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FOSTERING QUESTION POSING AND INQUIRY SKILLS OF HIGH SCHOOL ISRAELI ARAB STUDENTS IN A BILINGUAL CHEMISTRY LEARNING ENVIRONMENT

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Abstract

Most of chemistry learning materials for Israeli students are written in Hebrew which is a second language (SL) for Israeli Arabs. A partial SL immersion model via gradual translation into Arabic is proposed as a new teaching method. The research goals were to investigate (1) chemistry students' question posing and inquiry skills and (2) chemistry students' perceptions towards bilingual learning (BL). Both qualitative and quantitative research methods were used. A total of 31 high school Arab students were taught by one of the researchers in the Case-based Computerized Laboratory (CCL) environment with learning unit (module), originally written in Hebrew. The module underwent gradual translation into Arabic, i.e., the proportion of Arabic text decreased as the module progressed. This paper describes the first stage of a longitudinal study. In the researcher class the integration of Hebrew and Arabic was gradual due to the teacher's awareness of it being an essential component of bilingualism. The research findings indicated improvement in students' question posing and inquiry skills. Students, who experienced the partial SL immersion in the module, were in favor of the bilingual education. They indicated that BL is useful and beneficial as it helps them in their daily lives and in preparation for their higher education. The research has shown that partial translation of scientific learning materials is effective in promoting students' question posing and inquiry skills and attenuating their resistance to the introduction of learning materials written only in Hebrew.

Introduction

This paper is the first of series of articles reporting the findings of a longitudinal study on the impact of a new science teaching and learning method in Arab high schools in Israel. In this study we investigated (1) chemistry students' question posing and inquiry skills and (2) chemistry students' perceptions towards bilingual learning (BL) in a Case-based Computerized Laboratory (CCL) setting.

The paper first provides a theoretical background on computerized learning laboratory environments, bilingualism, and higher order thinking skills. Description of research settings, goals, instruments, and population follow. Findings regarding the development in question posing and inquiry skills in the CCL environment and students' perceptions are presented. We conclude with a discussion and recommendations.

Theoretical Background

The Case-based Computerized Laboratory Environment (CCL)

Researchers have emphasized the theoretical and practical aspects of integrating experiments into science teaching (Hofstein & Luneta, 1982; National Research Council, 1996). In our study, the theoretical aspects include fostering meaningful learning and stimulating critical scientific thinking. Practical aspects pertain to carrying out and monitoring processes and phenomena in a computerized chemistry laboratory setting (Dori, Sasson, Kaberman & Herscovitz, 2004).

Tobin (1990) suggested that meaningful learning is possible in the laboratory if the students are given opportunities to manipulate equipment and materials in an environment suitable for them to construct their knowledge of phenomena and related scientific concepts. Inquiry-based laboratories involve students in formulating hypotheses, conceiving scientific problems and questions, designing experiments, gathering and analyzing data, and drawing conclusions (Hofstein & Lunetta, 2004).

The CCL learning environment has several components: case-based learning, computerized inquiry-based learning and real-time graphing, and assignments aimed at developing higher order thinking skills.

Dori (2003) and Dori and Herscovitz (1999) emphasized the use of case studies as science-based teaching and assessment tools and argued that the case-based method develops students' higher order thinking skills. Integrating computerized experiments into chemistry teaching fosters students' higher order thinking skills. It motivates and stimulates students' learning by showing the relevance of chemistry to everyday life (Dori, Sasson, Kaberman & Herscovitz, 2004). The CCL inquiry-based approach also encourages students to express their ideas in a variety of ways and extend their thinking skills (Dori & Sasson, 2007).

Science teachers are aware of their students' reasoning incapability and occasionally address higher order thinking in class. However, they rarely recognize these skills as a distinct, explicit educational goal that should be addressed systematically (Zohar & Dori, 2003). Questions are an essential education tool for all disciplines in general and for science in particular. Shodell (1995) noted that although the essence of thinking is asking questions, most students perceive science as the study of facts.

Meaningful learning potentially encourages the students and teachers to ask the key relevant questions that expose the underlying problems and demonstrate critical thinking (Zoller, 1990). By asking questions, students frequently reveal what they want to learn, what they know, and what they don't know. Question posing capability could therefore be an effective strategy for improving students' problem solving ability (Dori & Herscovitz, 2005).

In inquiry-based environment students engage in exploring scientific phenomena via language contextualized activities that are related to the hands-on experimentation. In this setting, learners engage in authentic communicative interactions that include describing, hypothesizing, explaining, justifying, and summarizing their findings and conclusions. Furthermore, they can communicate their understanding in a variety of formats: writing, verbalizing, and creating tables and graphs (Lee & Fradd, 1998)

Bilingual learning

Lynch (2001) asserts that despite the best intentions to promote equity and to close achievement gaps, the science education reform movement has failed to respond adequately to the diversity of the student population. Students acquire content knowledge and develop their thinking skills when the medium of instruction is familiar. For the sake of developing content knowledge besides acquiring second language (SL) proficiency, Tucher (1999) has recommended to integrate first language into the instruction process. Acquiring the SL in an additive context, in which the first language is not lost but promoted, leads to uninterrupted cognitive development and thus increased academic achievements (Genesee, 1999).

Rossell and Baker (1996), who conducted a review of the literature on the effectiveness of bilingual education, concluded that the majority of 75 methodologically acceptable studies showed that bilingual education was not beneficial. Their review was re-examined by Green (1997) to verify the list of methodologically acceptable studies. After identifying only 11 studies that actually meet the standards for being methodologically acceptable, the study aggregated the results of those studies by meta-analysis. The conclusion of the meta-analysis was that the use of at least some native language in the instruction of limited English proficient children has moderate beneficial effects on those children relative to their being taught only in English.

Gardner and Lambert (1972) proposed to distinguish between instrumental and integrative motivation regarding SL learning. Instrumental motivation is based largely on the benefits that can be acquired from the acquisition of a language—a good job, social standing, or graduating from a university. Integrative motivation in language is the desire to learn the language for intrinsic reasons. such as learning a language in order to assimilate or participate in the culture of the SL. Most researchers support the view that integrative type is the more preferred source of SL learning motivation. Regardless of the ongoing debate and uncertainty, studies clearly show that both motivation types seem to have an equal level of effectiveness (Abu Rabia, 1998).

Research Setting and Goals

In this study, 31 high school Arab students studied the CCL module, originally written in Hebrew (Dori, Sasson, Kaberman & Herscovitz, 2004). CCL is a constructivist learning environment that integrates computerized experiments with emphasis on a variety of thinking skills, such as question posing, graphing, scientific inquiry, and comprehension of case studies. Dori and Sasson (2007) indicated that CCL activities include understanding case studies, collecting sensor-generated data, constructing graphs in real time, and interpreting results. The CCL case studies serve as science-based teaching and assessment tools that help develop students' higher order thinking skills. We have elaborated the partial SL immersion model via gradual translation into Arabic. In gradual translation the proportion between Arabic and Hebrew text decreases as the module progresses, starting with complete Arabic translation, which diminishes gradually toward the end of the module. Our assumption was that unlike complete Arabic translation of learning materials, which prevents students from experiencing Hebrew, gradual translation might contribute to improving students' scientific understanding and their ability to express themselves in Hebrew. The objective of teaching the CCL module using partial translation was to create a learning environment in which students feel secure while engaging in learning question posing and inquiry skills along with reading and comprehending case studies. While Arabic continued to be the language for social interaction among students, as time went by, the use of Hebrew during class for interaction between the teacher and the students increased to about half of the class time. Difficult concepts and activities were fully explained by the teacher, who switched freely between the two languages.

The research goals were to investigate (1) chemistry students' question posing and inquiry skills, and (2) chemistry students' perceptions towards BL in the CCL setting.

Research Instruments and Participants

Both qualitative and quantitative research tools were used. These included (1) a question for probing perceptions towards bilingual teaching and the CCL learning environment and (2) a case-based questionnaire, which tested higher order thinking skills, including question posing, inquiry, modeling, and graphing. However, in this paper we focus on question posing and inquiry skills only.

The perception question included a list of seven factors: learning solely in Arabic, learning solely in Hebrew, bilingual learning (Arabic and Hebrew integrated), a teacher who teaches in an interesting way, inquiry method, integrating computer into science learning. Students were required to (a) circle the three most influential factors in science learning, and (b) indicate which of the three is most important and explain.

The research participants were 31 Arab students from a 12th grade honors chemistry class in the northern part of Israel. They studied a gradually translated version (to Arabic) of the CCL module, originally written in Hebrew.

Rubrics to assess and analyze students' responses to the assignments in the case-based questionnaire were developed and validated by five chemistry educational experts. These experts also scored 10% of all the students' responses, achieving 90% inter-raters reliability.

As part of the case-based questionnaire, each student was asked to pose two questions, to which no answer was found in the given case study. Each question was analyzed by two criteria: (1) the thinking level required for answering the question, which could be a basic thinking level—knowledge and understanding, or higher-order thinking, and (2) the four levels of chemistry understanding: symbolic, macroscopic, microscopic, and process. The response to each question may include more than one chemistry understanding level.

Findings

Case-based Computerized Laboratory (CCL)

Analyzing students' responses to the case-based questionnaires, we found that the percentage of questions students posed in the pretest which expressed knowledge and understanding decreased from 76% to 45% in the posttest, while the percentage of questions which expressed higher order thinking skills increased by 34%.

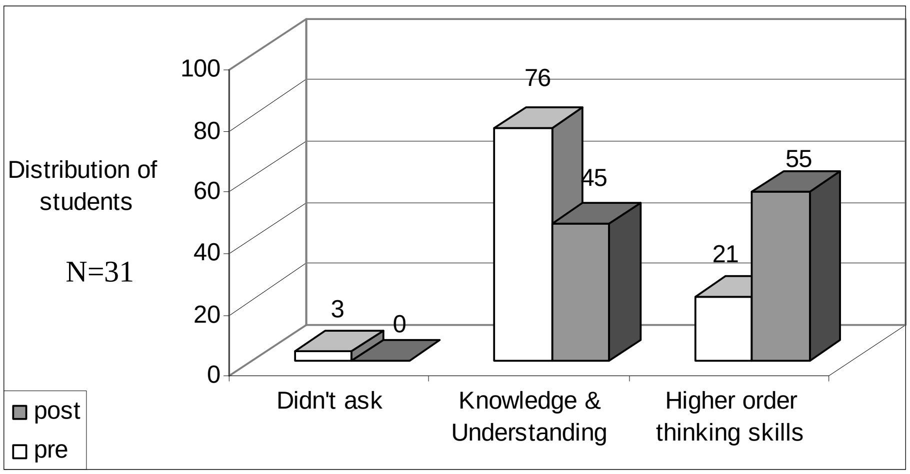

Figure 1: Distribution of students who posed questions sorted by thinking levels

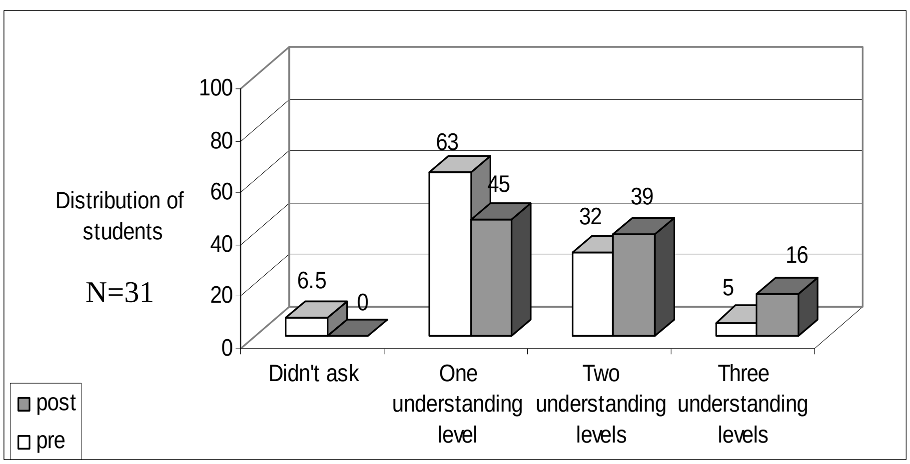

Figure 2: Distribution of students who posed questions sorted by levels of understanding in chemistry.

Figure 2 presents the distribution of students who posed questions sorted by levels of chemistry understanding. In the pretest about two thirds of the students posed questions the answers to which required only one level of chemistry understanding. About one third posed questions that required two chemistry understanding levels and only five percent posed questions requiring three understanding levels (the highest practical possibility). In the posttest, the questions asked by over than half of the students required two or three chemistry understanding levels.

Analyzing the inquiry skills we divided the students’ responses into several sub-skills: formulating an inquiry question, formulating hypotheses, defining the dependent and independent variables, and defining the control variables. The scores in all four sub-skills improved three-fold. For example, the posttest mean scores of formulating an inquiry question increased from 35% to 98% (see Figure 3).

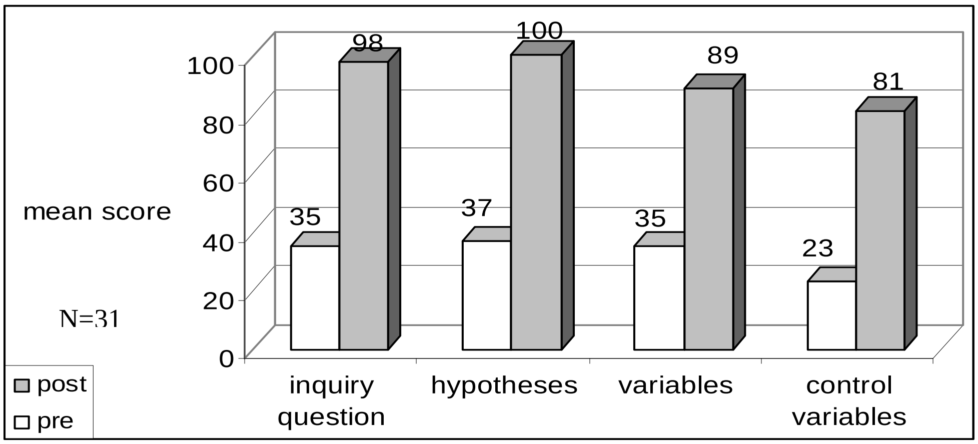

Figure 3: Students' mean scores in inquiry skills

Bilingual learning

To maintain consistency with our bilingual teaching and learning method, the question in which the students were asked to indicate the three most influential factors and argue for the most important one, was formulated in Arabic in the pretest and in an integrated combination of Arabic and Hebrew in the posttest. Table 1 shows students' choices of the language they used for writing before and after studying the CCL module in the BL method.

The percentage of students who chose to write in Hebrew increased from in the pre-perception question 40% to 73% in the post-perception question. The percentage of students who chose to write in Arabic decreased from 37% to 17%.

Perception question	Language used by students (N=31)			
	All Arabic %	All Hebrew %	Mostly Arabic %	Mostly Hebrew %
Pre	37	40	13	10
Post	17	73	3	7

Table 1. Comparison of language used by the students to respond to the perception question in the pretest vs. the posttest

Figures 4 and 5 show the distribution of students' choice of the three most influential factors of learning science before and after studying the CCL module in the BL method, respectively.

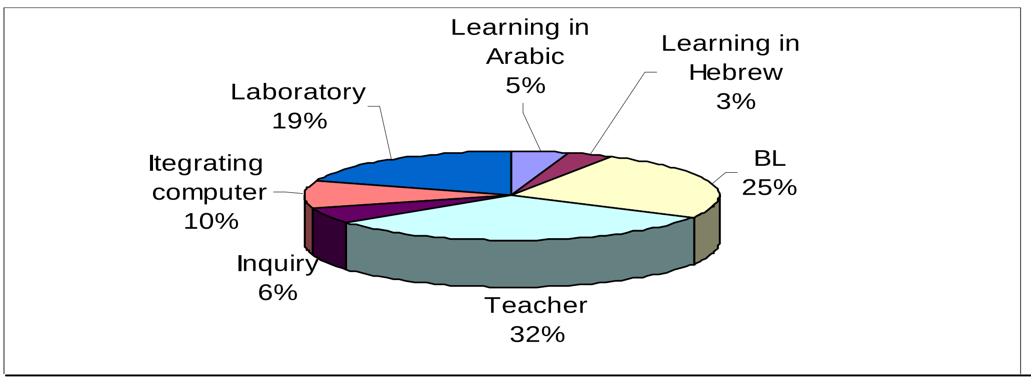

Figure 4. Distribution of factors students chose as influential before studying the CCL module in the BL method

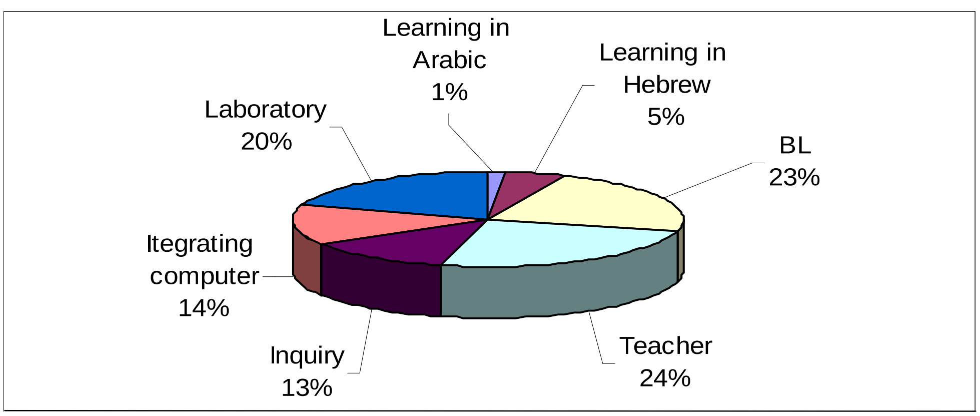

Figure 5. Distribution of factors students chose as influential after studying the CCL module in the BL method

The teacher's interesting way of teaching was indicated as the most influential factor both before and after the CCL learning. It seems that students were aware of the effectiveness of the BL method even before actually experiencing it. The percentage of students who choose the BL as an important factor while learning science remained almost the same (about quarter). The total percentage of the characteristics related to the CCL module—laboratory, integrating computers, and practicing the inquiry method—increased from 35% to 47%.

At the end of the learning process the characteristics of the CCL environment had been perceived by a large number of students (34%) as the most important factors, while before implementing the BL of the CCL module only a total of 13% of the choices were related to the CCL environment.

Perception question	Distribution of the most influential factor in learning science after omitting the teacher factor (N=31)					
	Learning in Arabic %	Learning in Hebrew %	BL %	Inquiry %	Integrating computer %	Laboratory %
Pre	33	17	17	8	8	17
Post	6	6	25	19	25	19

Table 2. Distribution of the most influential factor in learning science after omitting the teacher factor

Since the teacher factor was dominant (over 50% chose it as the most important factor) in both the pre and post perception question, Table 2 shows the rest of the factors with the teacher factor omitted. Here, one can see that after studying in the CCL environment the BL, inquiry, and the integration of computers increased, while learning in a single language decreased.

Students' argumentations regarding the most important factor in learning science were divided into two main categories: cognitive and affective. Students view BL as a gateway to social acceptance, and economic prosperity. A response emphasizing cognitive factors is exemplified in the following student's quotation: *"BL is the most important factor in learning science for enhancing Hebrew acquisition and extending the Hebrew vocabulary. This is essential for higher education.*"

Students emphasized the benefits of the inquiry- and computer-based laboratory. One student commented on the importance of integrating computerized experiments: *"Integrating computers into science learning is useful for everyday life and for developing thinking skills."* Another student commented on the inquiry-based laboratory and its contribution: *"We used to study chemistry as a theoretical subject and now we have had hands-on experience with the materials, investigated their properties, and we understand better what chemistry is all about."*

Affective factors are exemplified in the following student's note: *"The most important factor in learning science is having a teacher who teaches in an interesting and fascinating way. This ensures that the lesson would not be boring, so the student will be interested in learning no matter what language is used for instruction."*

Discussion

The research aimed at investigating chemistry students' question posing and inquiry skills and their perceptions towards BL of the CCL module. We found that the percentage of questions which expressed higher order thinking skills increased in the posttest. In parallel, the number of chemistry understanding levels required for answering the questions students posed in the posttest also increased. This might indicate correspondence between the thinking level required and the number of chemistry understanding levels. In the inquiry skills, the posttest results are three-fold higher than the pretest in all four sub-skills examined. This is in line with our previous findings (Dori et al., 2004) and an indication of the effectiveness of the CCL module and the teaching and learning methods it applies also in a BL setting.

Analyzing students' perceptions towards BL and CCL environment, we found that the teacher factor was indicated by the students as the most influential one. At the end of the learning process, the characteristics of the CCL environment were perceived by a large number of students as the most important factors affecting the learning of science. Students who experienced the gradual SL immersion in the CCL module were in favor of the bilingual education. They indicated that BL is useful and beneficial as it helps them in their daily lives and prepares them for higher education. These findings are congruent with those of Abu-Rabia (1998), who examined attitudes of the Arab minority towards learning Hebrew. He reported that cultural familiarity of text, the student's interest in the text, and instrumental motivation are powerful predictors of reading comprehension of second language by Arab students. Our research has shown that SL immersion via gradual translation of scientific learning materials from Hebrew to Arabic is effective in promoting students` understanding and attenuating their resistance to the introduction of learning materials written only in Hebrew.

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