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Empowering Engineering College Staff to Adopt Active Learning Methods

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There is a growing consensus that traditional instruction in basic science courses, in institutions of higher learning, do not lead to the desired results. Most of the students who complete these courses do not gain deep knowledge about the basic concepts and develop a negative approach to the sciences. In order to deal with this problem, a variety of methods have been proposed and implemented, during the last decade, which focus on the "active learning" of the participating students. We found that the methods developed in MIT and NCSU were fruitful and we adopted their approach. Despite research-based evidence of the success of these methods, they are often met by the resistance of the academic staff. This article describes how one institution of higher learning organized itself to introduce significant changes into its introductory science courses, as well as the stages teachers undergo, as they adopt innovative teaching methods. In the article, we adopt the Rogers model of the innovative-decision process, which we used to evaluate the degree of innovation adoption by seven members of the academic staff. An analysis of interview and observation data showed that four factors were identified which influence the degree innovation adoption: (1) teacher readiness to seriously learn the theoretical background of "active learning"; (2) the development of an appropriate local model, customized to the beliefs of the academic staff; (3) teacher expertise in information technologies, and (4) the teachers' design of creative solutions to problems that arose during their teaching.

KEY WORDS: Active learning; teaching development; adoption innovations; web-technology; staff report; motivation

INTRODUCTION

During the past decades, a consensus has formed that traditional teaching of basic science courses (e.g., physics, math, and chemistry) does not result in desired outcomes. Research universities in America, with their large classes, have a poor reputation for teaching science (Meltzer and Manivannan, 2002; Powell, 2003). Students complete these courses with a shallow understanding of basic concepts, poor abilities in problem-solving, a shaky understanding of scientific processes and a negative approach to learning science (Pundak and Maharshak, 2003; Pundak and Rozner, 2002). Experts in science education have dealt with this phenomenon by developing teaching methods which try to address significant student difficulties that occur during the learning process (Barak and Dori, 2005; Heller *et al.*, 1992; Laws, 1991; Mazur, 1997; Sokoloff and Thornton, 1997). In spite of evidence that these methods are successful in institutions of higher learning, many academic staff members in teaching colleges prefer to use traditional teaching methods.

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RESISTANCE TO INNOVATIVE TEACHING METHODS

The on-going practice of many experienced teachers continues to be based on traditional teaching methods, year after year, despite disappointing achievement and despite the negative reactions of students to these methods (Henkel, 2005). Changing these methods demands that these teachers invest effort to develop new learning materials, integrate modern technologies and confront unexpected conditions (Zellweger, 2005). When weighing the future advantage with the anticipated investment of effort, the common tendency is for many teachers to reject the desired change.

There are several reasons why an academic staff resists innovative educational change. Geoghegan (1994) suggested that there is the unwillingness to take risks. For example, teachers may suspect that their adoption of an innovative teaching method may involve situations where they might lose control and thus fail to achieve the desired results. A teacher who is confronted with the necessity of changing his role in the classroom—even if he has evidence that the innovative teaching method is effective—often experiences a threatening feeling of uncertainty (Bonk, 2001). For this reason, teachers often are not eager to invest the necessary energy needed to master an innovative teaching method which demands on-the-job experience to develop this mastery. In this case, the resistance to change is used to reduce one's feeling of inadequacy and to minimize the resulting conflict, as much as possible.

A second reason for resistance to change in teachers might be termed "justification of previous decisions" (Braskamp *et al*., 1984). This phenomenon goes well beyond the field of teaching and is present in decision-making processes, in many fields. People tend to continue to invest their energies in a failing activity due to the desire to prove to others (and to themselves) that their original decisions were correct. For example, even if teachers are aware that their teaching methods are ineffective and do not lead to the desired outcomes, these teachers experience a sense of conflict. Should they continue to teach with methods which have been developed with so much effort? Or should they change these methods and "start from scratch" to learn a new teaching method whose success is not guaranteed?

A third reason for resistance to change is the tendency of teachers to imitate the traditional teaching methods of leading universities. These teaching methods are based on "the final exam" as the main component of a student's evaluation in a given class (Donald *et al*., 1996); however, processes that occur during the semester—such as carrying out specific learning assignments, facing the challenges of problem solving and creativity (Heller *et al*., 1992), and committing oneself to working in a team—are a much less important component of the student's performance. Therefore, in addition to the above-mentioned reasons to resist change, this conventional approach to student evaluation, as practiced in leading universities, represents a serious problem to the academic staff in a teaching college. Moreover, many of these college staff members teach in the other institutions which are characterized by these traditional methods, so that they often need to teach with two different teaching methods for the same course.

THE CENTER FOR ACTIVE LEARNING

With the goal of improving its teaching practices in science education, the ORT-Braude Academic College for Engineering established the Center for Active Learning (Pundak and Rozner, 2006), which aims to encourage teaching practices with demonstrated effectiveness, such as the use of demonstrations, posing conceptual questions, as well as providing brief lectures, peer teaching and structured problem-solving. We adopted these methods from learning environments which were developed in MIT (Dori and Belcher, 2005a) and NCSU (Beichner *et al*., 2000). In these approaches, the lecture is replaced with a classroom workshop (Meltzer and Manivannan, 2002), in which the students sit near several roundtables. The lecturer is situated in the center of the classroom. For most of the class session, the students work on specific learning tasks which deal with problem solving and laboratory investigations. The class functions as a research group, in which different teams give reports about their work and results. The role of the lecturer focuses on planning the learning environment, activating the students and giving effective real-time feedback. The classroom learning activity is supported by a computer network between the lecturer and the students as well as between the students themselves. This network allows for retrieving tasks, presenting computerized models, presenting problems, giving feedback, establishing discussion groups, and the like. These changes in the culture of teaching often give rise to difficulties and reluctance of academic staff members, even those who are

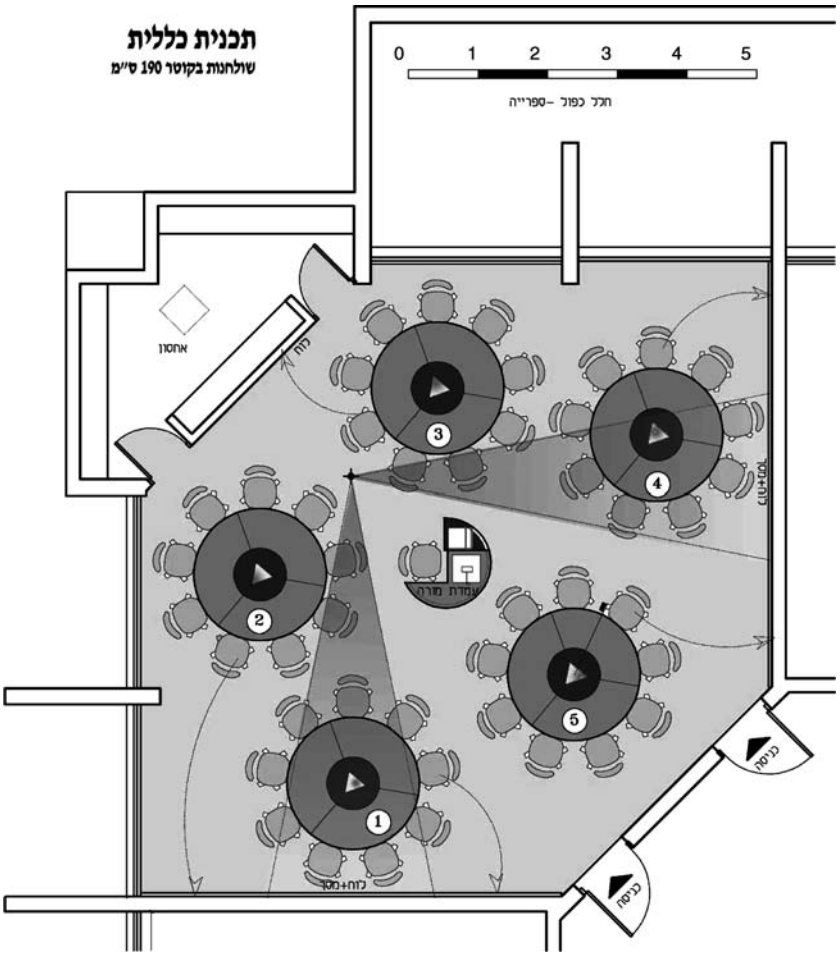

Fig. 1. Design of the Center for Active Learning in the Ort Braude College. Notice that the instructor is positioned in the middle of the room, surrounded by five sets of round tables and chairs, for the participating students.

interested in improving their classroom instruction (Figures 1, 2).

A MODEL FOR "THE ADOPTION OF INNOVATIVE TEACHING METHODS"

In many cases, the need to change teaching methods and to adapt them to new technologies is a result of external pressure, which results from processes which take place outside the activities of the academic teaching staff. Such processes include the development of new technologies, competition with other colleges or partnerships with them, awareness of the need to improve client services or the requirement of improving student achievement. In order to assist the teaching staff in the process of adopting innovative teaching methods, and to help them

Fig. 2. Collaborative learning with groups. Many innovative teaching methods involve student problem-solving, with the sharing of different points of view.

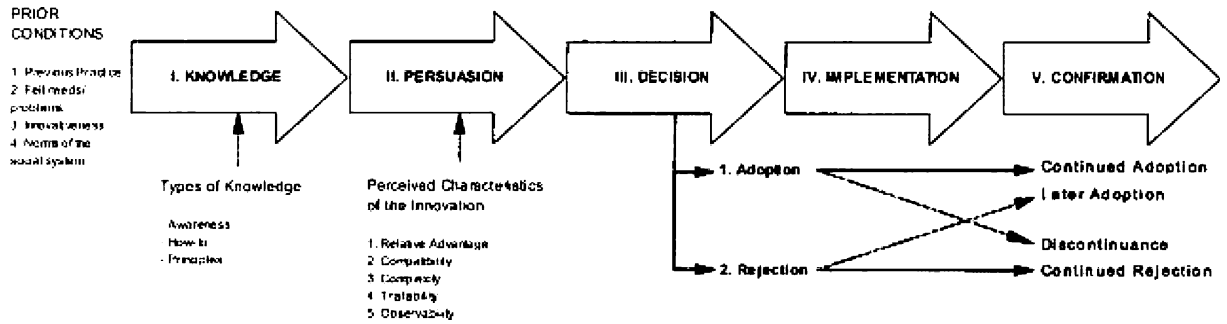

Fig. 3. The Rogers 5-stage model of the innovation-decision process.

identify in what stages of this process they are presently located, we have used the model of Rogers (Rogers, 1995), which deals with the processes of decision-making during the diffusion of innovations. Rogers developed his model over 40 years ago, based on innovation research in agriculture; the model was later applied to other fields, such as medicine and advanced technologies. The model presents various steps that lead to the successful diffusion of innovations, as well as expected difficulties that occur during this process. We thought that this model could be fruitful in guiding us to support our faculty to adopt innovations in their teaching methods (Figure 3).

As can be seen in Figure 1, the Rogers model of the innovative-decision process relates to prior conditions and several stages:

Prior Conditions

The teacher must feel dissatisfied with the way he teaches. In addition, a teacher's decision-making will be influenced by his beliefs and values about teaching and learning, by his prior teaching practice and by the common assumptions and norms of the institution and/or department in which he teaches.

Stage 1: Knowledge

In this stage, the instructor expands his knowledge about innovative teaching methods. There are three levels of knowledge. "Awareness-knowledge" relates to information that a particular innovation exists. "How-to knowledge" relates to the practical information needed to implement the innovation. "Principles-knowledge" deals with the functioning principles which underlie how the innovation works and how to deal with problems that arise during its implementation.

Stage 2: Persuasion

As a result of the acquired knowledge, the instructor developes a tendency to either adopt or reject the new teaching method. According to this model, five perceived characteristics of an innovation influence this tendency and account for between 49% and 87% of the variance for adopting it (Ellsworth, 2000). These variables can be defined as questions asked by the teacher about the new teaching method:

a. *Relative advantage*. Is the new teaching method better than the one I'm using now?
b. *Compatibility*. Does it conflict with my beliefs about learning and teaching or with my teaching experience?
c. *Complexity*. Is it too hard to understand or implement in the learning environment where I teach?
d. *Trialability*. Is it possible to try it and then return to the way I teach now?
e. *Observability*. Can I watch a instructor use it before I decide to adopt it?

Stage 3: Decision

According to his understanding, the instructor decides whether to adopt or reject the new teaching method. In some cases, the decision to reject the method derives from the fact that the instructor never considered it seriously. The decision to adopt or reject an innovation is not final and can change with time, depending on the level of success during implementation, or on new information that may cause the instructor to reconsider his position.

Stage 4: Implementation

The instructor usually implements only part of the new teaching method and does not implement it

exactly as designed by its developer. Instead, he usually modifies it to fit into his teaching practice, gained over years of experience.

Stage 5: Confirmation

The instructor's decision to continue teaching according to this new method is the result of his or her satisfaction with its successful implementation. However, it usually takes time for a instructor to learn how to successfully implement a new teaching method. Therefore, one of the dangers involved in the implementation of such a method is that, during its initial stages, the instructor will decide to give up and return to his or her old teaching practice, despite its limitations.

CONFRONTING THE CHALLENGES

To address the difficulties faced by the academic staff—the College undertook a number of steps in order to minimize instructor resistance to the new teaching methods. These steps were taken at the beginning of the prior conditions and the stages of knowledge, persuasion, decision, implementation and confirmation, in accordance with the Rogers' model.

Prior Conditions

The factors which led to changing teaching methods were:

(a) Dissatisfaction by the academic staff. Low students scores on the final exams created dissatisfaction with the academic staff as well as by the college administration.
(b) Student dissatisfaction. Many students who completed their studies claimed that the basic science courses did not contribute to their education as engineers, but rather used by the College as a "selective filter."
(c) Academic commitment. Some academic staff members were motivated to change because of need to improve student achievement, their belief in the importance of the basic science courses and the successful experience of other colleagues, in Israel and abroad, to integrate new teaching methods into their courses.

Stage 1: Knowledge

Knowledge acquisition was initiated in several ways: in some cases the initiative came from some academic staff members, sometimes it came from the Center for the Development and Advancement of Teaching at the College, and in other cases it came from informal meetings between members of the academic staff. Below are four methods that were used in this stage.

(a) *Integrating academic staff in planning the change*. During the past 5 years, the academic staff in the College has been engaged in a process of extending the student learning environments beyond traditional science courses. The research base for these changes rests on the benefits of active learning (Hake, 1998). During the past 2 years, some academic staff members have presented proposals to the instructors in the Center for Active Learning, based on two active learning programs, one from the North Carolina State University (Beichner *et al*., 2000), and another from MIT (Dori and Belcher, 2005a, b). The process of presenting proposals allowed instructors to become familiar with innovative teaching methods and to decide which components of these methods they wanted to adopt for themselves.
(b) *Involving the academic staff in implementing the change*. Fourteen teams of academic staff presented proposals to integrate Internet-based technologies and develop active learning methods, within the framework of the second CFP (Call for Proposals) of the country's Council of Higher Education; six of these proposals were awarded grants. In addition, two of the teams that were not awarded grants decided to develop active learning methods. Each staff worked in cooperation with an expert in science teaching, with the goal of deciding which active learning method to adopt, e.g., working in small groups (Heller *et al*., 1992), peer instruction (Mazur, 1997), active demonstrations (Sokoloff and Thornton, 1997), working with computer simulations (Eylon *et al*., 1996), alternative assessment, and the like. At this stage, the academic staff had to learn innovative teaching methods and to weigh their willingness to adopt parts of these methods.
(c) *Engaging in long-term R&D of active learning methods*. The process in the College of changing

to active learning started when Internet-based technologies were introduced, in the year 2000. The College administration initiated another change, with the establishment of the Center for Active Learning (Pundak and Rozner, 2006). The Center's process of research and development was undertaken with participation of the academic staff, taking into account the courses they taught.

(d) *Making connections with research centers with successful track records*. The College's change to active learning methods, such as those successfully developed, implemented and researched by other research centers, was accompanied by making connections with these institutions, e.g., the North Carolina State University, which developed the SCALE-UP program, and MIT, which developed the TEAL program. The goal of making contact with these research centers was to learn the philosophy of the respective active learning method, as well as the drawbacks and difficulties of the method, as experienced by the staff and students. Consulting with these centers occurred as a result of discussions we had with Prof. Beichner of the North Carolina State University and with Prof. Dori, who evaluated the TEAL program at MIT. These discussions made it possible for us to deepen our professional knowledge and gave us the opportunity to meet with experts who had the experience of successfully implementing these innovative teaching methods.

Stage 2: Persuasion

The stage of persuasion was based on the knowledge that the academic staff developed in the first stage. Along with getting to know the new teaching methods, the academic staff started to plan how they would adopt these methods. In spite of accumulated knowledge, some staff members still were not convinced of their ability to bring about the desired change. In order to deepen their knowledge and to allow them to express their doubts and worries, three methods were used:

(a) *Creating support groups to deal with the change*. In order to allow the academic staff to discuss the changes they are planning, two supportive working groups were set up: a small working group and a larger one. The small working group consists of 2–4 members of the academic staff who developed the work plan and associated learning materials associated with the specific teaching method; they met once a week. The larger working group, consisting of all the academic staff involved in the change to active learning, met every 2–3 months. In this way, the professional knowledge relating to each new teaching method was expanded and ways to implement each method were presented. This dual process made it possible for the teachers to express their legitimate worries and doubts regarding the adoption of each teaching method.

(b) *Dealing with uncertainty through knowledge*. Milliken (1987) describes three types of uncertainty which are created by the resistance to change: understanding the change, effects of the change and behaviors which might arise because of the change. The College attempted to lower this uncertainty and to increase the staff's feeling of control through collective participation in the learning process and identification of difficulties of the students and staff. For each teaching method, the following topics were discussed: (1) What are the anticipated changes which are likely to accompany this method? (2) How might this method affect the academic staff as well as its working conditions? (3) What types of resistance might negatively effect the successful adoption of this method? These discussions were accompanied by reading research articles that dealt with these topics, encouraging the expression of staff resistance and the presentation of the difficulties which were raised.

(c) *Taking account of the extra staff effort needed*. Staff members who involved in the project presented their work plan and schedule which included hours for developing the method and implementing it in the Center for Active Learning. This commitment by the College, which lasted 18 months, was appreciated by the participating staff. Although the monetary compensation did not cover all of the hours spent by the staff to adopt the new teaching methods, it expressed the College's appreciation for the extra staff effort.

Stage 3: Decision

Making the decision to adopt a new teaching method was taken after the stage of persuasion. This process took about 10 months, during the period

between November 2004 and October 2005. The process of implementing the kinds of new teaching methods that have been described above involved a process of planning, to be followed by a process of implementing an innovative learning environment. Despite the many doubts and worries of the staff, it appears that they were willing to "jump into the water." This decision was accompanied with the development of learning materials, which was an effort to critically investigate the advantages and disadvantages of the particular innovative teaching method (Dori *et al*., 2003). The closer the staff approached the date for the new semester, the faster their work pace on these materials became and the greater were their doubts about the new learning environment.

Stage 4: Implementation

During the winter semester of 2005, seven academic staff members taught four introductory science courses at the Center for Active Learning that was established at the college. The instructors had previously taught these courses, for at least eight times, using traditional teaching methods. Four of the instructors taught introductory courses in physics and three taught introductory courses in mathematics. Details relating to these courses appear in Table I.

During the semester, we conducted two interviews with each instructor. The first interview occurred at the beginning of the course, i.e., during the 2nd or 3rd week of the course. The interviews had several goals:

1. To evaluate which student difficulties arose, as a result of the innovative teaching method,
2. to investigate the actual teaching methods used, and
3. to identify the instructor's challenges.

Table I. Introductory Science Courses in the Study

Course title	Number of classes	Number of instructors	Number of students	Number of hours at the center for active learning
Physics 1	2	2	75	5
Physics 2	2	2	68	5
Differential calculus 1	2	2	73	4
Differential calculus 2	1	1	38	4
Total	7	7	254	18

Table II. Staff Awareness of Learning and Teaching Problems

Instructors:	1	2	3	4	5	6	7
Difficulties							
Students learn science in different ways	√	√	√	√	√	√	√
Students have naïve concepts that create obstacles to new ideas	√	√	√	–	√	–	√
Students usually have low abilities in problem solving	√	√	√	√	√	√	√
Difficulties in assessment—a good answer is not enough	–	√	√	–	√	–	√
Personal monitoring is important, but it doesn't work in large classes	√	√	√	√	√	√	√
Many difficulties exist in conceptual questions	√	√	√	√	√	√	√

The √ symbol represents awareness and the – symbol represents no awareness.

In the interview, the instructors were asked if certain problems occurred in their courses. These problems, which involve learning and teaching, were taken from the research literature. Table II presents the degree to which the instructors were aware of these problems. From Table II we can conclude that instructors are awarding to most of students' difficulties. But, they met a great challenge to answer on these difficulties in the conversional lecture hall. Dudu: I don't know what you want to say here…. The sentence is worded poorly and needs to be changed.

The second interview occurred at the end of the course, i.e., during the 12th and 13th week. The aims of this interview were: understanding the various difficulties associated with the adoption of innovative learning method, learning about successes, understanding in the changes in teaching approaches and evaluating the influence of this experience on the student and teacher attitudes. Below are the main reactions of the academic staff involved in the implementation of new teaching methods. These reactions have been collected via interviews, workshops, and working groups, which took place over a time period of 10 months:

(a) *Freedom versus control*. Traditional lecturers face a big difficulty, when required to give up the control they normally have during a conventional class session. The new class session, designed according to the principles of active learning, allows for greater freedom in planning the class session, but during the implementation stage the lecturer needs to fit a variety of teaching methods into a rigid schedule, which dictates

a limited time for implementing each of these methods. Every change requires the instructor to relate to the complete set of components which make up the innovative learning environment. During the traditional lecture courses, we noticed that when the instructor met with difficulties with the new teaching methods, he tended to return immediately to the traditional methods with which he was comfortable, i.e., the well-known approach of "chalk and talk." We assume that this is a common tendency.

(b) *Work overload*. Adopting active learning methods requires extra work for the academic staff; they are exposed to new learning materials and teaching methods, which they need to assimilate into their teaching. As one example, one lecturer reported that, after he decided to integrate the method of computer simulations into his course, he proceeded to review about two thousand simulations! During this process he chose about 60 simulations for use in his semester course. This intensive effort took many days, and it was only part of what the lecturer had to do, in order to adopt this new teaching method.

(c) *Challenges of new educational technologies*. In addition to understanding and adopting new educational methods, in order to work effectively, staff members also need to understand and use new educational technologies. They need to master computer systems which include a wide variety of programs to manage the instruction and present the course content; to operate a sound system, a video system, a system for collecting real-time data and a student feedback system. In contrast to the technology of the traditional lecturer, who operates the technology of "chalk and talk," this technology is much more complicated. Moreover, difficulties in operating these new technologies can be risky, i.e., they can be the source of serious problems during the actual class sessions. In order to deal with this difficulty the instructors are accompanied with a computer technician, from the beginning of the implementation stage until the time when the instructors feel competent operating these systems.

(d) *Dilemmas arising from finding new learning materials*. The adoption of new teaching methods requires the academic staff to venture outside the closed circle of their well-known teaching methods and into a wide world of new teaching methods, through which they can engage their students in active learning, as described earlier in this article.

(e) *Creativity*. The new Center requires the academic staff to critically re-examine their beliefs regarding teaching methods and their implementation, in light of the many options offered them. Although the decision to establish the Center was made by the College, the choice of innovative teaching methods required the instructors to devise solutions which would fit their personalities, as well as the subject matter of the courses. The information technology tools which were made available to the instructors gave them the opportunity to present complex and dynamic course content, which up to now had been presented in traditional ways. Some of them were creative enough to develop new methods and to write new and more appropriate learning material for students.

To What Extent was Active Learning Adopted by the Instructors?

To establish the degree to which the instructors adopted active learning in their courses, it was necessary to make observations of the actual class sessions. During the semester, two observations were conducted with five instructors and ten observations were conducted with two instructors. We adopted the case study approach (Yin, 2003) to integrate these observations with the interviews in establishing the degree of implementation of the active learning methods, for each of the seven instructors (Table III). The instructors reveal high variability regarding their levels of innovation adoption. On one hand, one instructor decided to leave the active learning center and return to the traditional classroom. On the hand, a team of two instructors in a calculus course exhibited high creativity in their teaching methods and formation assessment; they encouraged students to discuss their ideas regarding their mathematics statements and proofs. Sometimes, the groups work simultaneously on three different mathematical statements; after about 15–20 min, representatives of each group presented its work. Through this approach, the instructors were able to gain a high involvement level of students, to encourage their students to construct their own mathematical conceptual frameworks, and to attain a very positive learning atmosphere.

We further analyzed the interview and observation data according four levels of innovation adoption, as characterized by Henderson and Dancy

Table III. Degree of Instructor Implementation of Active Learning

Instructors:	1	2	3	4	5	6	7
Method							
Peer instruction	++	–	–	–	++	++	++
Animations as a tool for problem solving	++	–	++	+	++	++	++
Interactive demonstrations	+	–	++	+	–	–	–
Web assignment feedback	++	++	++	++	++	++	++
Collaborative problem solving	++	–	++	–	++	++	–
Interactive presentations	+	–	–	+	++	++	++

Based on interview and observation data, the degree of the active learning in the introductory science courses was determined for each of the seven instructors. ++ means "to a great degree", + means "to a lesser degree" and – means "not at all."

Table IV. Four Levels of Innovation Adoption (Henderson, 2005)

Adoption	Adaption	Informed invention	Informed
The instructor develops the materials or adopts it and implements it according to the SCALE-UP pedagogical approach	Materials and procedures are given to the instructor who changes them slightly before implementing them	The instructor uses the original ideas but significantly alters them or develops fundamentally new procedures based on the original ideas	The instructor develops materials and procedures that are fundamentally based on his/her own ideas

Each level is progressively more advanced, from left to right

(2005); see Table IV. Each of the instructors was classified into one of these four levels; see Figure 4.

Figure 4 also reveals a different between the math team and physics teams. The math team made greater efforts to adopt the new environment and prepare appropriate materials for active learning approach than did the physics team.

DISCUSSION

Our study investigates how innovations in teaching methods are adopted in an institution of higher learning. It presents the process of introducing innovations, both from the organizational perspective of the institution as well as the implementation perspective of the individual instructors. In keeping with Roger's model[11], an important initial condition for the adoption of innovations is the existence of some degree of dissatisfaction with the existing situation (Briscoe, 1991). At the ORT Braude Engineering College, there was a real sense of dissatisfaction with the state of science teaching at the institution, starting with the instructional methods and ending with the low level of student achievement in the introductory science courses. This dissatisfaction was characteristic of all of the seven instructors who participated in the study; they were able to identify student difficulties arising from the traditional teaching methods and they were aware of the need to change these methods. These initial conditions encouraged a small group of staff members to introduce the long and complicated process of learning, trial and development of innovative learning environments.

In contrast to traditional teaching, which was the pedagogical background of the instructors who

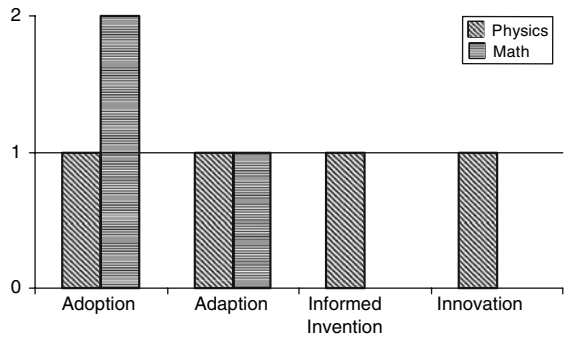

Fig. 4. Instructor levels of innovation adoption. Based on the interview and observation data, each of the seven instructors were classified according to Henderson's 4 levels of innovation adoption (Table IV). Note the high variability between the instructors.

participated in this study, innovative teaching—as exemplified by the work of the Center for Active Learning—demands a great deal of preparation. The ideal condition to implement a teaching method is for an expert instructor—who has mastered the innovation in practice—to accompany the instructors who are novices, in regard to the innovation. This condition did not exist at the college. Instead, development teams for each of the courses were established. Teams were combined from three to four faulty members. In most cases, each team had both young and senior faculty members. Teams met every week in order to develop teaching materials and pedagogical approaches; they met every month with an expert in science education. Based on interviews and observation data, participating instructors demonstrated a high degree of variability regarding their levels of innovation adoption, as illustrated in Figure 4.

This variability can be explained by the behavior of the development teams and the instructors, in each stage of the Roger model of the innovative-decision process (Figure 2), as described below:

1. *Knowledge Stage*. The development teams and the instructors were prepared to engage in deep learning, regarding the theoretical background behind the respective innovations. This learning focused on student learning processes, student difficulties and how to deal with them.
2. *Persuasion Stage*. The development teams and the instructors developed a model of active learning that was adapted to their own beliefs. Although active learning has been adopted by a number of different institutions (Beichner *et al*., 2000; Dori and Belcher, 2005a, b), it cannot be adopted blindly. While developing learning materials for the courses, at the Center for Active Learning, the academic staff developed teaching methods which expressed their beliefs. These teaching methods usually were a compromise between the traditional teaching model, to which they were accustomed before the introduction of the change, and selected components of the new learning environment.
3. *Implementation Stage*. During the implementation stage, we identified two main factors which can explain the wide variability regarding the degree of innovation adoption:

(a) *Instructor expertise in information technologies*. A great degree of variability existed between the participating instructors regarding their expertise in utilizing the various information technologies available at the Center for Active Learning, e.g., using computer simulations, controlling a classroom of computers, employing computer assistance to check student work, and using a computer system to gather personal responses (PRS).

(b) Instructor design of creative solutions to problems that arose during their teaching. During their class sessions, while the instructors attempted to implement their new teaching methods, students often behaved differently than expected. There was a constant need to quickly analyze these new challenges and to react accordingly. Some instructors succeeded in doing this, thereby developing the new teaching method. For example, the mathematics team decided to present theorems to the students, leaving them to work out the proofs via group work, in which each groups worked on a different theorem. Each group then presented its proof to the entire class and received feedback for the other students and the instructors; this approach was designed to develop student confidence in their own abilities (Van Heuvelen, 1991). However, some of these instructors reverted to traditional teaching methods, as soon as problems arose. In another example, toward the end of the semester, one of the physics instructors decided to return to his regular classroom, because he found it difficult to present lectures in the Center for Active Learning.

Today, after three semesters of work at the Center for Active Learning, we can say that the process of acculturating the academic staff to teaching in innovative and complex environments is a long, multi-year process, as documented in the research literature (Fullan, 2001; Loucks-Horsley *et al*., 1998). The most difficult stage, it appears, is at the beginning of the implementation stage, when instructors come face to face mostly with difficulties and unexpected situations in the innovative learning environment. By being forced to focus on student difficulties, the instructors became acutely aware of the gap between their expectations and their students' abilities (McDermott, 1991). Dealing with these difficulties resulted in frustration and different reactions from the instructors. Some of them decide to revert to their prior traditional teaching methods. Some argue that they have not been sufficiently prepared and others are willing to "take the plunge" and develop creative and innovative teaching methods in their teaching.

The seven instructors who taught in the Center for Active Learning reached two major conclusions, as a result of their efforts. On one hand, the students were more active and involved in their learning and, as a result, understand the basic concepts much better. They also succeeded more on tests, during the semester, than similar students who learned in the traditional settings. On the other hand, the learning pace was slower which resulted in students learning less than expected in the course.

In order to sustain an innovative learning environment, which offers many information technology options, many instructor workshops are needed. During the 2005–2006 school year, a workshop was established for the academic staff. Its goal was to critically examine different aspects connected with the change from traditional to active learning. The workshop was guided by a teaching expert, who invited the instructors to present difficulties and to discuss issues related to this change. The instructors were assisted by a technician who helped them use a wide range of technological learning aids in the Center for Active Learning. Based on our observations, during the first semester only a part of these options were utilized. Implementing the innovative teaching methods took much longer than expected. The teaching expert also helped instructors who were involved in developing the new learning materials to confront difficulties involving the process of changing to the innovative teaching method. This process assisted the academic staff to deal with the frustrations which are a normal part of changing from a traditional to an innovative teaching method, which focuses on helping to develop student understanding of scientific concepts in new ways (Goldberg and Bendall, 1995). Based on the many difficulties that the instructors faced in preparing for their courses, we can offer two suggestions:

1. Instructors who desire to use new teaching methods (e.g., those presented in this article) need to participate in appropriate workshops which focus on the mental changes that instructors undergo when a significant amount of the responsibility of learning passes from the instructor to the students.
2. Instructors should be accompanied by knowledgeable assistants, so that they can discuss their difficulties, as they arise, and offer possible solutions. These assistants can help the instructors successfully deal with their tendency to revert to their well-known prior traditional teaching methods.This article presents the way one academic institution dealt with the introduction of changes in teaching in introductory science courses. This process of change was guided by a theoretical model which made it possible for the management and academic staff of the college to identify and to deal with various difficulties during the process of introducing these changes. Our day-to-day work, with the assistance of the theoretical model, helped us to identify and reinforce successful learning and teaching processes, and with the help of these processes we hope to expand active learning in the college, by reinforcing its benefits.

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