ZGD Zeitschrift für Geographiedidaktik
Journal of Geography Education

Vol. 35(4), 246–259
ISSN 2698-6752
DOI: 10.60511/zgd.v35i4.223

A Design-based Research of an Oceanography Module as a Part of the Israeli High School Earth Sciences Program

Nir Orion, Carmit Cohen ✉

Zitieren dieses Artikels:

Orion, N., & Cohen, C. (2007). A Design-based Research of an Oceanography Module as a Part of the Israeli High School Earth Sciences Program. *Geographie und ihre Didaktik | Journal of Geography Education*, 35(4), S. 246–259. doi 10.60511/zgd.v35i4.223

Quote this article:

Orion, N., & Cohen, C. (2007). A Design-based Research of an Oceanography Module as a Part of the Israeli High School Earth Sciences Program. *Geographie und ihre Didaktik | Journal of Geography Education*, 35(4), pp. 246–259. doi 10.60511/zgd.v35i4.223

A Design-based Research of an Oceanography Module as a part of the Israeli High School Earth Sciences Program

Nir Orion and Carmit Cohen

Summary

This study is a Design-based Research type that was conducted in order to develop a new module: „Oceans and the Earth systems" as part of the environmental-based interdisciplinary component of the Israeli high school earth science curriculum.

The study included three spiral cycles of development-implementation-research and the collection of the data was based on a battery of both qualitative and quantitative research tools. The sample included about 120 students from 8 classes from five different schools. The design-based research method enables to identify the strengths and the weaknesses of the curriculum in order to modify the curriculum. It was repeatedly found throughout the three development cycles that the interest of students in oceanography topics is high. The students have increased their knowledge significantly and undergone through a meaningful conceptual change. The students' achievements and attitudes correlated positively with the implementation of inquiry based learning in the lab and the outdoor learning environments, and the ability of the students to choose what they would like to study - all of it or at least part of it.

Following our results it is suggested that the earth systems approach could serve as a powerful platform in motivating students to study complicated scientific concepts and processes from all the scientific disciplines.

Frame of the study

The Israeli high school earth sciences program is based on the earth systems approach and includes three components:

a) An introductory unit which mainly focuses on studying the earth systems within the rock cycle (including the hydrological and carbon cycles) and the structure of the earth and the plate tectonics.

b) An environmental-oriented interdisciplinary unit such as „Global warming and the earth systems"; „Earthquakes in an environmental context"; „Evolution in deep time perspective".

c) The „Geotop" – a mini research project.

Oceanography is the area in earth sciences which focuses on the exploration and understanding of the oceans system, and its interrelationships with other earth systems.

Oceanography serves as a very powerful tool for demonstrating the interralationships of the natural earth systems and to learn about the interralationships between the natuaral systems and the human activity on earth. Moreover, the understanding of many oceanography topics involves a multi disciplinary perspective. Therefore, the study of oceanography might serve as a concrete basis and as a relevant context for the understanding of scientific concepts in chemistry, physics and biology.

Design of the study and methods

The current study is a design-based research type that was conducted in order to develop a new module: „Oceans and the Earth systems" as part of the environmental-oriented interdisciplinary component of the program.

The design based research is a relatively new approach (Collins, 1992; Brown, 1992). The focus of a design based research is the study of the influence of curriculum and learning environment design on learning and teaching variables within the real situation of the classroom (Collins, 1992; Barb and Squire, 2004). A design based research is a multiple variables study and a multiple stages study. The first stage of a design based research is a pilot study. Following this predevelopment phase, the research progresses in a spiral cycle of curriculum development and implementation which is followed by a detailed study. Following the outcomes of the previous version the curriculum is then revised and improved. The design based research explores as many variables as possible regarding learners, learning activities, learning environments and the way these variables interact. In order to look over so many variables, a design based study should include a variety of research approaches (qualitative and quantitative) and tools (Collins et al., 2004). Based on the literature review the following are the characteristics of the current study:

1. Integration of curriculum development and educational research.
2. Multiple independent and dependent variables: The learners, learning environments and activities.
3. Multiple points of view: the learners, the teachers, external observer.
4. Mixed quantitative and qualitative approaches and tools.

Theoretical background and research question

The purpose of the current study is the development of a curriculum package that will enhance meaningful learning of oceanography topics. More specifically the study is looking for answers for the following questions:

1. What is the initial knowledge of 12th grade students of selected oceanography topics and does it include alternative frameworks?
2. What is the influence of the learning of the Oceanography module on the students' knowledge

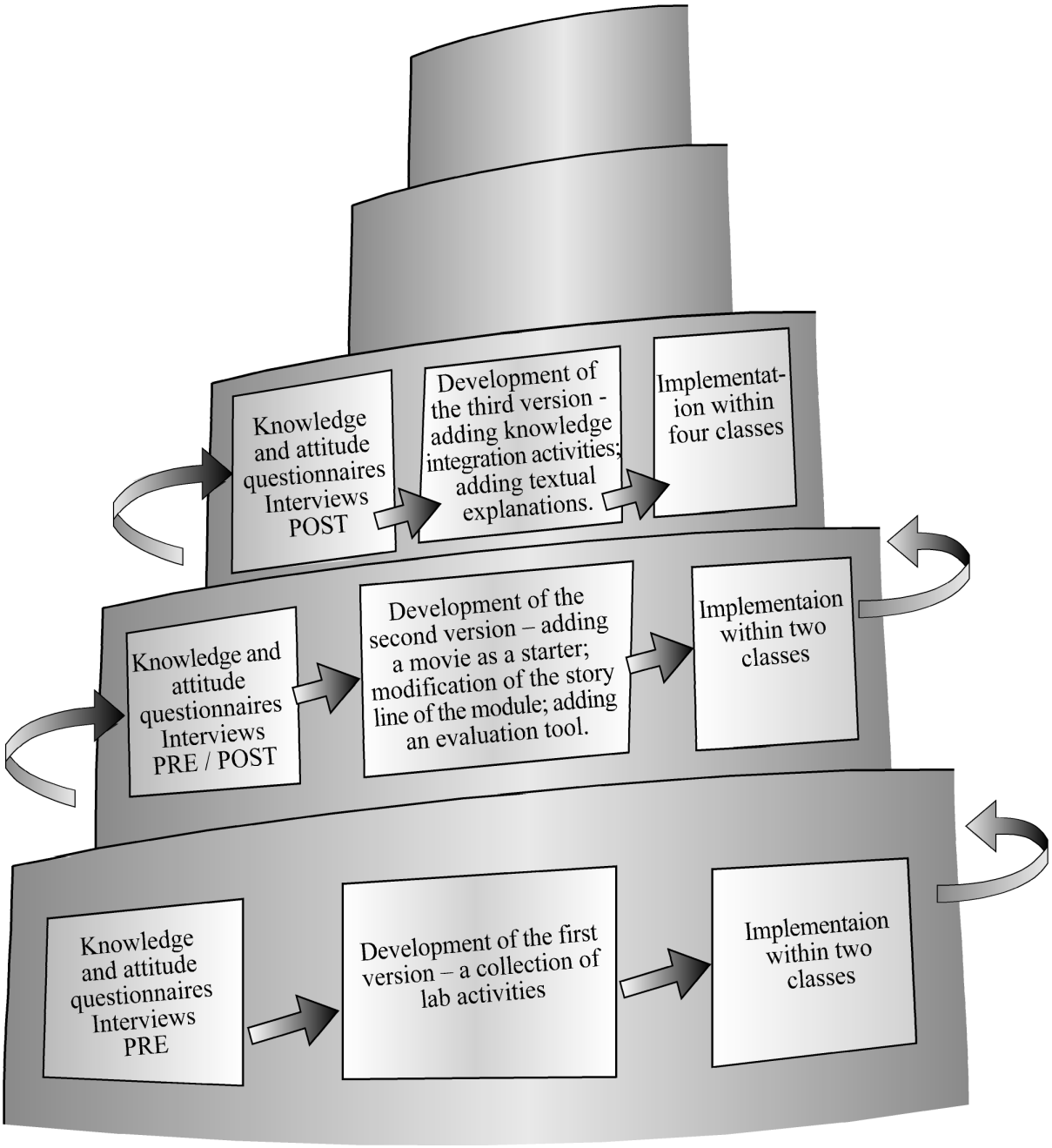

Figure 1: The design of the study

and understanding of selected oceanography topics?

3. How did the learning process influence students' attitudes towards other scientific disciplines (physics, chemistry, biology)?

Research tools:

As a mixed approach this study was based on the collection of both qualitative and quantitative data that were administered before (pre) and after (post) the learning of the module. The content validity of the questionnaires that were specifically developed for this study was determined by an expert judgment

procedure of five experts in Earth science education. The following is a description of the various research tools:

I.) Interest of Oceanography topics Questionnaire (IOC): This Likert type attitudes questionnaire was developed in order to identify the change of students' interest level of a list of 10 oceanography topics following the learning of the oceanography module. It includes five categories where the most negative category (1) is "I have no interest at all to learn about this topic" and the most positive category (5) is "I am very interesting to learn this topic".

II.) Knowledge Declaration of Oceanography Topics (KDOT): The knowledge declaration of the students was measured through a Likert type questionnaire of four categories. The lowest knowledge declaration category (1) is "I never met this subject" while the highest category (4) is "I understand this subject and can explain it to my friend".

III.) Knowledge of Oceanography Concepts (KOC): The knowledge level was measured through 18 open-ended questions and 4 multiple-choice questions. The questionnaire covered oceanography subjects such as the ability to locate the different oceans on the world map; the depth range of the oceans; the temperature range of the oceans; the salinity of the water and its change by the depth; oceanic currents; the interrelationships of oceanographic phenomena with other earth systems; the influence of the human activity on the ocean system.

The purpose of this questionnaire was to evaluate the initial level of knowledge and understanding of the students prior to the learning and the influence of the learning on these variables.

IV.) Attitudes towards the Leaching Techniques (ALT): A five categories Likert type questionnaire was developed for this study in order to measure the attitudes of the students towards the variety of learning techniques that were implemented during the module's learning process. The purpose of this questionnaire was to identify students' preferences of the various learning techniques which were implemented during the learning process.

V.) Attitudes towards the Traditional Scientific Disciplines (ATSD): A five categories Likert type questionnaire was developed for this study in order to look for the influence of the learning process on the students' attitudes towards the traditional science disciplines physics, chemistry and biology. The lowest attitude declaration category (1) is "I totally disagree", while the highest category (5) is "I totally agree".

VI.) Interviews:

The attitudes of the students towards the program were tested through interviews. The objectives of the interviews were to explore students' perceptions and the multi-disciplinary nature of the oceanography module.

The interviews were semi-structured offer topics and questions to the interviewee, but were carefully

designed not to lead the interviewee towards preconceived choices. They relied on a follow-up with probes done by the interviewer in order to get in-depth information on topics off interest (White and Gunstone, 1992). Each of the interviews was transcribed and analyzed qualitatively. The adopted methods of analysis were based on different approaches of qualitative research (Fontana and Frey, 1998; Creswell 1998; Miles and Huberman, 1994) and included the following stages and procedures:

i. Initial analysis of each interview - at this stage, the entire interview was divided into sections for expressions that constitute a response to a specific question asked (or not asked) by the interviewer. These "responses" to different concepts are content categories.
ii. Mapping the categories - organization of the content categories that were determined at previous stages and linking different categories to new concepts. The validity of the categories was based on an expert's judgment procedure of the first five interviews.
iii. Looking for the focus - this stage of analysis relates to the reorganization of the interview categories, so that the researchers can concentrate on the most interesting ones. At this stage, a general framework was arranged to focus on the interviews, based on the research questions. Any response or explanation offered by the students was coded and linked to a category. Thus, the unit of analysis is the explanation itself, rather than the individual student.
iv. Content analysis - at this stage the aim was both to search for patterns between different concepts expressed by the interviewees, and to make the similarities and differences more distinct.

VII) Observations:

One of the authors was present in each o lessons as a participant observer. During the observations the researcher took brief notes of the event and immediately after the participated observation she completed it through more detailed descriptions. In some cases during the interviews the students were asked to react to events that were observed earlier by the researchers.

Research Population

The research population composed of 12th grade high school students who study earth sciences as a major discipline (5 credit points) for their matriculation. The sample included about 120 students from 8 classes from five different schools. In the first year of the two, the sample included about 30 students from two classes and in the third year the sample included about 60 students from 4 classes.

Description of the oceanography module

The oceanography module consists of the following three components:

- The core unit: This 30-hours unit is mainly based on inquiry learning that took place in the lab

Table 1: The relationships between the research questions and the research tools

Research tools / **Research question**	Knowledge questionnaires II+III	Attitude questionnaires IV+V	Interviews VI	Observations VI
What is the initial knowledge?	V	V	V	
What is the influence of the learning on the development of knowledge and understanding?	V	V	V	V
How did the learning process influence attitudes towards other disciplines?		V	V	V

and in the field. The unit starts with the film „The Day After Tomorrow" which establishes the environmental context and the motivation for studying the next lab-based unit that actually explores the scientific basis of this movie. Following the lab activities (about 10) and two educational field trips, the students develop an understanding of basic oceanography concepts and phenomena. These concepts cross all the scientific disciplines. For example, oceans' bathymetry (earth science), waves (physics), salinity (chemistry), photosynthesis (biology).

- The project-based learning unit: Following the core unit each student has to choose a subject, and to define a research question that can be answered through a literature study. The project should include environmental and multidisciplinary aspects. The findings of the study are presented through a power-point presentation.
- The scientific study unit: At this

part of the module the students learn about research methodology in oceanography. In this stage the students use the knowledge and understanding that they reconstruct in order to study a real oceanography phenomena. This study involves collecting and measuring chemical characteristics of sea water in the Mediterranean and Red sea. This study is presented in a form of a scientific report.

The following is a summary of the main pedagogical characteristics of the Oceanography module:

1. Context-based learning.
2. Earth systems approach.
3. Multidiscipline: earth sciences, chemistry, physics, biology.
4. The learning sequence moves gradually form concrete to abstract.
5. The outdoor is a central part of the learning environments.
6. Inquiry-based learning.
7. Project-based learning.
8. Free choice learning.
9. Development of system thinking ability.
10. Authentic evaluation.

Results

Initial knowledge: The triangulation of the outcomes of the pretests attitude questionnaire (AKOS) and the knowledge test (KOC) points at an identical picture. These outcomes have repeated constantly throughout the three cycles of the implementation in all the classes that were measured. The initial range of the level of students' acquaintance with most of the oceanography concepts is between very low to medium. The KOC and mainly the interviews revealed several alternative frameworks. The followings are the alternative frameworks that were demonstrated by more than 25% of the students:

- The depth of the oceans: about third of the sample figured a depth of thousands of kilometers.
- The temperature of the ocean: about 25% of the students marked temperature as -100 Celsius degree.
- The geographical location of oceans and continents: about 50% could not identify the location of oceans and continents on the globe.
- Movement of the sea water within and between the oceans: about 30% of the students presented a static perception of the oceans' water.
- Interrelationships of the oceans and the earth system: about 50% of the students did not see any interrelationship between oceans and continents or between oceans and climate.

The interviews revealed the following additional types of alternative frameworks:

- The salinity of the oceans: "Salt floats and therefore the oceans are salty". "There are chunks of salt in the bottom of the sea and therefore it is saltier as we go down in the sea".
- The volcanoes and the temperature of the oceans: "There are volcanoes in the bottom of the

sea and therefore it becomes warmer as we go down".
- The origin of winds: "The wind is caused by the waves of the sea".

Level of knowledge and understanding following the learning:

Table 2 presents the analysis of the pre and post KDOT questionnaires of one of the classes that took part in the third implementation cycle. It indicates that following the learning of the unit the students declare that their level of knowledge is high to very high for most of the concepts that appear in the questionnaire. The Wilcoxon test analysis reveals that the positive change that occurred following the learning process was statistically significant for seven out of nine topics. However, while the post level of knowledge declaration of the first four concepts is above mean of 3, the attitudes towards the other three topics (5, 6 and 7) are still quit low (about 2.5). The analysis of the curriculum indicates that while the first four topics were taught through inquiry based learning in the lab and in the outdoor learning environments, the learning of the other three topics was merely based on traditional learning, na-

Table 2: Comparison Wilcoxon test (of students' (N=18) pre/post knowledge declaration. (The Mean is of 1-5 range).

Knowledge declaration	Pre		Post			
	M	SD	M	SD	S	P
1. Convection currents	1.8	0.1	3.4	0.8	39.0	0.0001
2. How does breeze wind form	2.2	0.7	3.3	0.7	27.5	0.0001
3. The ocean currents	1.9	0.7	3.1	1.1	25.5	0.0001
4. How do sea waves form	2.5	0.8	3.1	0.7	11.5	0.04
5. Artificial island	1.8	0.7	2.6	1.0	17.5	0.02
6. The oceans composition	2.0	0.8	2.5	0.9	14.0	0.03
7. Coral reefs	2.1	0.7	2.6	0.6	13.5	0.04
8. Photosynthesis	2.6	1.0	3.0	0.9	7.5	NS
9. Lagoons	1.8	0.7	1.9	0.9	5.5	NS

mely listening to the teacher's explanation and reading of texts. The last topic in the Table (9) was not included in the curriculum.

2: Comparison)Wilcoxon test (of students' (N=18) pre/post knowledge declaration. (The Mean is of 1-5 range).

The analysis of the post knowledge test reveals that most of the alternative frameworks mentioned earlier, were not found and most of the students presented a scientific perception in relation to these concepts.

Figure 2 presents the analysis of the open question concerning the influence of the oceans' pollution on the different earth systems. The analysis reveals that following the learning, there is a big improvement in students' understanding of the relationships between the human activity and earth systems. However, only a third of the class arrived to the very high level of understanding the complex interrelationships between the earth systems in the context of oceanography. Third of the class arrived only to the level of understanding of simple connections and third of the students did not improve their knowledge and understanding. Analysis of the observations of the students during

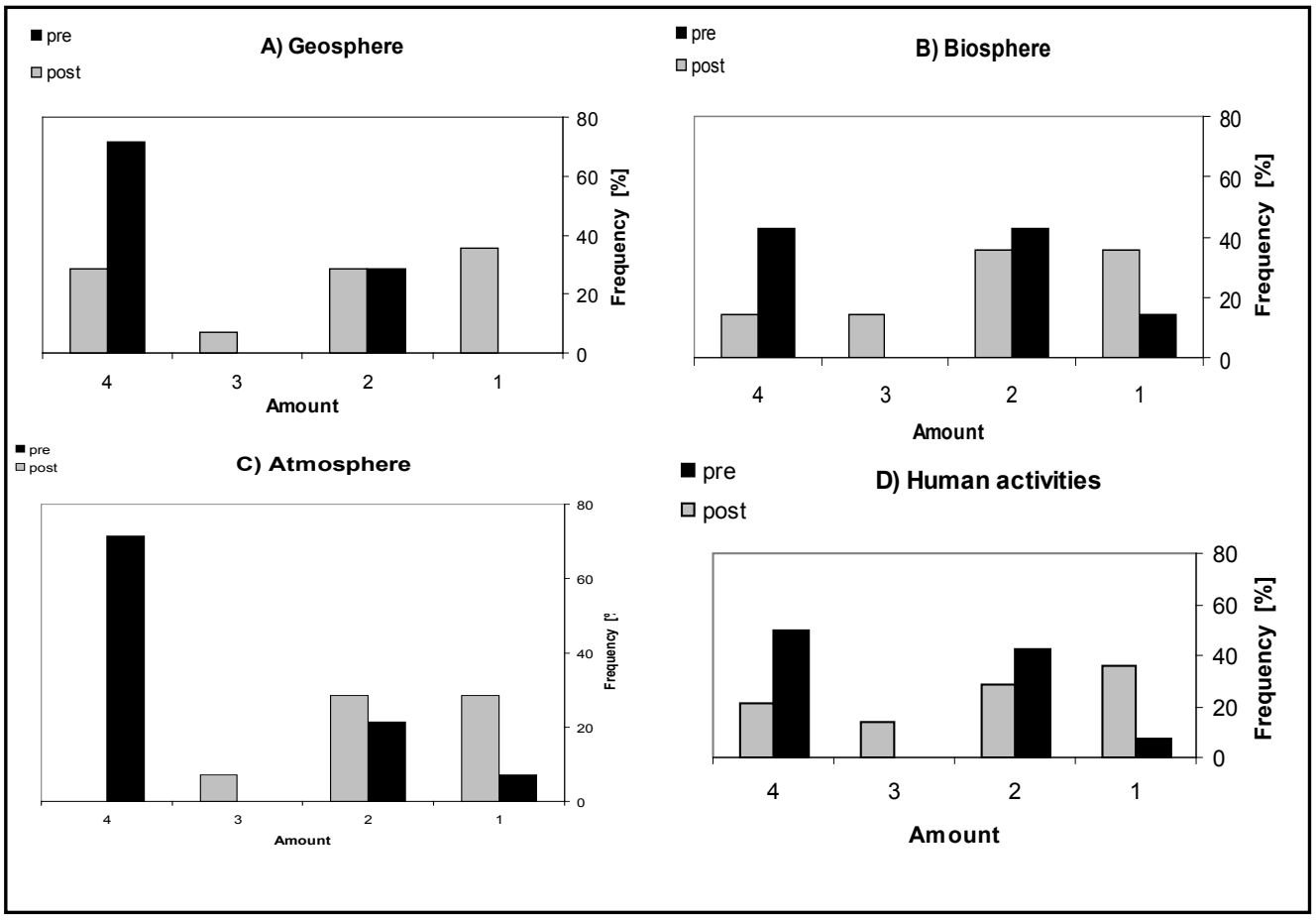

Figure 2: Pre/Post comparison of students' perceptions of the interrelationships of the pollution of the oceans on the earth systems (N-18).

the learning of the module revealed that there is a strong positive relationship between the students' involvement in the learning process and their knowledge and understanding gains.

Students' attitudes towards the different learning techniques of the module:

Table 3 presents the analysis of the pre and post attitudes towards the Learning Techniques questionnaire (ALT). The students started the learning with positive attitudes towards the inquiry based learning and low attitudes towards reading, class presentation and tests. Their initial attitudes towards self work and teacher's lecturing are moderate. A Wilcoxon test analysis of the pre and post attitudes reveals that the positive attitudes towards lab inquiry-based learning have improved to" very positive". The attitudes towards presenting knowledge to the class by power-point presentations were also significantly improved. These findings support the learning techniques that were selected for the oceanography module.

The content analysis of the interviews provided substantive information concerning students' attitudes towards the learning approach and techniques that were implemented throughout the oceanography module. In addition to the categories presented above, the analysis revealed the following three categories: (a) The earth sciences studies and the regular school learning; (b) The

Table 3: A comparison)Wilcoxon test(of students' (N=18) pre/post attitudes towards learning techniques (The Mean is of 1-5 range).

Learning techniques	Pre		Post			
	M	SD	M	SD	S	P
1. Inquiry learning through lab experiments	4.1	0.7	4.7	0.5	14.0	0.008
2. Presenting knowledge by PP presentations	1.9	0.9	3.3	1.3	22.5	0.002
3. Independent learning	2.6	1.3	3.1	1.0	4.5	NS
4. Teacher lecturing	2.5	1.0	2.8	1.2	6.0	NS
5. Traditional exams	1.7	0.9	2.1	1.4	5.5	NS
6. reading of popular science articles	1.8	0.6	2.0	0.7	2.5	NS

outdoor learning environment; (c) Free choice learning.

a) The earth sciences studies and the regular school learning:

"It is not much fun when the teacher shows you on the board what happens and you actually see nothing. It is much better to learn as we do in the earth sciences course, firstly to see and explore the phenomenon in nature".

"In the study of other disciplines all the idea of the learning is the exams. Here it is totally different, you have to do your projects and the teachers work with you till you understand".

"The other disciplines are a teacher, classroom and blackboard and you have to sit and memorize things like a parrot. Here you deal with daily life phenomena and things that really relevant for you".

b) The outdoor learning environment:

"When I see it in reality, I find it a lot more interesting then when I sit in the classroom and it is much easier for me to understand concrete subject".

"During the field trip I saw and experienced phenomena and when the teacher explained it in the classroom after that it was much easier for me to understand".

"We went to the Red Sea and to the Mediterranean Sea and found out that the Red Sea is saltier. It is very interesting this way since before I was not aware of the many things that we saw and felt during these outdoor activities".

(c) Free choice learning:

"The method of the ES learning is much free than the other learning in school. You have the option to choose what you want to study. In the other subject they force you, they sit on you head".

"I prefer the earth sciences than other disciplines in school since here you have a free choice to choose what you like to study".

The analysis of the interviews presents a good agreement between the students' attitudes and the curricular principles that served as the basis for the curriculum development of the oceanography module. The students perceive the outdoor as a powerful learning environment and highlight the free choice learning as a very important component of the earth sciences studies in general and the oceanography course in particular.

Students' attitudes towards the traditional disciplines:

Table 4 presents the analysis of the pre and post attitudes towards the Traditional Scientific Disciplines (ATSD). The pre test outcomes reveal that the following the first year of studying earth science most of the students felt that it had no strong influence on their understanding or interest of the traditional scientific disciplines. However, following the study of the oceanography module (post test) a Wilcoxon test reveals a significant improvement of their level of understanding but less positive influence on their level of interest.

The analysis of the interviews indi-

Table 4: A comparison)Wilcoxon test(of students' (N=18) pre/post attitudes towards the traditional scientific disciplines (The Mean is of 1-5 range).

Attitudes towards the traditional sciences	Pre		Post			
	M	SD	M	SD	S	P
1. Following my earth sciences studies I understand better several physics topics.	1.9	0.8	3.1	1.1	33.0	0.0001
2. Following my earth sciences studies I understand better several chemistry topics.	2.5	1.0	3.2	1.2	18.5	0.03
3. Following my earth sciences studies I understand better several biology topics.	2.4	1.4	3.4	1.4	29.5	0.01
4. Following my earth sciences studies I find physics more interesting.	2.0	1.0	2.9	1.2	18.0	0.01
5. Following my earth sciences studies I find chemistry more interesting.	2.6	1.2	2.9	1.2	5.0	NS
6. Following my earth sciences studies I find biology more interesting.	2.8	1.5	3.1	1.6	7.5	NS

cates that one of the reasons for the above outcomes is that students did not identify the chemistry, physics and biology that they study as an integral part of their oceanography course as a "real" chemistry, physics or biology. Following there are some citations of the students that present their perceptions of the traditional science as they are about to graduate from high school:

"…What we have learnt here (oceanography course) is not a real chemistry. The Chemistry that I had studied in the 10th grade is many sorts of balls with pluses and minuses around …and they have many scarring names with such a big letters and small numbers".

The following citation was made by a student who dealt in his project with the reasons for the distraction nature of the Tsunami wave, including the physical analysis of the

length, velocity and energy of the Tsunami. His answer to the question whether he has met some physics in his oceanography course was: "…No, I don't think so, Physics is a light ray that goes from here to there and coming back. …you see nothing and then the ray hit the eye and then we see it …and then it breaks my head".

"Physics is these all lenses and resistors …really not interesting".

A student, who conducted an in-depth project about the immigration of fish from the red sea to the Mediterranean Sea, did not recognize either that she met "biology" during the oceanography course. Her explanation was: "Biology is all this subject of Ribosomes and Shribosomes".

These outcomes indicate that students develop their attitudes towards the different sciences in the early stages of their school learning. Once they develop a negative attitude as a consequence of their early experiences, it is very difficult to change it. Yet, the overall findings suggest that the interdisciplinary approach of this study in which one starts from the phenomenon and then goes backward to understand it and thus can overcome negative stereotypes of physics, chemistry or biology studying successfully.

Conclusions

This study demonstrates the effectiveness and powerful of the design based research method. This method enables to identify the strengths and the weaknesses of the curriculum and then to modify the curriculum in order to deal with its weaknesses.

The strengths of the oceanography module that were repeatedly found throughout the three development cycles are the initial interest of students in oceanography topics and, they maintain this high level of interest till the end of the learning process. The students have increased their knowledge significantly and the students' achievements and attitudes were positively in correlation with the implementation of inquiry based learning in the lab and the outdoor learning environments, and the ability of the students to choose what they would like to study - all of it or at least part of it.

As a result of the learning process, the students have undergone through a meaningful conceptual change. The predevelopment study also revealed that most of the students came with a minimal background in other sciences, namely, chemistry, physics, biology and were reluctant to study these disciplines. Following the learning process those students improved their understanding of basic concepts such as pressure, heat transfer, chemical composition of water, dissolution, food web significantly.

Following our results it is suggested that the earth systems approach could serve as a powerful platform in motivating students to study complicated scientific concepts and processes from all the scientific disciplines.

Authors:
Prof. Dr. Nir Orion &
Carmit Cohen
Weizmann Institute of Science,
Science Teaching Department
Israel
E-mail:
nir.orion@weizmann.ac.il