a consequence, these activities increase the interest of the students in their studies. Teachers can provide students with a large amount of resources that they cannot usually show in the classroom due to time constraints. Lesson tasks within Moodle can be linked to any resources that are uploaded to one's server or that are available on the Internet. The students' exploration of any of the content-based resources can be easily assessed by using any of the Moodle based evaluation and feedback tools. Moodle is quite powerful in content creation due to its built-in HTML editor. The degree of expertise required is essentially the same as for any word processor. More sophisticated presentations such as animations or text-specific feedback provisions need to be created using exterior multimedia authoring programs. These materials cannot be added in a hard copy booklet.

Moodle has pedagogical advantages since it was built in accordance with the teaching approach which emphasizes the construction of knowledge through active and interactive learning, and learning multi-sensory experience through multimedia. The design of Moodle is based on socio-constructivist pedagogy (Brandl, 2005). This means its goal is to provide a set of tools that support an inquiry and discovery-based approach to online learning. Furthermore, it purports to create an environment that allows for collaborative interaction among students as a standalone or in addition to conventional classroom instruction.

In the Davidson Institute of Science Education, a non-profit organization committed to the promotion and nurturing of science and math education in Israel, Moodle serves as the primary learning platform for online learning. Since Moodle was first implemented three years ago, over 100 online math and science courses have been developed with over 5000 school students participating in them annually. A few of the leading programs are Math and Science by Mail, MOT-TEC and Beaver. Since its implementation, we have adapted Moodle for K-12 science and math teaching and learning and added many features, making it a technologically and pedagogically advanced platform (Lachmy et al 2012).

In this paper we present two of our Moodle based courses, "Math-By-Mail" and MOT-TEC, which include an array of activities that combine higher-order skills with content in math, and science and technology for junior and middle school students. In addition, we report on a pioneering attempt to run and evaluate the MOT-TEC environment among teachers and students. We will demonstrate how the MOT-TEC environment provides the teacher with many interesting tools to improve the teaching – learning process, and encourages students to reinforce their abilities and knowledge, in a user friendly, stimulative manner.

## Development of E-learning courses on the Moodle platform

To design the environment we developed a model to guide us in the environment design as shown by Lachmy et al 2012. This model borrows from the TPACK model (Koehler, Mishra & Yahya, 2007), which is a framework designated for the three aspects of teacher knowledge and transforming them into design aspects, namely, Technology Content and Pedagogy as shown in Figure 1(Lachmy et al 2012). Technological design refers to the technological tools implemented in the environment and the manner they are adapted to specific requirements. Content design refers to the way the content is integrated with the technological tools and includes task design considerations. Pedagogical design refers to the interrelations of different users (such as teachers and students) and related factors (such as schools) with the environment.

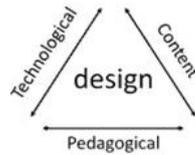


Figure 1: Design model (Lachmy et al 2012)

### Math by Mail (MBM)

"Math-by-Mail" (MBM) is one of the most prominent projects of the Davidson Institute of Science Education. The project was initiated 30 years ago targeting elementary school students who are high achievers in math, teaching them extracurricular math topics. The program was inaugurated as a correspondence project that connected students and mathematicians through a series of booklets sent to selected students through regular mail. In 2004, the program was transferred to the internet and correspondence was done via online forums. The booklets were available as PDF files which participants downloaded and then sent in via fax or mail. The Math-by-Mail staff reviewed the work done by the students and returned the marked booklets via regular mail. Lately, the program has undergone another major transformation by implementing the Moodle platform (see Figure 2).



Figure 2: Template of "Math by Mail" program in English and Arabic

The transformation was made possible because of the capabilities of Moodle: online wide range system support, 24 hours availability, a variety of network interfaces (Internet explorer, Google Chrome, Netscape, FireFox) and support in different languages. This change enabled enhanced communication with the projects staff at the Davidson Institute, and, more importantly, a completely interactive online booklet, submitted and reviewed online with no hardcopies necessary, in four languages (Hebrew, Arabic, English and Spanish). Close to 3000 participants worldwide registered to the program in 2012 from Israel, Canada, the US, Australia, Mexico, Brazil and Romania (Kotzer and Elran 2011).

Another important change was the feedback capability. Checking the booklets by students and then sending the marked booklets via regular mail takes a lot of time, hence, a lot of patience is required from participants. Students who participate in E-Learning environments often complain about the lack of feedback that is available in conventional classroom settings. In Moodle, almost all modules are designed to allow teachers or course participants to provide feedback in qualitative or quantitative form. For example, both the journal and assignment module gives the instructor the option to provide their comments in a feedback box. The assignment module, which is designed so that students can upload their assignments in any file format to the server, also allows the instructor to upload comments about the student's work in the form of text- or audio-based (e.g., MP3) files. Feedback can be teacher-restricted or made accessible to all participants in both forums. Closed questions in MBM are evaluated automatically using the instant feedback feature (Figure 3). If the booklets include also open questions, the instructor can review and comment on each assignment and even send a personal mail with feedback on the overall booklet. The feedback is given for each student at his or her pace.

The ability to monitor each individual student from amongst a huge number, providing them with the right feedback at the correct time is one of the most advantageous features of Moodle.



Figure 3: Instant Feedback

MBM offers talented and curious children (grades 3-9) extra-curricular activities in recreational mathematics that develop their creative thinking and logic. Activities include four in-depth topics that are spread over the school-year and, once uploaded, can be accessed anytime online, to be done at home or at school. The in-depth topics are exciting, challenging and, most importantly, fun because it is based on the ideal combination of content, pedagogy and technology. The Moodle platform enables this by allowing integration of a wide range of resources; online booklets, a variety of questions, collections of problems and exercises, lecture notes; including any kind of text-based or Html-formatted documents, multimedia resources such as graphics, video or audio (e.g., MP3 files), PowerPoint, or Flash-based applications and Java applets (Goodwin-Jones, 2003) as in Figure 4 (applet from the booklet “Conway’s game of life” and applet from the booklet “Graphs and Mazes”).



Figure 4: Applets in Booklets

In addition to the in depth topics, participants receive a weekly newsletter with additional riddles and challenges, the Mathletter. The Mathletter challenges and many other topics are discussed in the weekly chat with the MBM team - researchers at the Weizmann Institute of Science (see Figure 5). The chat is a unique opportunity for participants to have a conversation, share their ideas and get feedback from researchers in one of the world’s leading science research institutions



Figure 5: The Mathletter and Chat

The Forums and especially the weekly chats eased the interaction with students in real-time and facilitated interaction on an even level allowing students to share their opinions and suggestions; as a learning community, it allowed students to share and discuss their knowledge and difficulties, and also help each other. We noticed that at the beginning of the school year there were few students who participated in the chat, over time the number of students who participated increased and more importantly there was an increase in the number of active students who asked questions and contributed to the discussion (Figure 4).

There are two options for participation in the project: as an independent participant or as part of a class. In the latter case, in addition to the staff, there is a math teacher that follows the students’ activities. The Moodle as a learning management system allows the teachers to view the answers, see the dialogue in the forums and chats

and this enables teachers to understand in which part of their course students are experiencing the most difficulties and which parts are easy.

We note that the number of students using internet courses and booklets (such as "Math by Mail"), preferring them to hard copy assignments and booklets, increases over time, which suggest that students have interest in such E-Learning techniques. Last year when we implemented the program in Moodle only 50% of the participants used the internet course and booklets, while this year 90% are using the online booklets. Next school year we intend the program to be a fully online program without any hardcopy booklets. Overall, the perception of students of web-based homework testing was very positive. We implemented a similar Moodle course in Science, "Science by mail", with similar results.

*Evaluating MBM environment: MBM course of 2010-2011*

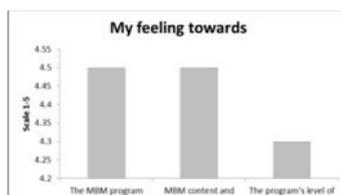
The evaluation was a short-term assessment conducted at the end of the period in July 2011. It was carried out in the course of the end of year participant conferences ("treasure hunts"). During the conference:

- 1 Questionnaires were distributed among the children (119 questionnaires were received from MBM participants).
- 2 16 parents were interviewed.
- 3 17 teachers were interviewed.
- 4 Focus groups were set up and conversations with children were conducted

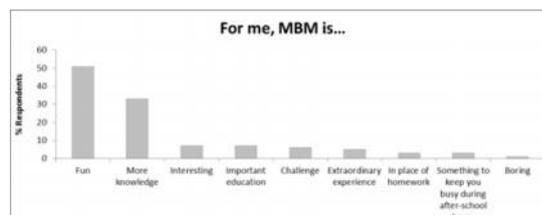
Questionnaires were distributed to all the children we were able to reach, and most of them filled in and returned the questionnaires. Parents and teachers were selected at random – based on accessibility and the time we had available to us. It should be noted that the teachers and parents interviewed were among those who came to the conference and thus constitute a sample of parents who are involved in the program in some way or another. The findings derived from student questionnaires and from the interviews with parents and teachers.

Student, parent and teacher satisfaction indicate a high level of satisfaction. The students liked the program and its contents to a very large extent. They liked the level of organization to a large extent. Children’s satisfaction with the program found expression in their almost universal willingness to recommend the program to others and their almost universal willingness to remain enrolled in the program. Parents and teachers felt that the program is an enriching and innovative one and has a good reputation in general. Many of the teachers have been acquainted with the program for some years and have chosen to continue their involvement with it because of its quality. Teachers commented that the program provides a response to the needs of a unique group of children as shown in Figure 6a.

The essence of the program as perceived by the children is shown in Figure 6b. The children experienced the program from two almost equal perspectives - they perceived it both as fun, and as educational and enriching - a combination of fun, information and interest in both programs. It seems that the program was able to combine a fun experience with the gaining of interesting knowledge. 6th grade MBM students said: "It is challenging because it is hard. It is not something mundane like 15 times 16... there are questions of a different sort-questions that are, let’s say, surprising". Other children emphasized the innovative aspects of MBM and that the learning was meaningful rather than technical: "I learned about things that I did not even know existed. Had you asked me who Fibonacci was, I would have said he was an artist, I had no idea what operators were". "If someone were to just tell me to write up a list of Fibonacci numbers, I suppose I might not remember how to do that, but if I were to get the first four numbers in the series and told to continue the series, I'd remember what to do..."



**Figure 6a: Average responses to the question – 'Here are a number of faces. On each row, select the face that best describes your feeling towards each of the following items'. Scale of 1-5.**



**Figure 6b: Distribution of student responses to an open question: "For me, MBM is..." % of students indicating each of the responses**

### *Implementation of Science by Mail (SBM)*

“Science by Mail” (SBM) offers school-children in grades 3 to 9 a glimpse of the cutting edge research that is taking place at one of the world’s leading research institute, The Weizmann Institute of Science. The program too, includes four in-depth topics, each from a different scientific field and based on the research conducted in a different laboratory at the Weizmann Institute. The in-depth topics are spread over the school-year and once the activities are uploaded, they can be accessed online anytime, at home or at school. The activities are based on simple experiments that can be performed at home, which lead even young participants to a much better understanding of complicated ideas and, equally important, to the process of scientific research and scientific thought. As in “MBM”, in addition to the in- depth topics, participants receive a weekly newsletter with additional experiments, riddles and challenges. The newsletter challenges and experiments are discussed and results compared in the weekly chat with the Science by Mail team, researchers at the Weizmann Institute of Science. The chat is a unique opportunity for participants to have a conversation, share their ideas and get feedback directly from researchers of science.

Another program we implemented in Moodle platform is “Beaver”. The program is engaged in solving challenging problems of interesting and intriguing in a variety of topics in computers. The purpose of the program is to create a foundation of basic understanding of computer science, development of personal abilities, better ability in solving problems and strategies selection. The program encourages computational thinking and creative and intelligent use of information technology. In the Beaver program a team of computer science teachers from middle and high school write the questions for the competitions. The participation in this program can be also as an independent participant or as a member of a class.

The “Beaver” program is part of an international contest of informatics and computer fluency established by Prof. Valentina Dagiene (<http://www.bebbras.org/en/welcome>). The first Bebras contest was organized in Lithuania in 2004. Today there are students from 17 countries participating and another 6 countries, within them Israel, that are planning to participate. Last year we had two internal competitions with 800 participants all done in Moodle platform (see Figure 7). The first competition was a week long and was held in different schools. The second stage of the competition was at the Davidson Institute of Science Education. Next year we intent to encourage the participants in this program by adding a competition between schools and by adding practicing lessons within school classes supervised by computer –science teachers.



**Figure 7: Beaver program**

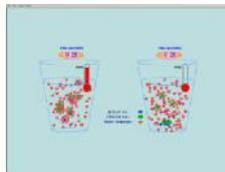
### **MOT-TEC**

MOT-TEC includes an array of activities that combine higher-order skills with content in science and technology to middle school, emphasizing learning and thinking skills such as asking questions and exploration. The MOT-TEC environment has been developed together with teachers as an enhancement of face-to-face teaching. The content of the units were chosen by a team of science teachers (content which was difficult to teach) and various activities were built in collaboration with them. The uniqueness of these environments is the freedom of teachers who teach with them to add, change or use them as is, according to their needs. Additionally, we developed and fitted tools according to the teachers’ needs for use in MOT -TEC based on Moodle. MOT-TEC consists of the following components:

- Visuals that combine short films, simulations, animations, and educational games related to the selected science topics.
- Interactive learning activities that support attaining high-order thinking and learning skills combined with scientific content.
- Feedback facilities that enable automated response regarding closed questions as well as teacher’s reactions to open-ended tasks.
- Learning management system options that facilitate assessment of learning through questionnaires, statistics, and reports.
- Flexibility for teachers: they can adapt the activities to their needs or the needs of their students and according to class technological conditions.

The first unit we developed in MOT-TEC emphasizes learning and thinking skills such as asking questions and exploration. These skills were incorporated on the subject of “water” in various aspects: water as a solvent with respect to macroscopic and microscopic material, detection of water by its properties, different water sources and the water cycle in nature (these aspects are part of the science and technology curriculum in junior high school). The students visually explore and experience water solubility phenomena of materials such as salt (NaCl), sand, and oil, as well as, their macroscopic explanations (in the case of NaCl). The computerized activities are structured, yet flexible, and lead to a variety of investigation-oriented activities through science films, games, and simulations as seen in Figure 8a. The teacher acts as a mediator and helps the students navigate according to their capabilities (Frailich et al 2011).

MOT-TEC combines computerized applications, such as, simulations, images, videos and games within learning tasks to enhance the understanding of the studied subject in an enjoyable and stimulating manner through inquiry- and discovery-based learning. We fitted the quiz module so that it is shown in the same window as the simulation (Figure 8b). The learning task appears at the top, and the simulation at the bottom. The student can change the sizes of each part according to their needs. The student can advance the task at his/her own pace and answer the questions according to the various conditions and results in the simulation.



**Figure 8a: A dynamic presentation of the particulate model of the dissolving process of Sodium chloride in water (Frailich et al 2011)**



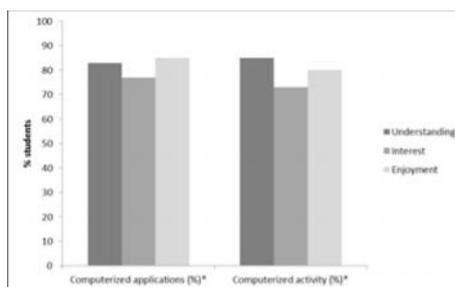
**Figure 8b: Fitted Quiz module in the first unit: exploration skills incorporated within the subject of “water”**

*Pilot evaluating MOT-TEC environment: first unit - exploration skills incorporated on the subject of “water”*

As shown by Frailich et al. 2011 a pilot program was run with teachers and students who used MOT-TEC as part of learning this topic in their material sciences lessons. The topic "solutions and solubility of materials" is usually studied in the last semester of 7th grade or at the beginning of 8th grade. We administered questionnaires to students who used our environment (3 classes, N=57). The questionnaires included Likert-type items in evaluation scale of 1-4 (1- Not at all, 2 – Slightly, 3 – Much, 4 – Very much) as well as open-ended questions about the E-learning environment, MOT-TEC. (Answers to open-ended questions were tested and classified by category using Shkedi 2003). The purpose was to examine students’ attitudes toward the different dimensions of learning in the MOT-TEC environment: The intention was to find out, specifically and individually, the students’ attitudes toward various interactive simulations (similar to their favourite video games) and attitudes towards learning tasks that required work practice, thinking, and application of skills and content that were learned.

The results of the students that responded to open feedback which students were asked to comment on MOT-TEC (82%) showed that most of the students (89%) expressed very positive attitudes towards the various dimensions of MOT-TEC (Frailich et al. 2011).

The results from the closed questions indicated that both the computerized applications (such as simulations) and the adjusted tasks contributed equally to students understanding, interest and enjoyment as shown in Figure 9.



**Figure 9: Students' responses regarding their levels of interest, understanding, and enjoyment of learning with MOT-TEC \*shown combined percentage of levels 3 (much) and 4 (very much) in a 1-4 Likert-type questionnaire**

#### *Implementation of MOT-TEC*

Last year we developed a second unit in MOT-TEC (based on the first unit template in Moodle PLATFORM) that combines the skills of scientific explanation and argument with the content in physics - interactions and forces and content in chemistry, material properties and particulate model of matter as in Figure 1.



**Figure 10: Fitted Quiz module in the second unit: explanation and argument skills incorporated within content in physics and chemistry**

Currently MOT-TEC units based on Moodle platform are embedded in 30 schools. Teachers reported that the MOT-TEC units enabled them to watch students' performance online and to intervene and support their learning processes accordingly. They also indicated that their students were actively engaged in the visual computerized activities and showed a high level of interest. The level of students' understanding of the scientific contents was higher than before.

The MOT-TEC units enrich teacher's repertoires of pedagogical strategies, consequently leading to the design of new and improved pedagogies. Teachers indicated that they wanted to implement similar applications in the future.

MOT-TEC has a unique approach in combining teaching, training and implementing of learning skills with content in science and technology. These reports have encouraged us to expand our design efforts covering a variety of contents and skills, where the computerized environment MOT-TEC stands as a framework for further developing for the following reasons:

- Teachers have need and desire for computerized environment such as MOT-TEC for teaching and learning because of the complication in developing due to lack of resources such as time and money.
- It is important to address the diversity of students, to challenge outstanding students and meanwhile provide good learning skills and knowledge to students with difficulties.
- Responding to existing needs in e-learning for short structured and targeted computerized environments that integrates contents and high-order thinking and learning skills.
- Lack of computerized environments that combine applets (as graphics, animation, audio, and video)
- with activities which enable a better understanding and learning of complex, abstract and molecular content.

We are continuing to develop additional units that combine various skills and content in science, while addressing and responding to student diversity. Additionally we conduct training for teachers on MOT- TEC units including pedagogy of teaching in a computerized environment. Some of the training courses are done in a completely E-learning environment that also was developed on the Moodle platform. The courses were successful and we intend to improve and continue them.

## Summary and Conclusion

MBM and MOT-TEC are both models of E-Learning environments developed on the Moodle platform, which is one of the major points of similarity. Other points of similarity are enabling a teaching –learning experience by promoting curiosity, interest, and understanding of the subject.

Development of MBM and MOT-TEC E-Learning environments on Moodle platform has led us to several important principles that need to be considered before developing additional environments:

- There is a huge need in E-learning environments based on curriculum content. The teachers do not have time to build them by themselves.
- It is important to base the environments according to teacher’s needs, content based or technology based.
- The environments should address the student diversity
- There should be emphasis on design and simplicity of the environment enabling easy and enjoyable use that leads to understanding and development of interest in subjects that are considered hard to learn.

Comparing the essence of the two models, we noticed the following differences:

- 1 Educational goals - MBM program is an extracurricular program. Its goals are developing math thinking skills, curiosity and interest in the field of math. The program is not integrated into the curricular school learning. This is its uniqueness and the source of its success. Success in the grades in school is not a goal of the program. MOT-TEC, on the other hand, is part of the curricular program as an enhancement to face-to-face teaching and the opportunity to supply teachers with many interesting tools that can be used to improve the teaching– learning process and there is an importance for grades.
- 2 Different audiences – MBM focuses on elementary and junior high school students where MOT-TEC focuses mainly on junior high school students
- 3 Size of the different community - The purpose of MBM is to create an international community of learning science and mathematics in popular areas. MOT-TEC communities consist of a teacher and students in schools in Israel who are learning certain curricular topics.

Overall, the perception of students of web-based homework testing was very positive. We plan to implement Moodle courses in additional subjects such as curricular chemistry and biology in order to improve and homogenize the basic knowledge of the students. We attend expanding the MBM by enabling communication between different schools in different countries and trying to develop a math learning communities .We intend to guide teachers using existing E-Learning environments and building independently new Moodle E-Learning environments for the benefit of their classroom learning.

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