Assessment and Evaluation

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This section focuses on new trends in student, teacher, and program assessment and evaluation, and aims to communicate the latest educational reform efforts.

Reasoning, Problem-solving and Reflections: Participating WISE Project in Israel

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Abstract

Our aim was to promote the expression of high-order thinking skills, such as argumentation, problem-solving, and reflective thinking, of students working on a Web-Based Inquiry Science Environment (WISE) project. Participants were ninth graders in three schools in Israel. We used portfolios, open response questionnaires, and interviews with target students. Our findings indicate that the students expressed high-order thinking skills, while engaged in learning about malaria. The students discussed and shared ideas in class and on the web, and eventually met for a conference.

Key words: WISE, malaria, argumentation, reflective thinking, problem solving.

INTRODUCTION

The Israeli Science National Curriculum for the junior high school (1996) and other curriculum initiatives (AAAS, 1993; Bybee, 1993; DeBoer, 2000; Solomon, 1993) call for the development of cognitive as well as communication skills. The students and future citizens are expected to take part in the technology-based society. Unfamiliar-complex environments challenge the traditional curriculum-based science teaching. This reality led to various curricular developments that suggested innovative teaching-learning methods, which are student-centered, technology-based, and open-ended. Approaches, such as Science-Technology-Society (STS) and Project-Based Science (PBS) aim at developing the students' scientific thinking (Chen & Stroup, 1993; Krajcik, Czerniak & Berger, 2002; Pedretti, 1999). Relevant topics that focus on local as well as global issues are recommended as part of curricular reform (Holbrook, 2001). Interactive learning environments allow students to incorporate previous knowledge with new information by posing questions, weighing possible answers and solutions, and reflecting upon them, and by discussing and debating with classmates or students elsewhere. These environments are known as "Knowledge Integration Environments" (KIE) (Bell & Linn, 2000; Linn & Slotta, 2000). KIE incorporate Web-base environments in the curriculum, and encourage the students to investigate authentic and relevant problems, such as genetic engineering, global warming, Aids, and so forth.

Developing high-order thinking skills (Resnick, 1987) that require complex cognitive processes have high priority in developing inquiry-based learning materials (Dori, Tal & Tsaushu, 2003; Ennis, 1996; Minstrell & Van Zee, 1999; Zohar, Weinberger & Tamir, 1994; Zohar & Nemet, 2002). Integrating skills, such as critically analyzing information, problem solving, argumentation, and reflective thinking, and incorporating those skills into relevant contents are highly supported (Coleman & Penuel, 2000; Linn, 1998; Resnick, 1987; Zohar et al., 1994).

Resnick (1987) found it hard to differentiate between the various high-order thinking skills. These skills are overlapping and integrative by their nature. Quite often they include a reflective aspect. Reflective skills encourage weighing possible consequences on the way towards solving a problem. They require an association of ideas and some kind of order in the sequence of ideas (Dewey, 1933; Ennis, 1996; Hogan, Nastasi, & Pressley, 2000).

In this study, we did not aim to separate between the different thinking skills. Rather, we accept their meta-cognitive and synergetic nature. In order to apply a learning environment that involves higher-order thinking and allows group and class discussions, we chose the Web-based Inquiry Science Environment (WISE) (Linn & Slotta, 2000; Linn, Clark & Slotta, 2003). In addition to WISE activities, we encouraged the teachers to add their self-designed learning materials and assessments to support their students' thinking.

The Web-based Inquiry Science Environment (WISE)

WISE is a free on-line science-learning environment for students in Grades 4-12 (Linn & Slotta, 2000; Linn et al., 2003). In WISE, students work on inquiry projects on topics, such as genetically modified foods, earthquake prediction, and malaria. Students use the World Wide Web in order to learn about and respond to contemporary scientific controversies through designing, debating, and critiquing solutions (Linn, Clark, & Slotta, 2003). They do most WISE activities on a computer, while the software guides them through "evidence web pages" that provide content, "notes," and "hints" that encourage students to reflect, and other tools for discussion with classmates and for self-assessment. All these elements appear on an inquiry map that communicates the patterns that students follow to investigate a topic. The map enables students to work individually and independently on their projects rather than constantly asking the teacher for guidance on what to do next.

Students work on WISE projects in pairs. Close collaboration encourages them to share their ideas and support each other. Meanwhile, the teacher has the freedom to circulate in the room, go over each pair's progress, and discuss ideas. The teacher frequently regroups the class to discuss their findings and questions.

WISE encourages a process of collaborating with others both locally and around the world. Currently, there are 25 English language projects in the WISE library, which can be found at "http://wise.berkeley.edu/pages/about.php" http://wise.berkeley.edu/pages/about.php. Other projects were developed by Norwegian, Dutch, and German design teams. In this study, the Israeli junior high school students used an English language project.

In a pilot study, we employed the "Deformed Frogs Mystery" project. The main conclusion from that study was that a more socially relevant topic should be selected and addressed. The reason for choosing the Malaria Project by the participating teachers was twofold. Malaria affected the history of settlement in Israel at the end of the 19th century and the early 20th century. Moreover, during the last ten years, Ethiopian Jews, who immigrated to the country, commonly carry malaria parasites. These facts make the topic not only important in general, but also locally relevant. In the Malaria Project, students learn about the biology of the disease, where it is prevalent, and how it spreads, and they compare three different strategies for controlling the spread of malaria.

Purpose of the Study

WISE introduces assignments that require various levels of thinking skills. High-order thinking skills are applied and required in a gradual manner, and WISE projects enable the teacher to design a preferred learning environment that enhances thinking, collaboration, and class discourse. Our research question was whether and in what ways participating in WISE project and using various assessment methods enhance thinking skills, such as argumentation, problem solving, and reflective thinking.

METHODOLOGY

Participants and settings

Our 159 ninth-grade students came from three

schools and represented three different groups of Israeli students. The main Hebrew speaking population (school 2), the new immigrants from the former Soviet Union, who study in Hebrew but speak Russian at home (school 1), and the Arabic students, who study mainly in Arabic and speak Arabic at home (school 3).

In order to implement the project in three schools, the teachers met for two planning sessions, in which they selected the project, got to know WISE, practiced the work with the website, and suggested and discussed additional and relevant learning materials. They decided to have portfolios, and discussed the content and the structure of them.

The participating students worked with the English language version of WISE, but they wrote their responses and communicated in Hebrew. The Arabic-speaking students read the materials in English, wrote their responses mostly in Hebrew, and discussed their ideas in Arabic. The overall scope of the project was similar in the three schools, and differed mainly because of different vacation schedule. The students worked mainly in pairs in the computer lab. At the end of the project, the teachers arranged a wrap up activity, which was conducted as a scientific conference, in which the students presented posters and conducted panel discussions.

Instruments

The data was collected using pre/post open-ended, case-based questionnaires for analyzing students' progress in their argumentation skills. Portfolios were used for analyzing argumentation, reflective thinking, and problem-solving skills. We videotaped and transcribed the teachers' meeting prior to the project and the final "Malaria Conference."

For the questionnaires, we chose other cases of public health issues, which are controversial and publicly discussed. The pre-stage questionnaire presented the issue of small pox virus eradication, and the post-stage questionnaire focused on protecting against the West-Nile Fever virus.

In each questionnaire, the students were requested to explain the problem, express scientific understanding, and address a controversy. In the final assignment in each questionnaire, the students were requested to provide their own opinion supported by evidence.

The main reason for having portfolios was the students' language limitation. The students were able to read the information in English, but preferred writing their responses in Hebrew and not using the "notes" function of WISE. In addition, the teachers recommended adding their own designed assignments. Therefore, the portfolios consisted of WISE assignments, which were written in Hebrew, and other assignments that the teachers added, such as allocating and reflecting on relevant newspaper articles, students' suggestions for class discussions, representations of the life cycle of the parasite, and so forth. WISE assignments, which were collected in the portfolios, included four assignments in which the students were required to provide their point of view. In the first assignment, which was part of WISE (activity 1), the students were asked to express their opinion on *why so many children suffer from malaria*. The other three assignments, in which the students had to provide their justified point of view, were part of the last WISE activity (activity 3). They were asked for their opinion on using DDT, about developing and using vaccines and about the use of bed-nets.

In order to gather more information, we observed the different classes throughout the project, and interviewed target students from all the schools. The teachers' professional development meeting prior to the project and the final conference were videotaped.

Data Analysis

In another analysis (Tall & Hochberg, 2003), we applied an instrument suggested by Hogan and colleagues (2000) to assess *Argumentation skills*. The instrument suggests six refined categories for assessing students' arguments, such as elaboration, justification, coherence, and synthesis. Although we documented substantial progress in most of the categories, we applied Zohar and Nemet's (2002) criteria for reasoning complexity, which is more simple and applicable for junior high school students, who are required to be

involved in argumentation in science for the first time. According to this framework, each student's response was analyzed for the number of justifications. The score range was 0-2 for each aspect of the argument. Thus, the score for the number of justifications was 0 for a conclusion with no justification, 1 for a conclusion and one valid justification, and 2 for a conclusion and two or more valid justifications. The score for the structure of the justification was 0 for no valid justification, 1 for a simple structure consisting of a conclusion supported by at least one reason, and 2 for a composite structure in which the justification was supported by another reason, usually explaining why the first reason should be accepted. We analyzed both the questionnaires and the written responses in the portfolio using this instrument. Following Zohar and Nemet (2002), we assessed the extent to which the students incorporated correct scientific knowledge in their claims on a four-level scale: 1) no scientific knowledge is considered, 2) incorrect consideration of knowledge, 3) consideration of non-specific scientific knowledge, and 4) correct consideration of scientific knowledge. Incorporating correct and relevant knowledge indicates that the students learn new content and make use of this knowledge to support their arguments. We assessed knowledge incorporation only in the portfolios, because the case study-based questionnaires provided limited information and were not based on previously learned content.

Our assertion was that any progress in *reflective thinking* would be expressed in the way the students incorporated suggestions, ideas, hypotheses, and explanations. Based on Dewey (1933), who stated that "reflective thinking is a process of detecting relations" (p. 77), and on Vygotsky (1978), who recommended to incorporate feelings in the process of learning, we searched for statements that incorporated students' feeling and personal views about the discussed contents.

Problem solving (PS) is usually defined as an organized sequence of activities that leads to a goal – the solution of a problem. We adapted criteria suggested by Oliver and Hannafin (2000), Wai and Hirakawa (2001), and Zoller (1991), and came up with a sequence of four stages for analyzing PS ability: 1) identifying the problem; 2) providing a coherent description of the problem; 3) evaluating alternatives; and 4) suggesting a rational/valid solution. Although the students evaluated an alternative or suggested a solution, which are advanced stages in PS; their response might have been either shallow or deep. Therefore, we identified two levels of complexity for PS stages. At the low level, the student provided a partial description, incorrect information, irrational, or unpractical solution. At the high level, the student provided a correct and supported description of the problem; formulated a creative or innovative solution, or synthesized existing solutions. For example a low level response in stage 3 (evaluating alternatives) was

> "Vaccines are the best approach. They prevent 95% of the population from getting malaria."

The student evaluated one of the solutions, but the information regarding the vaccine was not correct. An example for a high level response for this stage indicates that the student use thorough information, and uses it to support his/her claim.

> "DDT is not a good solution for malaria, even if it effectively kills the mosquitoes. The reason is because DDT is not specific to these mosquitoes, and it remains in the food chain. Mosquitoes get immune, and we are going to have the same problem in a few years from now."

FINDINGS

According to the students' reflection sheets and the interviews, they managed working with the English language website. The distribution of the 10% of the students, who reported language difficulties, was even among the schools. The teachers and the students reported that the portfolios not only served as a solution for the language issue, but they also allowed the students to go over their work and revise it. The teachers assumed that even if the website allows revising the students' work, they would not do it the way they revise a written-work paper.

Argumentation

The arguments the students provided in the post-stage questionnaires were much longer than in the

pre-stage. Unlike 1-2 sentence response in the pre-test, most of the answers in the post-test consisted of 3 and more sentences, and included more aspects of the malaria problem. Table 1 presents some examples and the total progress in incorporating different aspects in the students' arguments. Table 2 presents some examples for number and structure of students' arguments in the tests.

Figure 1 presents the progress in the number and the structure of the justifications in the case study questionnaire. Most of the students were capable of suggesting at least one reason and based their conclusion on a counter-argument.

In the post-tests, both the number and the structure of the justifications improved substantially. The students, who just finished learning about malaria, could implement their knowledge, while discussing the similar case of West Nile Fever virus.

Table 1
The Number of Aspects Incorporated by the Students in Their Arguments in the Pre/Post Questionnaires

Post		Pre	
More than one aspect	One aspect	More than one aspect	One aspect
We should vaccinate the people. Still, we need to close windows or nets, and to use personal rejecting-mosquito substances, and to teach people about the way these mosquitoes look like	We ought to develop a vaccine	I'd invite the best researchers and then use the medicine they develop	The *virus* must be eradicated by any cost – people are suffering
Aspects: medicine, behavior, chemistry, education	*Aspects: medicine*	*Aspects: science, medicine*	*Aspects: biology*
People should be examined frequently. We have to know about the distribution pattern and maybe fight the parasite by infecting the mosquitoes with something		People should avoid living by the water and learn how to defend themselves	Pesticides should be used against the mosquitoes
Aspects: medicine, demography-geography, biology		*Aspects: behavior, education*	*Aspects: chemistry*
84%	16%	19%	81%

Table 2
The Number and Structure of Students' Justifications in the Tests

	Pretest	Posttest
1	I'd destroy the small pox virus because we cannot leave it alive hoping that some day people would discover something	All the sickness phenomena result from infection of this virus. Therefore' I'd eradicate the mosquitoes, spray with something like DDT, develop a useful vaccine, maybe something which could be inherited. Above all, I'd limit transfer of animals from Africa to the West.
	1 simple justification	*2 justifications complex structure*
2	I'd decide to eradicate the virus because people's life is more important. The value of life is above all	DDT presents a dilemma because it is poisonous and causes unwanted effects to the environment and harm "friendly insects". However, is countries where they used DDT there was a decrease is such illnesses. Therefore, I'd continue using DDT for its affectivity but keep searching for another solution.
	1 complex justification	*2 justifications complex structure*

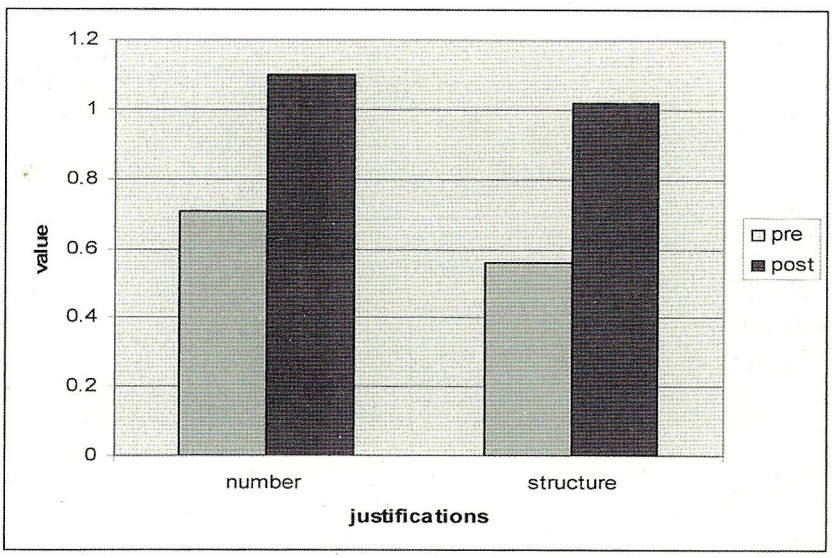

Figure 1.: Number and Structure of Justifications in the Pre/post Questionnaires

The analysis of the arguments in the four WISE argumentation activities, which were presented in the portfolios, indicated that in 96% of the portfolios, the students included counter-arguments and rebuttals, in order to justify their own point of view. In many cases, they did not present one final conclusion, and explained why they found it hard to decide. We found a substantial difference between the first argumentation-event at the beginning of the project and the last events, expressed mainly by incorporating more arguments in the composite structure.

In addition, we assessed the extent in which the students considered scientific knowledge in their responses. We analyzed knowledge incorporation only in the portfolios, because the tests did not include much content that could be tested. Table 3 presents the four categories for knowledge consideration, based on Zohar and Nemet (2002), and examples of students' statements.

As mentioned earlier, the students had four WISE activities, in which they were requested to provide arguments. We found that in the first argumentation event (why do you think so many children get malaria?), the students considered scientific knowledge in 63% of the responses, whereas at the fourth event (opinion about using bed-nets), 96% of the responses were based on knowledge consideration, and, in most cases, the knowledge was specific and correct. While at the first event, about 40% of the responses were from the first and second categories, meaning no use, or incorrect use of knowledge, at events 3 and 4, we found no responses of the first category, and only 4% were of the second category (incorrect consideration of knowledge). This means that the students used the knowledge they acquired as evidence in order to support their arguments.

Reflective Thinking

Throughout the learning process, the students expressed reflective thinking in class discussions, in private discussions with the teachers and the researchers, and in the written work presented in their portfolios. In the interviews and in informal talks, many students stated that this was their first experience of expressing their thoughts and feelings in science class. A few students even referred to their experience in social studies and emphasized the resemblance they found. Overall, 488 reflective responses were expressed in the portfolios. Initially, we identified three dimensions for reflective thinking which were 1) affective, in

Table 3
Students' Consideration of Scientific knowledge in the Portfolios

	Category	Example
1	No scientific knowledge is considered	The reason why so many kids get malaria is because they did not take quinine
2	Incorrect consideration of scientific knowledge	I think that the disease is genetic. Children get it if their parents have it
3	Consideration of non-specific scientific knowledge	The immune system of the children is not fully developed, they play in all these places which are not clean, and maybe there are mosquitoes there as well
4	Correct consideration of specific scientific knowledge	The children have greater chance to be sick because their immune system is still weak and undeveloped, and because of pure hygiene. They play in places of standing water where the mosquitoes are common

which the students write about their feelings; 2) social, in which the students respond about the social aspects of the problem; and 3) cognitive, in which the students identify a social need, criticize, and suggest solutions. Further analysis yielded an intermediate dimension; the affective social, in which the students expressed both their own feelings and awareness to other people's difficulties, and added another aspect to the cognitive dimension; the cognitive-social, in which the students expressed a desire to find a culture-related solution, and suggested innovative ideas.

Table 4 presents some examples for reflective responses according to the different dimensions,

Table 4
Dimension and Examples of Reflective Thinking

Dimension	Explanation	Example
1. Affective	Person's own feelings, individual impression from facts, and reflecting about previous knowledge	- A terrible disease that we hardly knew about - Thinking about Kofy and all the other sick kids and the millions who died make me anxious. I immediately thought about my chances to get sick and what could happen then.
2. Affective-social	Person's awareness and empathy towards others' feelings and difficulties	- Young kids are less aware and less caution - It was shocking to learn what happen to sick people. They seem in great pain.
3. Social	Acknowledging an important social process	It is terrible that no one cares about countries with such death ratio. These are countries with no financial resources and undeveloped science.
4. Cognitive	Identifying a certain social need, criticizing and/or suggesting a solution	- A complex parasite such as malaria, even if a preventive treatment is found, it would take long time, it would be expensive and would not be accessible to all. - Stopping the disease demands huge resources that developing countries do not have
5. Cognitive-social	Curiosity, search for a solution and providing innovative and unique ideas	- I choose not to be selfish and stop using DDT, and instead, find another solution for the malaria problem that will not harm any living species (was written in English) - In our country, where malaria is not a problem, increasing the public awareness is enough…if people would be aware, they would not pass next to standing water, without doing anything. If they'd be involved, the chance for malaria would be very small.

and Figure 2 presents the distribution of the five dimensions for reflection in all the statements we collected in the portfolios.

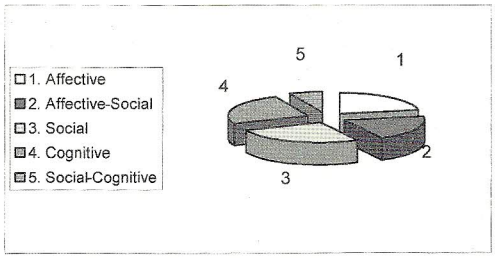

Figure 2. Distribution of Reflective Thinking

It is apparent that the expression of reflective thinking is similar in the first four dimensions: affective, affective-social, social, and cognitive. We found fewer expressions in the social-cognitive dimension. The last example, in Table 3, indicates that the student was able to transfer the knowledge he/she gained and went beyond the "malaria in Africa" case to discuss the issue of standing water in the local Israeli context. Furthermore, the student emphasized awareness and involvement of the public. We assume that the relative short scope of the project limited a greater use of this type of reflections compared with the other dimensions.

Towards the end of the project, the students used more correct knowledge in their statements, and expressed more cognitive and social-cognitive aspects. Table 5 presents some examples of one student's statements in different stages of the project. This example represents a large target group of students who were identified by the teachers as average performing students, who completed all the tasks. The numbers in parentheses indicate the total number of expressions in each dimension.

In addition to the data included in the portfolios, we documented reflective responses and statements in class discussions. At the beginning of the project, most of the expressions were at the affective and social-affective dimensions, whereas towards the end, there were much more social and cognitive reflective expressions.

Table 6 presents examples for students' reflective expressions that were collected by the different instruments, during the project.

Although we expected that some students would mention stories they heard in the elementary school, about the first settlers in the country, and how they suffered from malaria, which was quite common at that time, no one addressed these stories.

Problem solving

The analysis unit for analyzing PS was the whole portfolio. We focused mainly on the last assignment in WISE (activity 3) "What do you think the best approach is to controlling Malaria?"

Table 7 presents the stages for problem solving as were identified in the students' portfolios' according to the two levels of complexity.

Figure 3 presents the summary of the students' PS, as were presented in the portfolios. The numbers on the vertical-axis represent the total number of portfolios in each category. The data is arranged according to the two complexity levels.

Figure 3 shows that many more students presented the higher complexity solutions, which means that they were able to suggest new ideas or synthesize a few existing ideas. The students presented the highest skills in describing the problem coherently and in evaluating provided solutions, where the vast majority provided complex responses. It was evident that the students provided comprehensive responses that described the malaria problem coherently. We assume that this is due to an assignment that the teachers added, which served as a scaffold for this stage. The teachers asked the students to describe the life cycle of the parasite in details and add highlighted relevant drawings.

Evaluating given suggestions was an easier task than suggesting new ideas or synthesizing a few ideas to come up with an original solution, which explains the difference between the last two categories. With regards to this issue, the teachers criticized WISE's well-structured activities. They suggested that less structured activities might lead to higher PS capabilities, and a few students stated that "the answers were already there, so I did not have to bother too much to come up with my own solutions."

Table 5
Examples of One Student's Reflective Statements at the Beginning and Towards the End of the Project

Dimension	Stage 1 (total number of reflective statements)	Stage 2 (total number of reflective statements)
Affective	• I live, eat, travel and go to school, not knowing that at this moment, a young child, who experienced nothing in his life, dies from malaria (1)	(0)
Affective social	• Malaria is one of the major public health problems in the world. Millions are dying every year • I was impressed by the fact that most of the victims are children (3)	
Social	• A sick person could arrive from Africa and if we have the mosquitoes here, no one is protected • We need to fully know the disease, from both medical and public aspects (3)	• We have to deal with effective and more secure means for prevention • I heard about malaria before, but did not understand its distribution and danger to huge population (5)
Cognitive	(0)	• DDT is terribly damaging the environment. If we destroy the world now, what will happen to future generations? • Vaccines are great solution and even poor countries should invest in buying them • Scientists are concerned about a complex vaccine. Its development and use would demand long time and much money (7)
Social-cognitive		• People ought to be taught about risk reduction. If no ones teaches them then how they can protect themselves? (1)

Table 6
Examples for Student's Reflective Thinking

Dimension	Instrument	Example
Affective	Class observation	"We are full with anger about the fact that thousands of innocent people die in far countries"
Affective	Interview	"I wouldn't like to get malaria"
Affective-social	Class observation	"What is so shocking is that so many people, mostly children die, and there is nothing to do"
	Class observation	"...thinking about all the third world population that has to challenge all these diseases and risks"
Social	Portfolio	"Malaria is a serious problem to all human beings"
Cognitive	Portfolio	"The means against malaria are not the best so far, but even them are not used enough"
Social cognitive	Interview	"I think that various groups ought to raise money to help the sick people and their families"

The scientific conference as high-order thinking enhancement

School 2, the community school, hosted a one-day malaria conference. The program included two parallel sessions of students, teachers, and guests (community members, educationalists from various expertise, and municipality officials). In each of the two parallel sessions, the students presented their posters, which included text, photos, diagrams, and physical models. Then, a follow-up discussion about knowledge integration environments allowed all the participants to share their thoughts about innovative technology-based science learning. The teachers' feedback regarding the experience with WISE as an extended web-based learning was positive. Following are excerpts from the teachers' discussion at the malaria conference. The teachers' names are in parentheses.

> "The teacher is not transforming the knowledge any more. She is mentoring, supporting, and reflecting" (Panit)
>
> "The students are more responsible for their own work" (Michal)
>
> "The students have more freedom" (Michal)
>
> "Searching for information is an important skill. The students are learning not to get stressed if they do not find it right away. They learn how to approach people in other countries, and how to ask for help" (Tair)

Nevertheless, they argued that WISE does not provide a "complete learning environment," and that additional teacher-designed activities are needed.

> "We added graph analysis, drawing a life cycle and expressing one's opinion" (Tair)
>
> "We sent a few students to a Kibbutz that manufactured DDT to learn about its consequences" (Panit)

Assessing the students' work was discussed as well. The portfolios allowed continuous negotiation with the students that improved their work.

Table 7
Stages of Problem Solving

Stages of PS	Complexity	Examples or explanation of students' work
Identifying the problem	Low	"The Malaria is a lethal disease that caused death for millions"
	High	"Malaria is one of the complex diseases in the world. Millions are dicing from it each year. Doctors and scientists do not have a good way to neutralize it yet. "
Providing a coherent description of the problem	Low	Partial description of the life cycle of malaria
	High	A cyclic scheme or a verbal description of the life cycle of the Malaria parasite.
Evaluating alternative solutions	Low	"I think that vaccination is a preferred treatment, because the vaccine prevents 95% of the cases.
	High	"Malaria parasite is more complex than other microorganisms, so the vaccine should be equally complex. Most of the search is focused upon DNA and there are side effects such as sensitivity to other diseases"
Suggesting a rational solution	Low	"We think that a vaccine would be the best solution. The net helps as well, though it doesn't make sense to put a net above an adult's bed, so vaccines are the best."
	High	"Biological defense – we should find an effective predator that feeds on the mosquitoes" " Scientists should develop a substance that kills only the eggs of the mosquitoes" "Mosquito Traps – reservoirs of water, which are far away from human population, could decrease the mosquito population in settled areas."

"When the students got the assessed assignment, a kind of dialog began... the idea of a process-based product enhanced improvement" (Sophi)

"The corrections we provided were not the 'correct answers' they allowed a further dialog" (Panit)

"They (the students) had team-discussions, in which they verified things and explained to each other. After these short discussions, they refined their responses" (Panit)

The students addressed similar issues regarding the method. Their statements are presented in Table 8, and the following excerpts are from the interviews.

"We worked alone and became very independent. It made me feel good. The questions were interesting, which made me read to

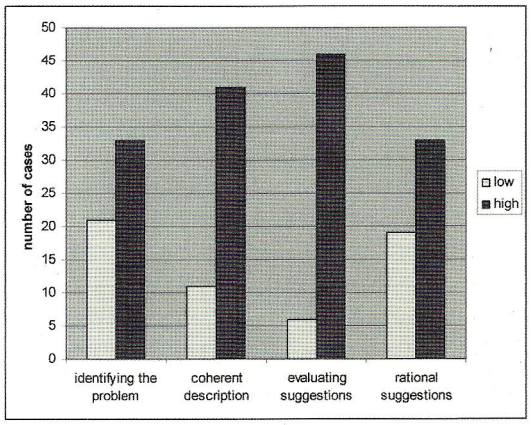

Figure 3. Distribution of the Four Stages for Problem Solving

know more about them. They asked things which I never thought of" (Lina, school 3)

"It is very important that they asked for our opinion. Each one has a different one, and it's interesting to learn about all these opinions." (Yulia, school 1)

"We learned not just science. We understood their poverty, lack of modern medicine and doctors. We felt sad and a will to help" (Yulia, school 1)

"The assignments needed more than straight answers and explanations. They asked for my opinion or how would I address it. The fact that there was no a teacher who led the class was less stressing, and each one could work on different stuff (Rami, school 2).

Table 8
Advantages and Disadvantages of WISE Project

Advantages	Disadvantages
• You work in your own pace	• Technical difficulties
• You improve your independent work skills	• Much work
• The activity is informal and so is the teacher	• The teacher is very busy and does not reach all the students
• It's visual and helps understanding	• The website is dull – no voice and motion
• The student has a right to choose the amount of learning he/she does	• We needed to invest much time and effort, and often we missed our breaks
• The teacher gave much freedom	
• Lots of collaboration and sharing ideas	
• More interesting than usual class	
• When I have to work by myself I learn better	
• I like thinking alone, and I like the teacher as a guide	
• Less stressing when the teacher is not in the front	

Although the students and the teachers criticized a few aspects, the overall experience was positive. In the following year, after the study was completed, and the schools did not get any support, school 2 implemented another WISE project. The teachers called us to report about an enjoyable and a successful implementation.

DISCUSSION

Complex learning environments that incorporate real-world dilemmas and encourage high order thinking are not common in science classes (AAAS, 1989; Chen & Stroup, 1993; Pedretti, 1999). WISE project allowed us to deal with a great public health problem, which is not often discussed in western countries, and to expose our students to the suffer of millions in Africa and other developing regions. Our students, who came from three different communities and backgrounds, had the opportunity to be involved and discuss socio-scientific issues and to share knowledge and learning experiences. WISE project allowed the teachers from these different schools to plan their teaching together and to share their ideas and feedback at the final conference. Using an English-language website allowed the Israeli students to challenge their language capabilities in addition to the challenges that aroused by web-based learning. This was a benefit, which was not part of WISE objectives.

Overall, we found that the students, in all the participating classes, employed high order thinking, while being engaged in the Malaria Project. The argumentation data that were collected by the questionnaires and the portfolios show that, throughout the project, the students had many opportunities to express reasoning. Their arguments were longer, more coherent, and complex at the end of the project. Zohar and Nemet (2002) reported a substantial improvement in reasoning skills of ninth graders in Israel, who dealt with moral dilemmas. The researchers, who did not monitor the complexity of the arguments, applied their analysis on simple arguments based on judgment and making conclusions. Our findings are supported as well by Dori and colleagues (2003), who investigated argumentation skills of tenth graders studying biotechnology dilemmas in a three-month curriculum. Because students do not have enough opportunities to learn and express high order thinking, and because they have difficulties in exhibiting deep understanding of scientific ideas, many researchers urge the promotion of learning higher-thinking skills (Driver et al., 2000; Krajcik et al., 2002; Salomon & Perkins, 1996). The science curricula worldwide allow and provide many opportunities for applying explanations and reasons for scientific phenomena (Driver et al., 2000), and teachers should encourage the expression of thinking in their classes.

The improvement of argumentation skills, according to Hogan and colleagues (2000), occurs when the student raises a partial or inadequate argument and refines it throughout the learning process. We believe that the WISE project structure, in which the students challenge a real problem that includes scientific, social and environmental aspects, and that guides them to constantly reveal new evidence, helps the students to evaluate their thinking over and over again. In this way, they practice and improve their reasoning ability (Bell & Linn, 2000). This is congruent with Penick (2002), who advocated STS approach as most suitable in the complex life of this era, and in accord with other studies that advocated the incorporation of socio-scientific issues into STS learning (Bybee, 1993; Dori, Tal & Tsaushu, 2003; Pedretti, 2000; Solomon, 1993). This is also supported by studies that claim that practicing argumentation leads to better learning of science (Driver et al., 2000; Krajcik et al., 2002: Salomon & Perkins, 1996).

We found much evidence for high level of reflective thinking that the students presented, while they were engaged in the Malaria Project. The need to educate reflective learners was already expressed by Dewey in the 1930's (Dewey, 1933). In recent years, many studies dealt with reflective thinking (Bodker, 2000; Dana & Tippins, 1998; Lin & Lehman, 1999; Seale & Cann, 2000). Most of this body of literature addresses reflective skills of teachers and student teachers. The need for developing self-regulated learners in project-based science led our interest in reflective thinking of junior high school students. WISE project encouraged the students to reflect about the information they received, because it initially focused

on one child's story as an anchor, and because they were requested to argue, respond, and provide reasons throughout the learning process. We found that all the portfolios included reflective comments and expressions in different frequency and depth. At the beginning stages, most of these expressions were in the affective dimension and focused on the student's own-feelings. In the more advanced stages, we identified many more social and cognitive expressions. Some explanation for that we could find in the constructive structure of the project, where at the beginning the students are asked general questions that invite them to express feelings and empathy, whereas in later stages they are being asked specific questions that require some knowledge base and evidence in order to support their answers. In their reflection sheets, the students reported that they conducted group discussions prior to answering the questions. The teachers also emphasized these team discussions. The importance of the collaboration was obvious especially in the second argumentation activity. The students spent much time on trying to convince each other. We would quote Vygotsky (1978) in order to support this social process that occurred in class.

> "The specifically human capacity for language enables children to provide for auxiliary tools in the solution of difficult tasks, to overcome impulsive action, to plan a solution to a problem prior to its execution, and to master their own behavior" (p. 28).

Reflective thinking helped the students to perform better, when they were requested to justify their action (Lin & Lehman, 1999). As Dewey (1933) stated, reflective thinking is not random thinking.

> "There is no thinking without what is called 'association of ideas'... Only when the succession is so controlled that it is an orderly sequence leading up to a conclusion that contains the intellectual force of the proceeding ideas, do we have reflective thought." (p. 47)

WISE project created a sequence that allowed the students to improve their reflections on the learning process. Nevertheless, our findings imply that more questions that focus on cognitive and social aspects would provide a better expression of the higher categories for reflection.

Our findings that show problem solving skills, within a technology- based learning environment, are supported by Oliver and Hannafin (2000), who described the way web-based learning helped students to collect, organize, and evaluate information through the use of authentic inquiry assignment. These researchers, however, claim that technology itself is not enough for enhancing problem solving, although with an adequate direction, this learning environment has a great potential. WISE project provides many opportunities for problem solving. When the students have to suggest and discuss solutions, they need to provide a higher level of solution as they proceed, and the amount of information they gather increases during the project. Although the majority of the students expressed the higher level of suggesting a practical-rational solution, other students were satisfied with describing the problem in their own words. We believe that longer exposure to open-ended problems that do not necessarily have one or correct solution (Penick, 2002; Zoller, 1991) would increase the number of students who suggest a practical-rational solution. Although we expected that some students would use previous knowledge about malaria in Israel, which was a common disease at the beginning of the 20th century, no one addressed this historical aspect. In a discussion with the teachers, they suggested that although the history of malaria in Israel was one of the reasons for selecting this project, they did not refer to previous learning experiences of the students in the assignments they added to the portfolios.

The conference at the end of the project allowed all the involved parties, teachers and students from three junior high schools, to present artifacts and share ideas about WISE, and web-based teaching and learning. Given that our students represent different backgrounds and culture, the Malaria Project allowed them to communicate over a joint project, and, eventually, meet and discuss ideas. This learning experience brought together students who do not commonly interact. This was a very positive social and learning experience in a country that faces so many cultural-political conflicts.

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