# Integrating inquiry activities into physics instruction in a computer-based information technology environment

Thesis for the degree of Ph.D.

Presented to the Scientific Council of the Weizmann Institute of Science

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August 2001

## Summary

**Subject**
This thesis deals with the development, implementation and evaluation of an instructional intervention aimed at integrating inquiry activities in a computer-based information technology environment into high school physics instruction. The instructional intervention comprises of an instructional method and learning materials to scaffold active processes of applying, strengthening and extending physics subject matter knowledge and inquiry knowledge and skills.

**Background**
The call to integrate of inquiry activities as a significant component of science instruction and to foster the development of inquiry skills has been heard repeatedly over the past four decades in the western world as well as in Israel. The common justifications of this involve ideas concerning instructional objectives and ways of achieving them. Some designate inquiry activities as a means of learning concepts and laws by discovery, and relate to the role of active interaction with the human and material environment in the natural development of thinking and skill in young people. This notion is often accompanied by a demand for relevance of the subject matter to the learner (learner authenticity). Some believe in developing inquiry skills as a means to developing thinking skills. Yet others see inquiry activities as means to acquaint the students with the scientific method and to foster a realistic image of the development of science. The latter trend leads to a demand that learning science at school should imitate the processes of real scientific advancement (discipline related authenticity).

Opponents of the integration of inquiry activities into science instruction base their claims on research evidence showing students' difficulties in designing and planning inquiry and their failure to discover scientific concepts and laws. To this is added the claim concerning the lack of relevance of developing inquiry skills for the general population and the impossibility of maintaining the prerequisite conditions for training "Young Scientists" in schools.

The current situation in high school physics instruction is dominated by traditional, teacher-centered instruction focusing on traditional problem solving. At present, inquiry activities have a very limited scope in high school physics teaching in Israel .

Reports on research concerning inquiry activities over the past two decades indicate a trend towards developing a variety of ways for scaffolding students including the use of computer-based information technology. There also appears to be a trend towards changes in the research perspective concerning the students' activities and towards ways of evaluating their products.

In view of the above mentioned developments and of the complex problematic situation in physics instruction there seems to be a case for re-examining the potential of integrating inquiry activities into high school physics instruction. The presented research was conducted against this backdrop with the following general aims:

1. Suggesting goals for inquiry activities for high school physics instruction.
2. Designing an instructional model for attaining these goals and developing an instructional strategy and materials for implementing that model.
3. Implementing the designed instructional model in several experimental sites.
4. Investigating processes and products of the implementation from the perspective of students and teachers.

**Development of the Investigation**

The idea originated during the work of the researcher whom is a physics teacher specializing in integrating computer-based information technology (CBIT) into instruction. The development of the instructional intervention is based on a diagnostic stage comprising of three preliminary investigations that led to the crystallization of the instructional method and to the preparation of instructional materials. During the pilot investigation in my own class I checked the initial model of the instructional intervention and characterized its instructional gains and drawbacks. The investigation of the classroom behavior of two expert teachers assisted in validating and reshaping my initial model. I also concluded that the expert teachers were driven by a metaphor of "instructional engineering" and a personal as well as professional directedness towards learning. The investigation of over 200 physics students' ideas about knowledge development in physics showed that students rated "absorbing from the teacher" and "solving textbook problems" as the most contributing factors. The students also rated favorably the contribution to their physics knowledge of inquiry activities in a CBIT environment. These findings indicated a favorable attitude towards the proposed instructional intervention.

The designed instructional intervention contains, as a central pedagogic element, a complex instructional task termed "an inquiry activity in a CBIT environment" which entails the application of existing physics knowledge. The idea behind the instructional intervention is that the inquiry activity can be harnessed to establishing and extending the students' physics content knowledge by extending the range of applying it and by expanding the types of problems the students encounter. Such an activity is expected to increase the students' disposition towards independent thought and their independent learner skills. The instructional intervention defines different forms of pedgagogical support and indicates ways the teacher can behave to respond to the needs of a heterogeneous population. The integration of CBIT is intended to support various goals of the instructional intervention, one of which is the enhancement of learners' independence by using a teacher independent resource and expanding the range of tools employed in the learning process.

The instructional approach in the intervention is based on "modeling, scaffolding and fading". This means that during the initial stages, inquiry and thinking skills are modeled by the teacher or by other instructional agents and later various scaffolding methods are used to support the student.

The instructional intervention employs a printed activity guide and computer-based materials. The inquiry activity utilizes several features of CBIT: 1. Creating a visual or symbolic inquiry environment. 2. Using sensors to exhibit values of physical properties in a material environment. 3. Logging, storing, analyzing and presenting numerical data. 4. Generating teacher independent feedback directly related to the learners' actions.

Following the development of the instructional intervention it was implemented in 4 schools for various periods during three school years. Over 130 students, mostly in the 11th grade, participated in a total of 18 inquiry activities (16 of them related to printed activity guides) and other activities related to fostering inquiry skills. The teachers in the experimental sites were one of the expert teachers, two experienced "traditional" teachers and the researcher herself. The researcher was present in the other three experimental sites and was involved in research, teaching and guiding the class teacher.

The instructional intervention was evaluated with respect to the following objectives:

1. Characterizing the implementation of the instructional intervention in different sites.
2. Evaluating the instructional intervention with respect to the students.
3. Evaluating the instructional intervention by the teachers and analyzing the effect of the implementation on their professional characteristics.

**Research methodology and data analysis**

The research was conducted in an authentic learning environment, i.e. in school classrooms during the normal schedule and with the presence of the class teacher as well as the researcher. Varied data were collected (completed activity guides, computer files) and a research journal was kept documenting events, observations, transcripts of audio and video recordings. This data was analyzed in several ways relevant to the stated objectives. The research journal was the chief source for data on the implementation in different sites. Data analysis tools were developed to evaluate the instructional intervention with respect to the students. Following an initial analysis of the students' work, detailed categories of learning opportunities were defined in the areas of physics content knowledge, inquiry knowledge and skills, thinking skills and ways of learning and instruction. The students' completed activity guides and computer files were scored using prepared forms. Later the individual results were collated in class forms. A representative sample of 7 implementation events was selected for reporting the results of this detailed analysis. For each of these implementation events we describe the specific inquiry activity, the implementation sequence, the instructional method and the results of the analysis of the materialization of the learning opportunities in the 4 defined areas of knowledge, skill and conduct .

Data relevant to the teachers (interviews, questionnaires, and documentation in the research journal) were analyzed using descriptive, qualitative methods. This analysis generated characterizations of the participating teachers, a list of tasks they performed and their performance levels. We defined and analyzed the effects of participating in the instructional intervention on the teachers' professional characteristics. Finally the teachers' evaluation of the instructional intervention was analyzed.

**Results**

1. The instructional intervention was implemented in different experimental sites for different periods and the anxiety concerning "coverage of content" was the main limiting factor. Where a longer implementation was made possible, more significant changes were found in the learning and instruction styles. The development of the instructional intervention from its intended design to the implemented form depended mainly on the teacher's ideas and vision about instruction.
2. Students responded to the instructional intervention, carried out the tasks and rated the level of interest and contribution to understanding quite highly. These findings confirm that the instructional intervention deals with some of the students' concerns about studying physics.
3. Realization of the learning opportunities in the area of physics content knowledge: Students mobilized knowledge and applied it as a conceptual framework (a language) for describing, explaining and predicting in written and oral forms, as a tool for calculating values and for constructing a computational model and as a logical framework for decision making and reflection. However, there were many instances of inappropriate use of knowledge without heed to the applicability to the investigated situation. The inquiry activity sometimes, but not always, resulted in "debugging" such errors.
4. Realization of the learning opportunities in the area of inquiry knowledge and skills: Students showed a greater disposition towards systematic inquiry based on a syntactically correct inquiry question than students who had not been exposed to the intervention. Evidence was found of transfer of inquiry skills (posing inquiry questions and sampling) acquired in a CBIT environment to a laboratory setting devoid of CBIT. We also found the operative understanding of posing an inquiry question develops quickly but that faced with activities which are more open and have less support, students tend to revert to novice skills. Although we did not teach inquiry related knowledge (e.g. inquiry concepts) formally, it appears that operative knowledge of the concepts "inquiry question", "prediction" and "sampling" was formed. There is also evidence of a development of declarative knowledge with respect to these terms.

Students' ideas about the purpose of inquiry were examined according to their understanding inquiry as a process of knowledge-based discovery and according to the description of conclusions in terms of functional relations between the variables. Students' performance in these issues was partial, indicating either a lack of disposition towards deep thought, or a difficulty stemming from faulty knowledge in physics or mathematics. Inquiry skills were examined by the ability to formulate inquiry questions, to design an inquiry environment, to perform measurements, to present data in graph form and to match a function to the graph using CBIT (e.g. visual simulations or spreadsheets). The findings showed that students learnt these skills quite quickly and their performance was reasonable considering the shortage of time.

5. Realization of the learning opportunities in the area of thinking skills: Encouraging findings were found with respect to posing questions, making predictions and several forms of critical thinking. Evidence was found that these skills were mobilized in the absence of concrete instructions. However, the findings indicate a general tendency towards shallow thinking.
6. Methods of learning and instruction changed during the intervention period. The teacher moved between the roles of modeling and supporting according to the level of guidance of the activity. Students worked in teams and at any given moment different teams were at different stages or were dealing with different questions. Students used the printed material to guide their progress. Working in teams and using the computer increased the students' independence and changed the tools they used.
7. The changes in the organization of instruction and in the nature of the tasks effected students differently. Some students who had not been high achievers in the traditional learning environment, benefited from the instructional intervention, and seemed more motivated and engaged. Other students, who had been high achievers in the traditional learning environment, showed little enthusiasm and their work was mediocre. Another finding was that students tended to tire of prolonged implementation of the intervention .
8. Analysis of the teachers' motivation to participate in the implementation of the instructional intervention showed two sources: a personally focused motivation and a student focused motivation.
9. Participation in the instructional intervention provided the teachers with opportunities for performing several functions related to the implementation or to the research and involving interaction with the researcher. The findings show that realizing these opportunities effected the teachers as professionals in several areas: pedagogical content knowledge, inquiry knowledge and skills, methods of learning and instruction and personal pedagogical insight. The longer a teacher participated in the intervention, the more varied were the functions he performed and the greater was the observed effect in areas of initial low skill.
10. Ambivalent feeling can be detected in the “traditional” teachers' attitude towards the instructional intervention: On the one hand, they appreciated

the learning opportunities that it provided their students while on the other hand they were disappointed with the faults revealed in the students' knowledge and with the lack of active engagement of some of the students. During the initial stages they reported personal feelings of uncertainty about the learning that was occurring and anxiety about the loss of control. The final interviews indicated that in the future these teachers would continue implementing the instructional intervention, possibly with some adjustments.

**Conclusions**

The evaluation of the implementation of the instructional intervention confirms that, using the designed instructional method, inquiry activities in a CBIT environment can be integrated into the instruction of high school physics, alongside other instructional activities. The implementation of the instructional intervention provided opportunities for the application, establishment and extension of physics content knowledge, development of inquiry knowledge and skills, fostered higher order thinking skills and altered ways of learning and teaching. The findings also point to student difficulties and indicate areas for improving the intervention.

The participation in the instructional intervention while interacting with the researcher contributed to the teachers' professional development in several areas. It seems that in the future these teachers will apply the knowledge and skills they acquired to design their preferred method of integrating inquiry activities into teaching physics.

**Products**

A. An instructional intervention for integrating inquiry activities into physics instruction in a CBIT environment comprising of an instructional method, a collection of printed activity guides, computer files, solved examples, feedback and assessment tools, implementation histories and samples of student performance.

B. Categories of learning opportunities in the areas of physics content knowledge and inquiry and tools for evaluating their realization.