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Editorial Office:
Mehmet Fatih TAŞAR (**Editor-in-Chief**)
Gazi Universitesi, Gazi Eğitim Fakültesi,
İlköğretim Bölümü,
K Blok 228, 06500, Teknikokullar,
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CONTENTS

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Editorial

Mehmet Fatih Taşar
Gazi Üniversitesi, Ankara, TURKIYE

Five years has passed since EURASIA was launched in 2005. Although, at that time, there were already several journals devoted solely to scholarship on science education research, time has proven that there is a need for still another journal. The rapid progress of the internet age gave opportunities for new initiatives like ours without a huge investment other than the human resources. Many talented and ambitious colleagues have invested their time and effort and made this journal a reality. Thanks to their hard work, we can now look ahead into the future in more confidence and pride. If we need to speak with real numbers, it is going to be sufficient to cite here the fact that the articles published in EURASIA were cited and referenced 47 times in ISI Web of Knowledge's Cited Reference Search (with journal abbreviations EURASIA J MATH SCI & T and EURASIAN J MATH SCI), although EURASIA itself is not included in ISI journal list.

We are determined to serve our community by publishing only higher quality articles and increasing journal's reputation. This will happen only with the support of our editorial board and the reviewers. Providing quality feedback for authors to improve their papers always plays a vital role. I am confident that this all volunteer endeavor will continue with ever increasing quality and scholarship.

In this first issue of the sixth volume I wish to take the opportunity and thank all of the contributors of this fine journal.

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Misconceptions or Missing Conceptions?

Claudia von Aufschnaiter and Christian Rogge
Justus Liebig University Giessen, Giessen, GERMANY

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Research on conceptual change assumes that students enter a science classroom with prior (mis-)conceptions. When being exposed to instruction, students are supposed to develop or change their conceptions to (more) scientific concepts. As a consequence, instruction typically concentrates on appropriate examples demonstrating that students' conceptions are limited and need to be extended or revised (*Posner criteria*). Based on our studies on students' conceptual development in Physics, we rather argue that students typically lack any (explanatory) conceptual understanding of the science content offered. We therefore conclude that a focus on missing conceptions is much more promising than a focus on misconceptions. This paper addresses theoretical arguments and empirical results supporting our proposition as well as suggests possible implications for the design of instruction and for teacher education.

Keywords: Conceptual Change, Conceptual Development, Learning Processes, Video, Physics.

INTRODUCTION

Conceptual change research has been a major focus of science education research throughout the last 30 years (e.g., Duit, 2009). Some of the instruments developed within this research are very popular and frequently used for study purposes, such as the "Force Concept Inventory" (Halloun, Hake, & Mosca, 1995). One of the items included in this questionnaire is presented in Figure 1. The item addresses a common misconception of (physics) students who assume that moving an object at any speed requires a (resulting) force, even if speed and velocity do not change.

Within the university curriculum for prospective teachers we sometimes ask our students to complete the "Force Concept Inventory" together with a partner. Their discussions about the items are documented on video in order to find out how the students conceptualize the context given and what their arguments in favor or against a specific answer are. With one student group (21 years old) the following discourse about Item 25 (Figure 1) occurred:

Correspondence to: Claudia von Aufschnaiter, Professor of Physics Education, Justus Liebig University Giessen, Institute for Physics Education, Karl-Gloeckner-Strasse21 C, 35394 Giessen, GERMANY
E -mail: cvauf@cvauf.de

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S2: […] Well, I would say greater, isn't it?
S1: Greater? (reads aloud) "than the total force which resists the motion of the box." (reads) "greater than the weight of the box." I don't understand…
S2: (interrupts) But no, wait. Hold it. Same magnitude, because the box is moving already. We don't have to accelerate it. It says "the box moves at a constant speed", that is, it moves. (indicates movement on the table) And we are right in the middle of the movement. Therefore, they have to have the same magnitude.
S1: Well, you mean, it's the same as the example with the lorry, only different?
S2: I don't know, I don't think so. But if they had the same magnitude, then they would stand still, wouldn't they? (indicates stopping with his hands)
S1: Oh gosh, what a mess!

Transcript 1. Two university students discuss Item 25 from the Force Concept Inventory (duration of the excerpt: 35 seconds).

State of the literature

- Current research offers a large number of references about students' misconceptions in various science topics.
- Current research offers assumptions, ideas, and approaches on how to help students to overcome their misconceptions in various science topics but has rarely investigated in detail how students work on the instruction offered, rather.
- Typically, research concentrates on a particular topic and describes learning difficulties and approaches towards overcoming these difficulties within this particular topic. Thus, a transfer of results to other topics is often not straight forward.

Contribution of this paper to the literature

- The paper offers ways to investigate and analyze students' learning processes with video in order to infer how students arrive at any conceptual understanding and which instruction does have a positive impact and when during learning.
- The paper offers new insights into how students develop conceptual understanding (either correct or incorrect). It describes conceptual development as a process that develops from explorations to intuitive rule-based and then to explicit rule-based understanding.
- Categories used to describe conceptual development can possibly be transferred to any science discipline and can be used to design instruction of appropriate learning demand.

A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "v_0".
The constant horizontal force applied by the woman:
(A) has the same magnitude as the weight of the box.
(B) is greater than the weight of the box.
(C) has the same magnitude as the total force which resists the motion of the box.
(D) is greater than the total force which resists the motion of the box.
(E) is greater than either the weight of the box or the total force which resists its motion.

Figure 1. Item 25 from the Force Concept Inventory (Halloun, Hake, & Mosca, 1995).

The interesting bit about this transcript is that student S2 changes his understanding of the situation twice. Initially, he argues for answer D (which is wrong) but then seems to realize that it is answer C because the box moves at constant speed and is not accelerated. He also demonstrates the process with his hands. Finally, he switches back to answer D by asking himself (and his peer) that the box would come to rest if forces have the same magnitude. Interestingly, S1 compares this task with another one from the questionnaire in which a car pushes a lorry. S1's remarks show that even though S1 seems not to know the appropriate answer he has some understanding of which examples are similar.

The excerpt clearly demonstrates that looking only at the answer students choose in the questionnaire does not say very much about their understanding. Also, it does not reveal which cross-references they make in order to solve this task and how they incorporate (conceptual) understanding into their considerations. If the students from Transcript 1 opt for answer C it would be assumed that they possess the correct concept (at least within this context). Would they opt for D it is suggested that they have a misconception. Conceptual change research traditionally regards conceptions as something a student possesses. As a consequence, research investigates the conceptions students have prior and/or post to instruction. This kind of research has revealed students' typical misconceptions and can also generate global results on which instruction is more effective than other. Describing precisely how students utilize conceptual understanding while working on particular experiments, problems, and tasks would require more in depth-studies which are sometimes conducted through interviews (e.g., Ioannides & Vosniadou, 2002; Sherin, 2006; Slotta, Chi, & Joram, 1995). Similar to our example in Transcript 1 an interview can provide more information on how students conceptualize problems and in which way they generate a solution. However, students often tend not to discuss their problems as openly with an (expert) interviewer. In order to avoid this situation one rather confronts a team of two (or more) students with typical problems to work on. This way students discuss their ideas and misconceptions more open and vividly, especially when they are told that they have to agree on one answer.

Despite the important information one gains when assessing students' conceptions either with tests, questionnaires, or interviews it is mostly impossible to retrieve information on how these conceptions have developed over time. For example, in Transcript 1 we do not know how S2 has grasped the idea of Newton's first Law. Neither do we know what makes him assume that the pushing force needs to be greater than all other forces. In addition to describing what kind of conceptions students "possess" research focusing on how students *establish* and use conceptions would provide helpful insights about *mechanisms* of learning and teaching (see also Siegler & Crowley, 1991). These mechanisms can then be used to infer about teaching approaches.

In our research we therefore focus rather on learning processes instead of learning outcomes only. With this approach we can describe in detail how students develop conceptual understanding and how they use their understanding while working on physics tasks (e.g., v. Aufschnaiter & v. Aufschnaiter, 2003a). Empirical results are also used to establish theoretical descriptions about conceptual change processes. Results of this research are used to develop methods and criteria for the design of learning environments in physics that take students' processes of concept formation into account. Finally, content and structure of our teacher education are designed according to the results on processes of concept formation. Therefore, the main goal of our research is to explore, describe, and theorize the mechanisms of teaching and learning physics. In this paper we present a summary of our recent work, including a detailed description of our process based analyses of concept formation and concept use. Also, we provide information on how we design learning material with respect to our results. Moreover, we report our results and discuss their possible impact on teacher education.

Investigating processes of concept formation and concept use

Video as a means to investigate teaching and learning processes

Like many researchers we use video documentation to assess students' learning processes. Often, video-based research focuses on teacher activities in order to characterize the quality of instruction. If possible, two cameras are used, one of which focuses on the teacher (Figures 2a,b) and one of which is directed towards the whole class (Figures 2c,d). The teacher camera focuses on the teacher activity. It is a moving camera capturing experiments he/she is carrying out, his/her writing on the blackboard, his/her contribution to group work etc. Therefore, the teacher camera "captures the teacher-student-interactions completely and further interactions that characterize the teaching process as comprehensively as possible." (Seidel, Prenzel, & Kobarg, 2005, p. 32). The classroom camera is typically either a fixed camera or a moving camera (moving from student to student/from group to group).[1] The main

Figure 2a. Screenshot from a teacher camera (camera position does not exactly match Figure 2b).

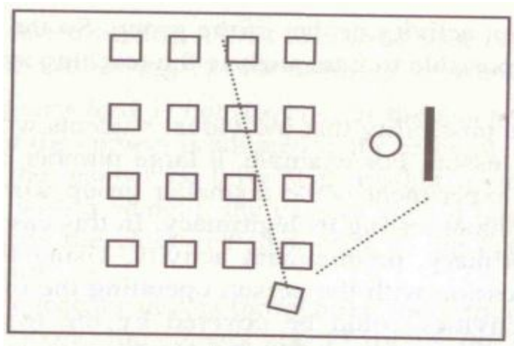

Figure 2b. Typical position of a teacher camera (Seidel, Prenzel & Kobarg, 2005, p. 33).

Figure 2c. Screenshot from a classroom camera.

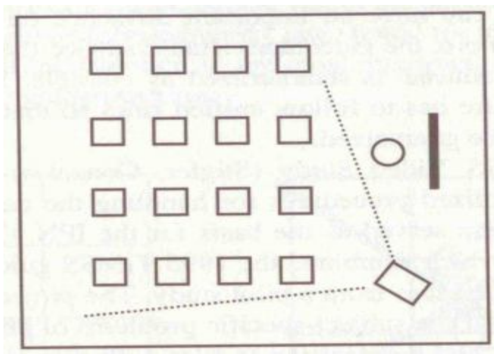

Figure 2d. Position of a classroom camera (Seidel, Prenzel & Kobarg, 2005, p. 32)

purpose of this camera is "to film as much as possible of what is happening in the entire classroom. Further, it should compensate any possible loss of information from the […teacher] camera." (Seidel, Prenzel, & Kobarg, 2005, p. 33).

Even though this procedure is very popular in video-based classroom research (e.g., Jacobs, Kawanaka, & Stigler 1999; Seidel, Prenzel, & Kobarg, 2005) it also has at least one limitation which is obvious from the quotes presented above: Neither a fixed nor a moving classroom camera can reveal how in detail students understand the instruction. Do students work on the instruction as expected? How long do they talk about the content, when are they off-task (and why)? How about individual differences? Also, almost no information can be gained on how in detail students develop conceptual understanding and use their knowledge while working on tasks and problems.

In order to gain more information on students' learning processes we use cameras and microphones which focus on student groups (typically two per classroom). Screenshots and position of camera for different instructions are presented in Figures 3a-d. We are well aware that a group focus is usually limited to a small number of groups and, thus, to a small number of students per class. Therefore, we also do not gain information on *all* students of *one* class. However, we asses about 20% of the students in great detail and receive our information about learning processes from the large number of students incorporated into different studies (see below). In addition to details of group work and individual processes we can usually also assess all teacher and student statements in teacher centered phases. Our cameras remain fixed without any camera person, but in classroom settings we usually have an observer sitting in the back of the room who takes notes on what is written on the blackboard and happening at the teacher's desk.

Obviously, investigating some or all students in a classroom in great detail causes more effort than focusing on the class as a whole. However, there is at least one more possible reason why video as a means to focus on learner activities is still rare in (large scale) video studies: The quality of instruction can be described and judged from an observer's point of view. An (expert) observer can assess whether the instruction is correct or incorrect, whether it is coherent or incoherent, whether the teacher dialogue is authoritative or dialogic, or whether the presented problem is demanding or simple (for according codes see for example Mortimer & Scott, 2003; Seidel, Prenzel, & Kobarg, 2005; Widodo, 2004). In contrast, if the interest lies on the students' performance it is important to understand how a particular student interprets the

Figure 3a. Teaching experiment with grade 11 students (electrostatics).

Figure 3b. University laboratory (RC-elements).

Figure 3c. Classroom instruction with grade 5 (electric circuits) (Buchmann, 2006).

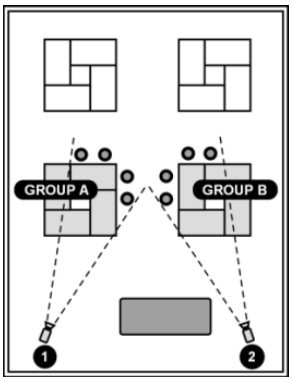

Figure 3d. Position of camera in the classroom on Figure 3c (drawing from K. Buchmann).

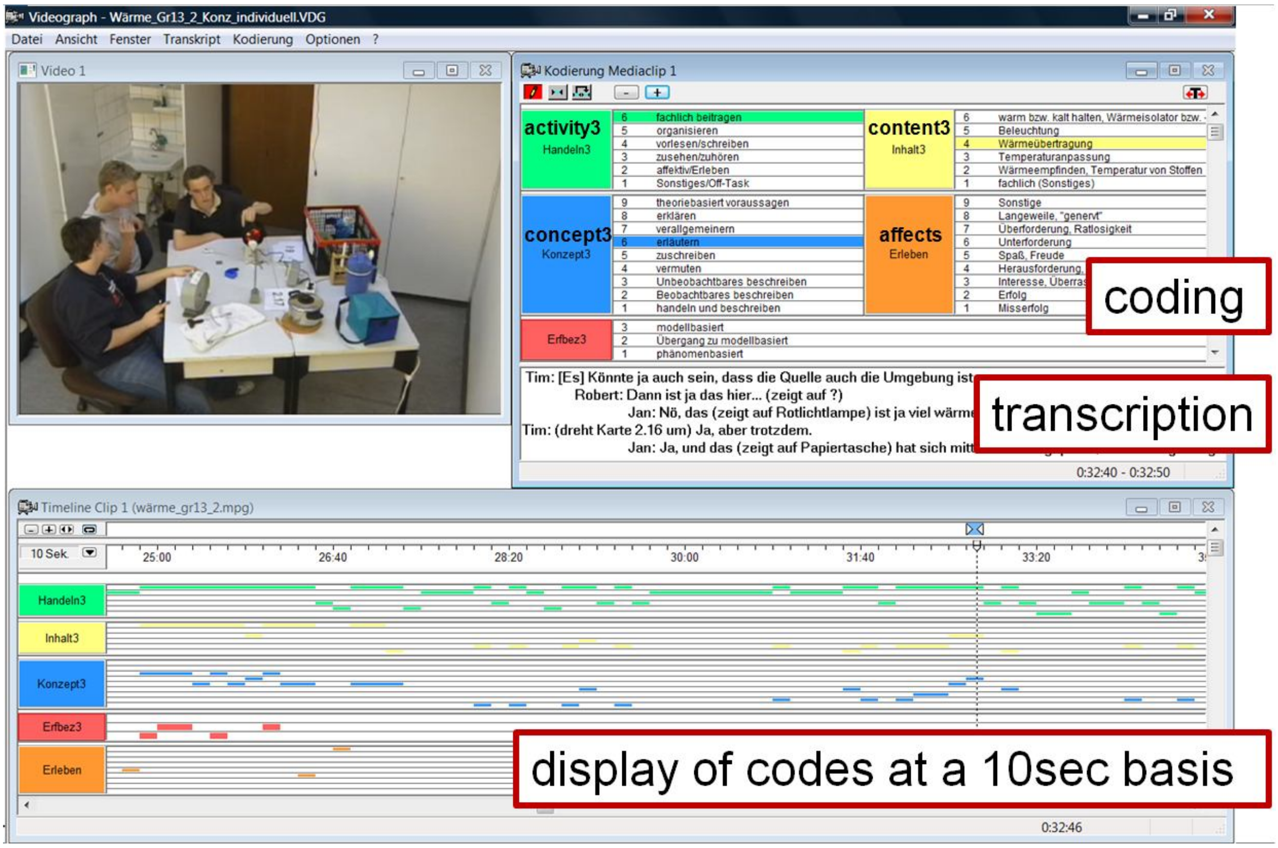

Figure 4. Screenshot from Videograph (codes and transcript in German).

instruction: Is the "simple" task really simple for that learner? (For all learners in the group?) Does the learner realize that a given information is correct or incorrect? Is the learner (surprisingly) content with the authoritative teacher? Is a repetition really repetitious for the learner (or does he/she experience the information as being new)? All these questions require seeing the world "through the learner's eyes". Marton and Booth would describe the former focus as a 1st order perspective, whereas the latter is referred to being a 2nd order perspective (e.g., Marton & Booth, 1997; Marton & Pang, 2008). The challenge of a 2nd order perspective is to avoid interpreting learner activities with the observer's understanding. For this reason we orient as close as possible on students' activities rather than assuming any conceptual qualities behind these activities (see also v. Aufschnaiter & v. Aufschnaiter, 2003a).

Samples and Methods

During the last 12 years we have investigated more than 150 students from lower and upper secondary (11 - 18 years old) (e.g., v. Aufschnaiter 2006a,b; v. Aufschnaiter & v. Aufschnaiter, 2003a) and from university level (typically about 21 years old) (e.g., v. Aufschnaiter & v. Aufschnaiter, 2007). Even though we have done some classroom studies, our main emphasis within the last years has been put on laboratory studies similar to teaching experiments. These investigations have the advantage that parameters can be controlled better than in classroom settings which helps to identify relevant processes. Currently, we turn our focus back to classroom settings in order to investigate whether processes are similar to those in our laboratory.

Topics of our investigations cover mainly electrodynamics but also thermodynamics and optics. Students are followed in small groups of two to four students with video typically over several successive lessons or sessions. In addition to video we sometimes assess students' interests and their situated experiences with questionnaires (e.g., v. Aufschnaiter, Schoster, & v. Aufschnaiter, 1999) and document their processes of concept-mapping.

Video-data are analyzed with a multilevel approach. In order to get an overview about the data and to generate quantitative results, videos are coded in 10 second intervals. These coding procedures focus on general dynamics and distinguish, for instance, between organizational and content-specific student activities or assess different types of discourse or student argumentation. Also, coding of video is used to identify sequences which are interesting for a specific research question. These sequences are then transcribed and investigated in more detail. Coding of the videos and transcription is performed with the software "Videograph" (Rimmele, 2008, see Figure 4).

The second step of our analyses are in-depth investigations of the transcript (together with the video data) in order to assess details of individual meaning making processes (e.g., how a student understands tasks or contributions from other students). The notion of "processes" refers to the time scales on which we assume cognitions to change. Humans typically change their clothes on a daily basis, so "processes" here would refer to 24 hour-intervals. Moods in contrast might change very quickly, so that intervals need to be much shorter (maybe on a minute-basis). Research on human cognition indicates that immediate behavior is "always new; always a sensorimotor circuit." (Clancey, 1993, pp. 111). From this and other work (e.g., Pöppel, 1994) we assume that a mental image (one cognition) takes up to 3 seconds and a line of thought takes up to 30 seconds (v. Aufschnaiter & v. Aufschnaiter, 2003b). Thus, "in-depth" analyses not only refer to close investigation but also to rather short time scales (utterance by utterance, activity by activity).

In our research, step 1 (coding of videos) and step 2 (in-depth analyses of transcripts) are interrelated. In both steps criteria are used to describe processes or criteria are generated. Thus, the approach is explorative but also tests hypotheses. Which codes are applied or developed depend on our specific research question. We want to stress that this criteria-based approach differentiates between "case stories" and "case studies". For case stories, individual learning (and teaching) processes are described in great detail such as what students do and how they do it. Even though these often result in vivid and interesting descriptions, the implications of these descriptions often remain unclear. However, they often cannot reveal commonalities and differences between different individuals. Here, clear criteria are needed as well as coding scheme (an example is given in Appendix 1) that help to set-up valid coding procedures (including the calculation of the intercoder reliability). With thorough coding procedures, individual processes can be compared and hypotheses can be formulated (see also Jacobs, Kawanaka, & Stigler, 1999).

Missing conceptions and (mis-)conceptions: Some empirical results and theoretical considerations

Conceptual qualities

In our earlier work on students' learning processes in physics we have noticed that students fairly often talk about particular situations, phenomena, or objects (e.g., v. Aufschnaiter, 2006b). This happens even if students are explicitly asked to generate a rule, such as with the example presented in Transcript 2. Before the question is presented to the students they already realized that the temperature of an object adapts to room temperature if the object remains in that particular room for some time. With the question offered in Transcript 2 we expected students to generate an answer such as "The object will get the same temperature as the warm environment." Rather than presenting an answer like this, the students discuss two different phenomena. First an experience with a snowball is reported and then the student S2 tries to create a specific situation when considering what happens to the temperature of a metal cube.

"Imagine a cold object is brought into a warm environment. Explain without measuring: What happens to the temperature of the object?"
S3: For instance, during summer a friend had a snowball which he took out of the freezer.
S1: If you take it from the cold to the warm environment it either melts or…
S2: Did it melt? How quickly?
S3: That was during summer. It melted within 20 seconds, maybe even quicker.
S2: Ok, if I take this metal cube in a real warm environment. Right now, this cube has about 22.5 degrees Celsius. It would then have about 25, I reckon.
S3: Not more than two degrees warmer, the most.

Transcript 2. Students discuss a question (unit on heat transfer, sequence shortened, duration about 1:30 minutes).

Similar to this example students often report descriptions of particular events or ask for them. They describe their observations or remembered phenomena, for instance: "Look, the metal cube feels cold but it has 22°C.", "Does this lamp still shine so brightly if you add a second one in this circuit?", or "Last time in the cinema, I could see how the light traveled to the screen." On the other hand, students sometimes explicitly state a rule, for instance: "Even if two objects feel differently warm, they can have the same temperature.", "If you add a lamp in a series circuit, all lamps will shine less brightly.", or "Light always travels in strait lines." This distinction between concrete events and rules which we found in our data concurs with arguments claiming that conceptual knowledge refers to an "implicit or explicit understanding of the principles that govern a domain […]." (Rittle-Johnson, Siegler, & Alibali, 2001, p. 341; see also diSessa & Sherin, 1998).

In our data, students only explicitly express conceptual knowledge in less than 20% of the time spent with the instruction. That is, dealing with specific objects or phenomena makes up the majority of students' activities. However, we identified in these activities another distinction which is also present in Rittle-Johnson's quote from above: "implicit […] understanding of the principles that govern a domain […]." (Rittle-Johnson, Siegler, & Alibali, 2001, p. 341). When following Transcript 1 it seems that the student

S2 has grasped conceptual ideas (both correct and incorrect) when he tries to decide whether the forces compensate or not. But he does not explicitly say something like "If an object is moved (moves) at constant speed (and velocity) all forces acting on the object compensate to zero." (Or "Whenever you want to move an object at steady speed you need to exert a (constant) force on the object.") In addition to distinguishing between activity which does not explicitly refer to conceptual understanding and statements in which conceptual knowledge is explicitly expressed we, therefore, identify an intermediate level. At this level, students predict specific events or phenomena, they attribute expressions (for instance, physics terms) to events, phenomena and objects or they describe how different aspects relate to each other. However, even though at this level students seem to have an intuitive understanding of the underpinning concepts, their explicit verbalizations refer to particular events. When students use physics expressions these serve as labels rather than as generalizations (concepts). Examples for this intermediate level of conceptual understanding are: "I reckon, you'll measure again something like 22°C", "This is the same electric circuit than we had yesterday.", "The shadow is there, because the light cannot pass this box.", or "Last week, our teacher told us to say 'energy' when talking about this situation."

The more experienced students will more likely action the basis of an intuitive understanding. In a comparison between students from grade 8 (about 13 years old) and grade 11 (about 16 years old) who were working on an identical unit on heat transfer (see Transcript 2 for a group of 8 graders and Table 1 for examples of the material) the 11th graders developed significantly more ideas which are based on an intuitive understanding (Rogge, 2009; Rogge, in preparation). We have not yet identified significantly more explicit conceptions with the older students. This result seems to be disappointing because differences between novices in physics and students who have had physics for at least 4 years in school appear to be rather small. However, it has to be noticed that distinguishing between concrete, intuitive, and explicit conceptual understanding is only one way to characterize the quality of students' understanding. In addition, descriptions can focus on scientific appropriateness, complexity of ideas, or time needed to construct these ideas (e.g., v. Aufschnaiter & v. Aufschnaiter, 2003a). Differences between less and more experienced students' knowledge of physics might, therefore, not include more explicit conceptions and/or these being scientifically (much) more appropriate. Rather, differences might refer, for instance, to the amount of different elements of the content integrated and/or the speed with which these are developed (see also v. Aufschnaiter, 2006b; v. Aufschnaiter & v. Aufschnaiter, 2003a).

From conceptual qualities to the learning of concepts

In the previous section, three different conceptual qualities were established from the discussion of examples (for a more detailed description of these main categories and related subcategories refer to Appendix 1):

1) Students argue and behave in a way that seems to have no conceptual ground, for instance, while "simply" describing what they observe or exploring what happens when they change something in an experimental set-up. In our research we would label this an **explorative approach.**
2) Students argue and behave in a way which indicates that they have already grasped some idea about underpinning rules but do not yet explicitly refer to these rules. For instance, they predict purposefully (but not based on explicit generalizations) what will happen next or they have grasped how to describe a particular event with physics expressions. These activities are labeled as **intuitive rule-based approach.**[2]
3) On the third level students explicitly express conceptual knowledge by generalizing over several events, objects, or phenomena. This is what we label as **explicit rule-based approach.**

Whereas levels 1 and 2 imply that students deal with particular events, level 3 refers to a conceptual level. The notion of "missing conceptions", therefore, refers to levels 1 and 2. At these levels, students either lack any conceptual understanding of that particular topic or are currently not explicitly expressing their understanding.

Distinguishing different conceptual qualities is useful to identify at which level students currently behave (see also coding scheme in Appendix 1). However, it does not provide any hints on how students move between levels, whether there is a definite level at which they start their movement, and which learning material promotes or hinders such movement. Our results on students' learning processes indicate that for any new aspect of a topic (new for the students) students start by exploring related phenomena, opportunities to solve tasks, to treat experiments and to verbalize aspects (level 1). If instruction offers explicit concepts at this level students either seem to "ignore" the information, express that they are puzzled or develop a concrete understanding of the information (for instance, by creating an example that matches from their point of view). At this level 1, students' activities often seem to follow a trail-and-error-like behavior, especially for open instructions. Teachers then often realize that students seem not to follow the instruction and do not control parameters.

Table 1. Examples of the instruction from a unit on heat transfer (Rogge & Linxweiler, 2008) aiming to establish conceptual understanding about the adaption of temperature (thermal equilibrium)

Tasks for students (partly shortened, pictures and lines for notes excluded)
1 Take a pair of scissors out of the box. How warm do the scissors seem to be? Do all parts of the scissors seem to be equally warm? Tip: Hold the scissors at the back of your hand or at your cheek.
2 Analyze different objects in the material box with respect to how warm they feel. Assign the objects to a) feel warm, b) feel normal, c) feel cold.
3 Roughly estimate temperatures of the objects in groups a), b), c) of card 2.
4 Measure the temperatures of the scissors' handle and blades. Measure all temperatures of the objects you have used for card 2. [All temperatures have to be noted on this card.]
5 What do you observe when comparing measured temperatures of the objects from card 4? […] Compare these temperatures with your estimations from card 2. What do you notice?
7 Use the surface thermometer to measure the air's temperature. Compare this temperature with the objects' temperatures from card 4. […] What do you observe?
8 [Thermometers placed in different objects in a closed electric cooler.] Consider which temperatures will be shown without looking into the cooler.
9 [Students have to look at all thermometers including one that is lying on the ground of the cooler.] What do you notice?
Information 2 *Objects sitting together for a long time have the same temperature.* If objects sit for a longer time in the same room with a specific air temperature, all objects have the temperature of the room. Which temperature would the objects in the material box have if the room would be at 30°C?
13 You've just observed that hot water cools down and that cool water gets warmer (card 11). Also, a cold plastic knife gets warmer (card 12). Consider: To which temperature will the hot water decrease? To which temperature will the cold water and the cold knife increase? You can use your observation from card 7.
14 Imagine, you would bake cookies in an oven at 200°C for half an hour. Afterwards, the cookies have to cool down for a while. Which temperatures will the cookies have right when they are coming out of the oven? Which temperatures would the cookies reach when sitting for a long time on the kitchen table?
15 Imagine, a cold object is brought into a warm environment. Explain without measuring: What happens to the temperature of the object?
Information 4 If objects or substances are in an environment (e.g., a room, a fridge, an oven) for a long time they will have the same temperature as the environment. If an object or substance is initially at a different temperature it will reach the temperature of the environment by getting warmer or getting cooler.
18 [A plastic knife has to be heated with a lamp.] Consider, which temperature does the knife have before being heated?
One week later
1 [Four gel-packs lying in hot water. Students have to measure the temperature of one of these gel-packs.] Explain without measurement why the other gel-packs should have the same temperature.
2 [Picture: A cup of hot tea which is sitting on a table.] How long will the temperature of the tea decrease?
6 [Similar to 1 with four cold gel-packs from the cooler.]
11 [Plates made from different material on which ice cubes have to be placed in order to observe their melting process.] Explain why all these plates roughly had the same temperature before putting the ice cubes on top of each of them.
14 […] Why does the small paper bag increase its temperature when being touched for a longer time with your hand?
25 Imagine, you are in a park on a sunny day with about 28°C. You have a bottle of lemonade with you which comes from the cooler and has about 10°C. What will happen to the temperature of the lemonade if you don't drink it?

Table 2. Examples of phenomenon- and model-based concepts

Phenomenon-based concepts	Model-based concepts
Whenever my teacher says "Ohm's Law" he wants to hear V=R • I.	Internal energy is the total amount of energy in an object.
If you add a lamp in a series circuit, all lamps will shine less brightly.	In order to see an object light has to be scattered from the object into our eyes.
Even if two objects feel differently warm, they can have the same temperature.	Sound is transferred by pressure variation.
All force meters include a spring.	Whenever an object changes its movement a force is exerted on the object.

From their explorations students develop an intuitive idea what will happen next or how they have to work on an experiment or a problem in order to get a specific result. From their explorations of ways to express things they also develop an intuitive understanding which words/phrases refer to which situations. Students who have some experiences on a particular aspect of the topic already sometimes almost directly start at an intuitive rule-based level when dealing with that aspect. Intuitive rules stabilize while students work on similar phenomena and problems. In these phases, students often explore the learning material again even though they already have an intuitive idea what will happen. Within this circular movement between levels and also within the same level students are also more and more able to integrate different content elements into their considerations.

Surprisingly, students rarely move to the next level 3. Explicit conceptualizations often occur in single sentences but not in long and extensive discussions. Moreover, students typically express a rule after they have already developed an intuitive understanding of this particular rule. However, conceptual understanding is usually expressed only after students' explorations of specific phenomena and problems. That is, students very rarely construct a hypothesis which is explicitly based on a conception before they work on the relating problem. While moving from level 2 to 3 and at level 3 explicit (short) information on underpinning concepts seems to be useful. Other than at an early stage of their learning, conceptual explanations offered help students to realize that they are "on the correct way" or have not fully grasped the idea. That is, if instruction wants students to understand a particular concept, these students need to discover this concept at least intuitively *before* they are likely to grasp the related conceptual information. Or, conversely, students are likely to understand any concept that they already "know" at least intuitively. However, it should be noted that establishing a concept once is not enough for a robust understanding. Even though we do see a general movement (for a specific aspect of a topic) from level 1 to level 3, a "robust" understanding at level 3 requires the opportunity for students to (re-)explore related phenomena and problems, to stabilize their intuitive rules and to re-discover conceptual knowledge after dealing with a specific phenomenon or problem. As can be observed in Transcript 2 students will not (immediately) remember a not well established concept when being presented with a slightly changed situation. The more experienced students are the more likely will they only need few hints and also be quicker in re-constructing conceptual knowledge. Establishing conceptual understanding at level 3 also includes to integrate more and more events within one conception and to relate different concepts (dynamically) together.

The previously presented description on how students develop a conceptual understanding has primarily emerged from our more recent teaching experiments. Therefore, we have to stress that these occur in learning settings which have a "bottom-up-design" in respect to establishing conceptual understanding (see examples in Table 1). Thus, we cannot clearly state that the processes of concept formation described match students' learning in other settings, even though some of our and other classroom data indicate similar dynamics. Also, we have to stress that we can only assume how learning processes to level 3 and at that level occur because explicit conceptualizations are rare in students' activities. Therefore, the description above should, overall, be regarded as a hypothesis which needs further research in physics and probably also in other science subjects.

So far, we have described that our students mainly act and verbalize at levels 1 and 2, that is, they deal with particular events no matter of their age or prior experiences. We have also described that in comparison to younger students, students of higher grades with more experiences in physics do significantly more often construct an intuitive rule-based understanding (level 2). The processes by which students develop from a concrete to a conceptual understanding seems to be circular (see also for example Fischer, 2008), often very slow and require several repetitions, much more than are usually offered by instruction. From a conceptual change perspective this result is either artificial (because of our distinction) or frustrating. We, therefore, would like to stress that:

A) Assuming that "missing" conceptions are either missing because they are not (yet) established or are missing because they are currently not explicitly constructed as conceptions, is probably not very popular. Rather, conceptual change research typically assumes that almost all activity is based on conceptual knowledge (Chi, 2008; Vosniadou, 1994). In an earlier study we already developed some theoretical arguments why we do not agree with the idea of conceptual knowledge being a prerequisite of any student behavior (for more details see v. Aufschnaiter, 2006a). We would like to stress that the idea of mental entities or concepts which are seen as the initiator of students' activities weakens the differences we find in what students say and do. On a conceptual basis, no matter whether students reach level 1, 2, 3, or above, activities with a similar content would refer to the same conception. Thus, this kind of progress in students' understanding is not assessed.

B) Researchers who agree with our distinction might be frustrated by the small number of explicit conceptions we identify empirically. Rather than being frustrated we would argue that "good" intuitions in a topic are very valuable. If students have grasped an idea of how to express phenomena correctly – even if they do not really know why it is correct – and how to work on a wide variety of scientific problems successfully – even without really knowing why the chosen approach is successful – they are already on their way to develop an explicit conceptual understanding. Furthermore, our results pose a challenge to instruction. It has to be accepted that conceptual knowledge itself and not just changing this knowledge is demanding for students, no matter if conceptions are correct or incorrect. Thus, we cannot simply inform students about appropriate concepts by one or two examples (see also below) and then expect that these students understand the concept's generalizing character. Rather, we have to put lots of effort into creating appropriate experiences (systematically arranged phenomena, problems, etc.) to help students to establish intuitive and explicit rule-based understandings. From our work on the development of study material we know that the design of such material is very demanding and time consuming.

Phenomenon-based and model-based concepts

Even though the amount of explicit conceptions is small in our data, we found a noticeable difference between students' conceptions which also applies to physics concepts. Table 2 indicates two different groups of concepts. The left column refers to concepts that can be derived from experiences (observations on what can be heart or felt, how people express things, how to work on problems). We label these concepts as "phenomenon-based concepts".[4] The right column, in contrast, includes concepts which cannot be inferred directly from experiences. Rather, one has to construct a (theoretical) understanding of the principles that explain phenomena and phenomenon-based concepts ("why…"). We label this group "model-based concepts" even though this notion may cause some misunderstandings. If students, for instance, observe atomic models which are presented in a picture, on a computer screen or as a real model (e.g., illustrating atomic bonding), and then generalize that atoms are always round and have a color (which is incorrect but conceptual) we would assign this to a phenomenon-based concept as students have experienced (observed) the features over which they generalize.

Our data indicate that phenomenon-based conceptions occur (slightly) more often than model-based conceptions and seem to be less demanding for students (compared to model-based conceptions). However, due to the small number of explicit conceptualizations we still lack clear criteria to distinguish these two types of concepts in students' verbalizations. For such distinction it is also very important to hold a 2nd order perspective to reveal how a student conceptualizes a particular aspect. Especially, if students know and conceptually apply specific phrases such as "Batteries need to supply enough energy for any electrical device." we have difficulties identifying whether these phrases refer to a phenomenon-based understanding (a conceptual understanding of how to phrase things) or to a model-based understanding of the concepts involved into that phrase (e.g., the meaning of energy). Our impression from observations in schools is that students fairly quickly grasp explicitly or intuitively how to "say things right" without having (fully) grasped the model-based concept that they communicate. Teachers, in contrast, tend to assume that students who express model-based conceptions correctly have also understood their meaning.

Conclusions: Misconceptions and missing conceptions

Distinguishing between different qualities of conceptual understanding and between phenomenon-based and model-based conceptualizations as well as considering processes of concept formation offers insights into students' misconceptions. Some (mis-) conceptions occur as a result of students repeated experiences with phenomena of their everyday world. For instance, students who assume that in order to see an object one has to look at it have experienced for several times that one cannot see anything that is on the back of one's head. Assuming that metals are colder than, for instance, wood is a result of the sensory experience: usually they *feel* colder. Students' everyday experience with cycling, pushing objects, and similar activities is, indeed, that they have to exert a (constant) force to get a steady speed for any linear motion. These kinds of (mis-)conceptions are correct in a way that they refer to correct experiences students make and which are then generalized to intuitive rules and explicit conceptions. However, they also indicate which experiences are not yet (fully) present to the learner. Students have not experienced that almost all objects give off light (and this is, indeed, difficult to experience because for most objects this cannot be seen); they have not measured the temperature of different objects and compared this to their experience of these objects feeling differently warm (see also Table 1); and they have not grasped that there is a force which hinders movement (friction) and which they have to compensate for any object to move at steady speed. Thus, some of students' misconceptions explicitly point to misleading or missing experiences which, in turn, have to be made during instruction.

We conclude from our results and observations in classroom settings that all model-based concepts are difficult for students. These are, for instance, force and energy and their distinction as well as the distinction between energy, voltage, and current. As soon as students are asked about their ideas on model-based aspects, students typically either express that they don't know or they try to transfer experiences to that particular topic. Again, the effort to utilize everyday experiences creates misconceptions, such as the idea that atoms have similar properties as macroscopic objects. Unfortunately there seems to be no direct way to address model-based concepts. Either students lack any conceptual understanding or they refer to phenomenon-based ideas. Rather than approaching model-based concepts directly (for example, by contrasting these to students' ideas) we assume that a thorough analysis is needed which phenomenon-based concepts have to be established in advance of related model-based concepts. In order to, for instance, establish some conceptual understanding of the model-based concepts of electric current and voltage students should be exposed to extensive and systematical measurements of something being labeled as current and voltage so that they can discover that there are two different parameters in electric circuits that behave in particular ways. (In advance of this, students need to be able to distinguish and set-up serial and parallel circuits and mixtures of both which most of our university students cannot at the beginning of their studies. Also, they need phenomenon-based conceptual understandings of the phenomena that occur in different electrical circuits with different electrical devices (lamps, motors, LEDs, bells, …) and different power supplies. Again, our university students typically lack systematic ideas about these phenomena.) When having grasped phenomenon-based concepts about measures of current and voltage in different circuits and under different conditions it is more likely that students can and will understand (slightly) what these two concepts "mean" and why measures behave in specific ways.[3]

Instruction and teacher education

Considerations and results presented so far have considerable impact on how to design instruction and on teacher education. A detailed elaboration on both issues would require another two papers and can, therefore, only be described very briefly here.

Designing instruction

For the design of instruction, we plan the instruction from the end to the starting point of students' process of concept formation:

(1) Content to be taught is analyzed first in terms of its phenomenon- and model-based concepts. Even though different approaches towards designing instruction stress that such an analysis is important, the focus is typically on model-based concepts. In contrast, we put special emphasis on phenomenon-based concepts because these are easier to grasp for students and seem to provide the basis for any further model-based conceptualization.

(2) Documented students' misconceptions (e.g., Duit, 2009) about the topic to be taught are considered. We analyze these conceptions in terms of underpinning experiences and which experiences probably lack for an appropriate understanding of corresponding physics concepts. Also, an interrelationship to step 1 is created: Which concepts will students most likely establish because they have some matching experiences already? Which concepts are not considered? Thus, like other approaches we stress the importance of inclusion of students' misconceptions into instruction. However, our approach refers to these in order to *design* instruction rather than discussing them explicitly in the classroom (aiming to "contrast" students' misconceptions with scientific concepts).

(3) Typically, not all concepts noted in step 1 are included (extensively) into instruction (some are too difficult, some are established with students already or can be established relatively easily, some are not really required, etc.). For those included, an order is fixed (in accordance with analyses of step 2) and appropriate experiences to establish them are trialed.

(4) Study material and corresponding experiments are fixed focusing on variances and in-variances needed for students to establish an intuitive-rule based and an explicit rule-based understanding. Additional information to promote students to stabilize their ideas is prepared.

(5) In addition to step 4 examples and problems are constructed that help students to re-discover conceptions established before. These examples and problems are included into further study material which aims to establish expanding or additional conceptual understanding (e.g., Table 1).

Overall, our ideas on how to create instruction are not new. Similar ideas are, for instance, described in the Model of Educational Reconstruction (e.g., Duit, Gropengießer, & Kattmann, 2004) or with the design tool of learning demand (Ametller, Leach, & Scott, 2007). Also, conceptual change approaches stress to take scientific concepts and students' prior conceptions into account for the design of instruction. However, our impression is that no matter of the specific approach towards designing instruction and teaching (for example social constructivist, inquiry-based, context-specific) typically a small number of "good" (convincing) examples is either used to establish (inductive approach) or demonstrate (deductive approach) a scientific concept. Thus, the number of examples and the opportunities to re-discover conceptual knowledge are usually so small that students are most likely able to learn how they have to talk about these examples correctly but will only rarely build up conceptual understanding about the concepts that are to be established. Also, instruction too often focuses directly on model-based concepts by asking "why-questions" before students really know what phenomenon-based rule is to be explained.[5] As a result of experiments which do not systematically create appropriate experiences and help students to focus on these experiences, teachers often need to interrogatively find out about the conception or at least the relevant phenomenon from their students. This is demonstrated by the following Transcript 3 in which a teacher (probably) wants to establish finally that electricity can cause heat. Obviously, students have not noticed that there was some heat, let alone that the preceding experiment "demonstrated" a concept:

T: Do you remember the electric bell?
C: Yes! [in chorus]
T: OK! Did any of you notice, did any of you actually hold on to the bell after it had…been working? What did you notice?
S: Vibration.
T: Well, the arm vibrated, yes. Sound. What else did you notice?
S: It was loud.
T: That's not quite what I'm getting at. Remember the bell. There's the bell [holding up a bell in front of the class]. You did the experiment. If you held on to this bit here where the wires were [indicating], did you notice anything there?
S: There were sparks there.
T: Did you notice some heat?
S: There were sparks from there.
T: There were?
S: Sparks.
T: There were some sparks, yes. Let's just ignore the sparks a minute…some heat. There was a little bit of heat there with that one.

Transcript 3. Classroom discussion about an electric bell (from Mortimer & Scott, 2003, p. 35).

Stressing the importance of students' experiences is not entirely new. However, how much these experiences matter and how important it is to arrange them systematically in order to promote concept formation seems not to be implemented in science instruction yet (see also Marton & Booth, 1997; Marton & Pang, 2006). As a result of this, we are typically not able to understand why students often fail to grasp "simple" concepts offered and accept that the development of scientific concepts is a gradual and (very) slow process especially for model-based concepts.

Teachers as learners

It can be assumed that for prospective teachers, science education issues are as new as, for instance, physics for pupils. Like pupils in physics, prospective teachers typically hold misconceptions about teaching and learning which they have mostly developed from their experiences as pupils at school. If this assumption is valid than we can expect prospective teachers' learning processes about educational issues to be similar to pupils' learning processes in physics. Therefore, prospective teachers have to explore educational examples systematically in order to establish at least an intuitive understanding of appropriate (phenomenon-based) concepts about learning and teaching. They need to express these concepts explicitly and have to have the opportunity to re-discover them with similar examples and problems before they are able to use these concepts to plan their instruction and will understand model-based explanations. Subsequently, we can expect that teachers are able to "activate" their conceptual knowledge while teaching. Hence, the common experience that teachers do not connect theory to practice might be a result of our teacher education. Typically, we inform teachers about theory and expect them to transfer this theory into practice. With respect to the results on students' processes of concept formation we should develop theory from practice rather than expecting that teachers can "simply" be informed successfully about theory. Using just a few "good" examples to demonstrate concepts about science education will, similar to students, result in teachers learning the appropriate descriptions without understanding them conceptually: "Whenever I am asked about constructivism, I have to answer XY" (this would be a phenomenon-based conception about phrasing rather than a model-based understanding about constructivism).

Again, it seems fairly trivial to conclude that teacher education requires appropriate examples. As also discussed above, our impression is that the amount of specific examples and the way these have to be structured is by and large underestimated in teacher education. To be a little provocative, our experience with teacher education is sometimes that there is almost no connection between what is taught and how it is taught.

Summary

The main idea communicated throughout this paper is to distinguish between non-conceptual understanding (which we labeled as explorative and intuitive rule-based approaches) and conceptual understanding (which we labeled as explicit rule based-approach). Rather than focusing solely on students' ideas being correct or incorrect, these qualities together with the distinction between phenomenon-based and model-based concepts provide a powerful framework for the analysis of students' learning processes and the demands of instruction (see also v. Aufschnaiter, 2006a; v. Aufschnaiter & v. Aufschnaiter, 2007). As the distinction has to be applied to students' content specific activities but does not include content specific descriptions in itself, it can be used in different topics and (probably) in different subjects.

On the basis of our findings we have argued that conceptual knowledge is a result and not an initiator of (learning) activities and, thus, that students' prior experiences promote and hinder intended concept formation. Taking our findings into account, we furthermore argue that the problem of inert knowledge (respectively the mismatch between theory and practice) might often be a result of conceptual understanding not yet established rather than not being transferred. Students, prospective teachers and teachers often either develop an intuitive rule-based understanding of how to describe specific events or develop an explicit rule-based conceptual understanding of when to say what but do not grasp the content of the scientific concepts they can talk about.

Despite our findings, further research on that topic is needed. For instance, the following research questions still remain to be worked on:

- Is there any instruction resulting in (much) more explicit conceptualizations than reported in this paper?
- Can the distinctions be applied successfully to other science subjects?
- Which kind of conceptual quality do students incorporate into their argumentations (see also v. Aufschnaiter, Erduran, Osborne, & Simon, 2008)?
- Does the development of a conceptual understanding about the nature of science and about scientific inquiry follow similar processes?
- What kind of impact do different approaches towards teaching (dialogic vs. authoritative, constructivistic, inquiry-based, etc.) have on students' situated conceptual understanding?
- Is the assumption valid that teachers' learning processes about educational issues can be described similar to students' learning processes in physics?

Finally, we have to notice that almost everything presented in this paper refers to phenomenon-based conceptions which we have developed from our thorough analysis of students' learning processes. Even though we agree that model-based conceptions are important in our field (and have presented some of these for neuro-cognitive arguments, e.g., v. Aufschnaiter & v. Aufschnaiter, 2003a), we would also like to stress that improved phenomenon-based conceptions about the mechanisms of teaching and learning provide a powerful basis for any further educational research. Furthermore, they offer the possibility for theory formation aiming to explain why we identify specific rules about the mechanisms. Thus, all research questions presented above seek to explore in detail the phenomena occurring while learning and teaching.

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Notes

[1]*Any moving camera requires a camera person behind the camera. Our experience with such a person is that he/she attracts students' attention more than a fixed camera. This is the reason why we set our cameras up in advance of any video-recording. These cameras already record when students enter the room and the recording is stopped only when students have left the room. Thus, the cameras very quickly become some sort of furniture typically only attracting students' attention when they are bored, frustrated, or very satisfied (i.e., need to express some emotions).*

[2]*The reason why we are not stating that this is an implicit understanding (according to Rittle-Johnson, Siegler, & Alibali, 2001) is our idea of the meaning of the term "implicit". In our understanding "implicit" refers to something that is already "there" and is obvious to an observer. "Intuitive" in our understanding stresses a little more how the understanding is created rather than that it is already located somewhere. However, we are well aware that in some research projects "intuitive" is used for knowledge developed outside school contexts (e.g., Sherin, 2006), which does not match our meaning.*

[3]*We have trialed similar approaches in our content specific pre-service teacher education. Typically, students express that this is the first time they really "understand" electric circuits. However, it is obvious that the dynamic interrelationship between the set-up, included resistors, measures of current, and measures of voltage is at any level difficult for students. They often fail to connect three or more parameters in one line of thought and have then problems in approaching a phenomenon appropriately.*

[4]*The "p-prims" described by diSessa (1993) are probably either intuitive rule-based or explicit rule-based phenomenon-related ideas (which concurs with the notion of "phenomenological primitives").*

[5]*Such as asking questions like "Why is the sea salty" before students have established an understanding that the sea is salty (probably a common experience to a large number but not to all students), that not all seas are (similarly) salty, what is different between these seas and so on (see, SAC, 2008).*

APPENDIX 1. Brief coding schema on students' (conceptual) understanding

Main categories	Subcategories *Students…*	Description	Example (heat transfer)
explorative approach	act/ experiment	Students explore phenomena, e.g. carry out an experiment or measure a value. In addition, students can simultaneously describe their activity. [Just watching, reading or writing is not coded.]	(student touches an iron cube) "Touch this iron cube. It's cold."
	describe with visual aid	Students observe objects, events or situations and describe them.	(student looks at the thermometer) "The temperature is increasing."
	describe without visual aid	Students describe objects, activities or situations without observing them. Also: Students make a guess what will happen.	[student remembers:] "The water got colder."
intuitive rule-based approach	assume	Students make an assumption about what will happen. Students emphasize an aspect that is important from their point of view.	"The cold water in the petri dish will certainly reach 22 degree."
	attribute	Students make use of specific linguistic elements (particularly Physics terms) to label and describe phenomena and objects.	"This hot gel pack is a heat source."
	explain	Students explain how different concrete aspects, phenomena or situations relate to each other.	"This gel pack didn't cool down because it's wrapped in a newspaper."
explicit rule-based approach (conceptual)	generalize	Students express a generaliztion explicitly. They formulate a rule-based relationship.	"Objects adapt to the temperature of the environment."
	explain rule-based	Students use generalisations or rule-based relationships in order to explain a particular or general situation.	"This rod is at room temperature because objects adapt to the temperature of the environment."
	predict rule-based	Students explicitly refer to generalizations or rule-based connections when predicting the progress of a particular or general situation (e.g., the result of an experiment).	"The white sheet of paper won't get that warm because light and bright surfaces reflect thermal radiation."

Note. This schema is a shortened version of the German coding manual (Rogge, in prep.). This manual as well as the schema are still under revision

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Pre-Service Mathematics Teachers' Use of Multiple Representations in Technology-Rich Environments

Mehmet Fatih Özmantar
Gaziantep Üniversitesi, Gaziantep, TURKİYE

Hatice Akkoç
Marmara Üniversitesi, İstanbul, TURKİYE

Erhan Bingölbali and Servet Demir
Gaziantep Üniversitesi, Gaziantep, TURKİYE

Berna Ergene
Beşiktaş Anadolu Lisesi, İstanbul, TURKİYE

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In this paper, we examine the development of pre-service mathematics teachers' use of multiple representations during teaching in technology-rich environments. The pre-service teachers took part in a preparation program aimed at integration of technology into teaching mathematics. The program was designed on the basis of Technological Pedagogical Content Knowledge (TPCK) framework; and the mathematical content chosen for the program was the concept of derivative. The pre-service teachers' development was scrutinized in terms of their knowledge of representations, of connections established among the representations, and of the aspects of derivative emphasized by these connections. On the basis of our analyses we argue that any attempt to prepare pre-service teachers for effective use of technology in teaching mathematics needs to explicitly focus on the functions of multiple representations in tandem with the mathematical content under consideration. We discuss the educational implications of the study in designing and conducting of the preparation programs related to the successful integration of technology in teaching mathematics.

Keywords: derivative, multiple representations, pre-service teachers, TPCK

INTRODUCTION

The issue of multiple representations (MRs) is an important one in mathematics education and attracted the interest of researchers especially within the last three decades. One reason for the increasing interest is related to the NCTM (National Council of Teachers of Mathematics) Standards (NCTM, 1989) in which use of MRs while teaching mathematics is strongly emphasized:

> *Different representations of problems serve as different lenses through which students interpret the problems and the solutions. If students are to become mathematically powerful, they must be flexible enough to approach situations in a variety of ways and recognize the relationships among different points of view (p.84).*

Here in these lines it is suggested that each individual representation provides students with a point of view through which they can approach to a problem and this

Correspondence to: Mehmet Fatih Özmantar, Ph.D in Mathematics Education, Gaziantep Üniversitesi, Eğitim Fakültesi, Gaziantep, TURKEY
E-mail: ozmantar@gantep.edu.tr

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State of the literature

- Use of multiple representations (MRs) is important as they can potentially create conditions for effective learning and as they lead to deeper levels of understanding of the subject.
- Research on MRs show that unless the links between and among the MRs are stressed, student experience difficulties in connecting the MRs by themselves. However teachers do not explicitly focus on the links in their instructions.
- As the technology has the potential to make these links explicit, we, in this study, focus on pre-service teachers' utilization of MRs in technology rich environments after they took a course designed for the integration of technology into teaching.

Contribution of this paper to the literature

- The study contributed to the extant literature in at least four ways. First of all there was rather limited research on how pre-service teachers make use of technology in addressing MRs and on the ways in which their competence for that matter can be developed. This study contributes to our understanding of these issues.
- Secondly, our participants showed important developments in the use of MRs via technology. This development comes about through a course designed on the basis of Technological Pedagogical Content Knowledge framework (TPCK). The results suggest that TPCK is a useful design tool for that matter.
- Thirdly, integration programs need to be designed in ways that allow participants to eliminate obstacles stemming from the lack of technological pedagogical and technological content knowledge with reference to MRs.
- Finally, in order for future teachers to make an effective use of MRs in their teaching, they themselves need to experience and explore the potentials of technology as a learning resource rather than a computational device.

in turn allows them to become more competent in handling mathematical problems. The research on MRs indicates two important benefits in their use: 1) MRs cater for wider range of students with different learning styles and hence promote conditions for effective learning (Mallet, 2007) and 2) use of MRs leads students into deeper understanding of the subject as each representation emphasizes different aspect of the same concept (Berthold et al., 2009).

The issue of MRs attracted more attention from the Council with the spread of digital technologies in teaching and learning environments. In 2001, for example, the Council's yearbook focused on the roles of representation in school mathematics (Cuoco, 2001). The yearbook attaches considerable importance to the use of digital technologies in making representations available to the students. As NCTM suggests, digital technologies provide visual models or representations that many students are unable to generate through their independent efforts. Zbiek et al. (2007) note that technology can potentially underline the important qualities of individual representations, making it easier for the students to interconnect them and hence achieve a robust understanding.

In an extensive literature review, Ainsworth (1999) examines the representations that educational technologies offer. On the basis of this examination, the author develops a functional taxonomy of MRs. The taxonomy differentiates three main functions that MRs serve in learning situations: to complement, constrain and construct. The three main functions are further divided into several sub-classes (see Figure 1). Ainsworth argues that one single representation could involve more than one function.

The first function Ainsworth cites is that MRs can be used for complementary roles; that is, different representations involve distinct yet complementary information or may support different processes. Combination of MRs with complementary roles is expected to create an environment where learners can benefit from the aggregate of their advantages. Consider, for example, the absolute value function compactly expressed in algebraic form as $y=|x|-5$. This representation affords one to find the value of y for any given value of x, regardless of how large the x is. However, this representation does not show the variation as explicitly as the equivalent graph which also unveils trends and interaction between the values of x and y. Hence these two representations support different processes and carries different yet complementary information from which learners can benefit in understanding the notion of, for instance, absolute value functions.

The second function that Ainsworth points out is that MRs can be employed to constrain interpretations: representations can confine inferences, allowing one to constrain potential (mis)understandings stemming from the use of another one. This can be done either by employing a known representation to construe a less familiar one or by making use of inherent properties of one representation to limit the inferences drawn from a second one. As an example, consider the absolute value functions once again. Students may over-generalize the meaning of absolute value and have a misconception that these functions must take only positive values (as it involves absolute value; see Ozmantar (2005) for more on this) and hence have misinterpretations as to the

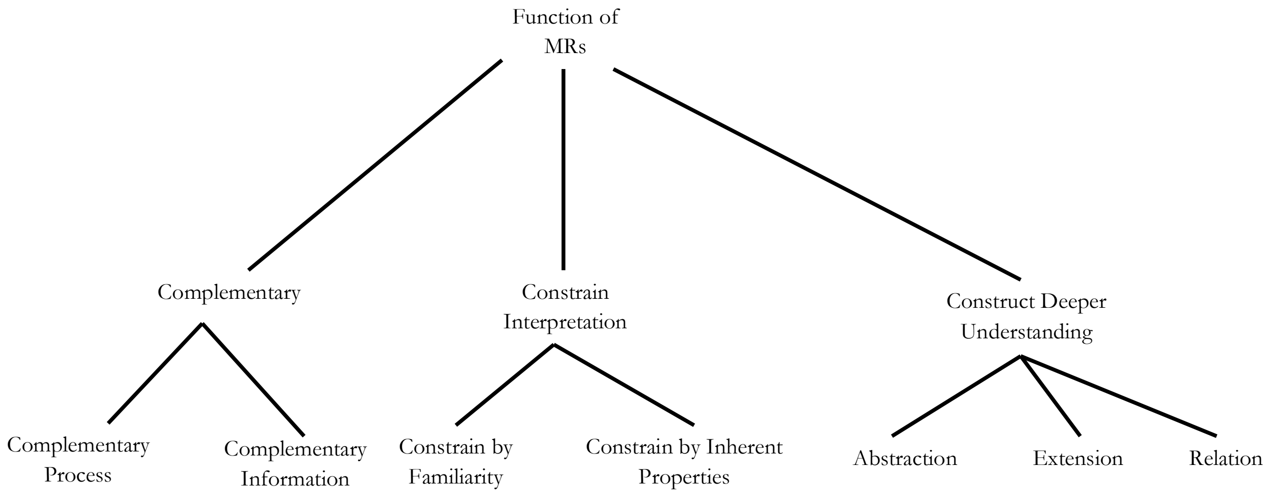

Figure 1. A functional taxonomy of multiple representations (Ainsworth, 1999, p.134).

graphs of such functions. Graphs of absolute value functions such as $f(x) = |x| - 1$ can be used to constrain the students' conceptions of the graphical representations of absolute value functions. Hence when the MRs are used for constraining, the purpose is not necessarily provide new information but "to support a learner's reasoning about a less familiar one. It is the learner's familiarity with the constraining representation, or its ease of interpretation, that is essential to its function" (Ainsworth, 1999, p.139).

The third function is that MRs could be used to construct deeper understanding of the concept under consideration. Ainsworth (1999, p.141) cites Kaput (1989) that "the cognitive linking of representations creates a whole that is more than the sum of its parts. ... It enables us to 'see' complex ideas in a new way and apply them more effectively." Ainsworth claims that construction of deeper understanding occurs through abstraction, generalization (or extension) and relations. With regard to abstraction, exposure of MRs is hoped to lead learner to construct references across the representations. This knowledge is then assumed to allow the learner to find out the underlying structure of the concept under investigation. Generalization refers to a learner's extension of his/her knowledge without fundamentally changing the nature of that knowledge. For example, one may know how to interpret increasing or decreasing functions on the basis of their algebraic representations. He/she may later extend this knowledge to the interpretations of such representations as the increasing (or decreasing) graphs or tables of values. Finally, construction of deeper understanding can also occur through teaching the relations among different representations. The pedagogical concern here is not so much with teaching each representation but rather with teaching to translate between two or more representations which are introduced simultaneously.

When the research studies are scrutinized carefully, it is realized that teachers stand out as important factors that make a difference in successful use of MRs in technology rich-environments. Hence teachers' knowledge about the representations, how they use MRs for teaching, and how they make use of technology in addressing the MRs are all important issues to be considered while teaching with MRs through technology. Despite its importance, there does not appear much research on how teachers or pre-service teachers use MRs for teaching in technology-rich environments. We found two studies focusing on this issue (Juersvich et al., 2009; Alagic & Palenz, 2006). In their study, Juersivich et al. (2009) investigated how pre-service teachers utilized the provided technology to generate MRs. They found that pre-service teachers realized the potential of technology to provide MRs that support pupils' sense making in ways that could not be possible under typical conditions. Alagic and Palenz (2006) emphasize that teachers need pedagogical and technological support when integrating technology into teaching and provided technology-based representations in real-life contexts for mathematics teachers as part of a professional development program. They found that teachers learnt how to make connections between MRs using technology. However these studies provide insufficient details as to the way in which pre-service mathematics teachers (PSMTs) employ MRs and of how their competence to effectively use MRs in technology-rich environments can be developed.

With this gap in the literature in mind, our purpose in the paper is to examine the development of PSMTs with regard to the use of MRs during teaching in technology-rich environments. To this end, in the rest of this paper, we first briefly detail the context of our research that aimed to develop a program for PSMTs to integrate technology into teaching. Then we focus on methodology and present data analyses and our findings. The paper ends with a discussion of the issues regarding the effective use of MRs through technology and the educational implications of our findings.

THE RESEARCH AND METHODOLOGY

In this part of the paper, we briefly sketch out the research project that gave rise to this study. To do this, we first attend to the course designed for the pre-service teachers on the basis of "Technological Pedagogical Content Knowledge" (TPCK) framework and second provide the content of the course with regard to MRs.

COURSE DESIGN WITH TPCK FRAMEWORK

This study is part of a research project which aims to develop pre-service mathematics teachers' TPCK (Mishra & Koehler, 2006). For this aim, a course was designed by using TPCK framework which has been recently used to investigate the characteristics of knowledge required by teachers for successful technology integration. TPCK framework was originated from the notion of "Pedagogical Content Knowledge (PCK)" offered by Shulman (1986, 1987). Shulman (1987) drew attention to the significance of "subject matter for teaching" and considered PCK as an important domain of teachers' knowledge. In Shulman's view PCK is an amalgam of content knowledge and pedagogical knowledge. In Shulman's (1987, p.8) view, "pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue."

The notion of PCK is extensively studied in many domains and guided the efforts to understand the teaching approaches of both in-service and pre-service teachers (e.g., Uşak, 2009; Abd-El-Khalick, 2006).As the importance and potential of technology in teaching and learning is realized, Pierson (2001) has included the

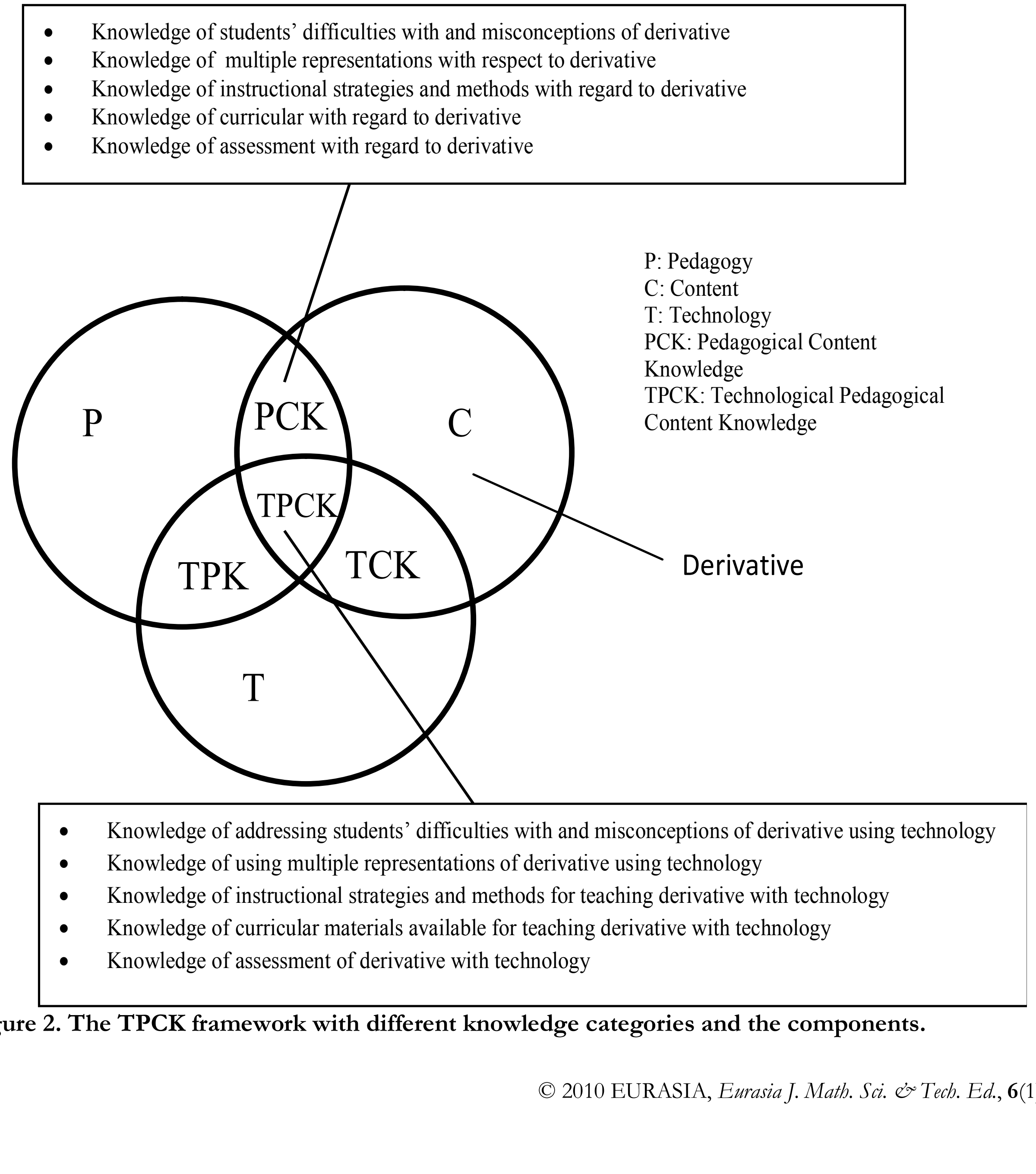

Figure 2. The TPCK framework with different knowledge categories and the components.

technology component into the idea of PCK and considered TPCK as a blend of three categories of knowledge: content, pedagogy and technology. Mishra and Koehler (2006) depict TPCK as an intersection of these three types of knowledge (see Figure 2). The authors also classify where the pairs of different types of knowledge intersects: pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK). TCK is concerned with the inter-animation between the technology and content; that is, for example, the knowledge of MRs of a concept that a software is able to offer. In this regard, Mishra and Koehler (2006) write "teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology" (p. 1028). TPK is "the knowledge of pedagogical strategies and the ability to apply those strategies for use of technologies" (ibid., p. 1028) e.g. knowledge of how to make use of a specific software in establishing the links among the different representations.

We employed TPCK framework to design the course for the PSMTs to successfully integrate the technology in teaching. However, this framework, though provided us with a lens for the design, was lacking in sufficient details with regard to the components that each intersection of the pairs of knowledge categories has. To overcome this problem, we examined PCK components suggested by the relevant literature and used them to determine the components of TPCK. In our examination, we found the components of PCK suggested by Grossman (1989, 1990) and Magnusson et al. (1999) rather useful; these components were:

i.knowledge of instructional strategies and methods for teaching a particular concept
ii.knowledge of representations of a particular concept
iii.knowledge of student misconceptions of the concept
iv.knowledge of purposes for teaching the concept
v.knowledge of curriculum materials available for teaching the concept.

We adapted these components to the TPCK framework for the design of the course. Our endeavor eventually led us to generate the following components of TPCK for the design of our courses:

- *Knowledge of addressing students' difficulties and misconceptions for a particular concept using technology;*
- *Knowledge of using MRs with technology;*
- *Knowledge of instructional strategies and methods for teaching a particular concept using technology;*
- *Knowledge of curricular materials available for teaching a particular concept with technology;*
- *Knowledge of assessment of a particular concept with technology*

We aimed to use TPCK framework with its five components to develop contents for two courses (which we name as Methods for Teaching Mathematics II and Technology-Aided Mathematics Teaching in this paper) as part of a project for PSMTs in Turkey. The course contents were developed by three of the authors collaboratively and they were run by the second author. The aims of these courses were, broadly speaking, to get PSMTs equipped with the skills of teaching mathematics with the aid of technology at secondary level.

We used the five components of PCK to develop contents in five parts. First we amended PCK's five components to generate five corresponding components that we interpret as components of general pedagogical knowledge (PK). The reason we do this was to develop a generic approach and get PSMTs equipped with an overall perspective for any concept in mathematics. Second we brought the content aspect

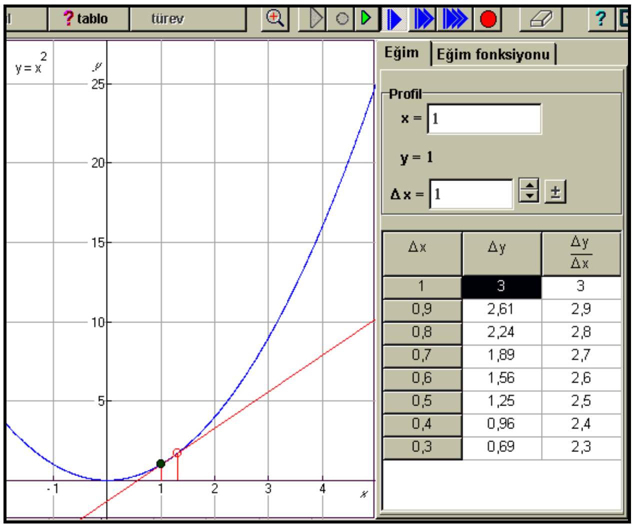

Figure 3. Derivative at a point in Graphic Calculus

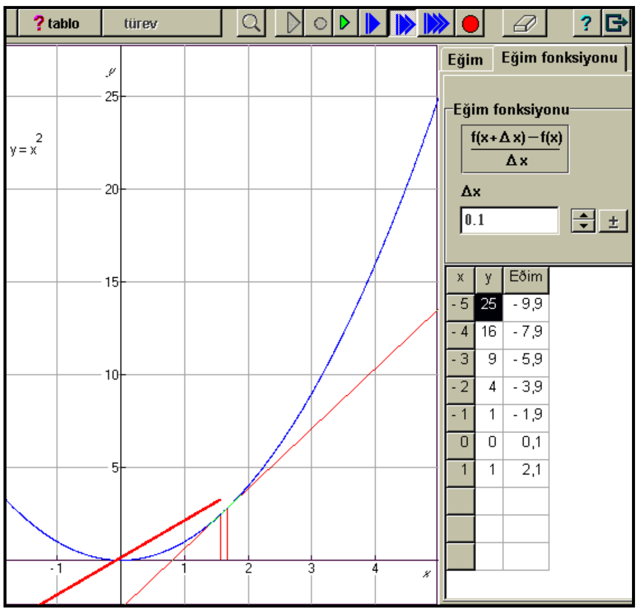

Figure 4. Slope function of derivative

into play and aimed to exemplify how these components can be applied with a particular mathematical concept and we used the concept of derivative for that purpose. Thirdly, we introduced the software (a Turkish version of Graphic Calculus) and planned hands-on activities to explore technological content of the software in general (TK) and technological content of the software for derivative in particular (TCK). Fourth, we amended TPCK's five components to generate five corresponding components that we interpret as components of general technological pedagogical knowledge (TPK). Finally, we brought content aspect into play in the context of technology and aimed to exemplify how these components can be applied with teaching derivative concept using technology.

As our focus in this paper is on MRs, we now turn our attention to "multiple representation component" and first present its content with regard to PCK and TPCK. Before presenting the course content, it will be explicative to mention about how the course content was presented to the PSMTs. During the courses, the instructor made use of PSMTs prior knowledge and asked them questions for discussions using PowerPoint software. Pre-service teachers worked in groups on the discussion points and shared their ideas with the whole class. When technology came into plan, the PSMTs used computers in pairs and used the software in a computer lab. PSMTs were informed about the TPCK framework and objectives of the course which were specified by the course designers for each component of PK, PCK, TCK, TPK and TPCK.

Content for PK with regard to multiple representations

During the course, PSMTs were asked to share their existing knowledge of MRs and provided with the knowledge of algebraic, numerical and graphical representations of mathematical concepts, the relationships among them, and how to take them into account in teaching. Function and limit concepts are used to exemplify the MRs. Limitations and affordances of each representation were also discussed in the contexts of functions and limit.

Content for PCK of derivative with regard to multiple representations

PSMTs were presented with an example of a function and were asked to produce algebraic, numerical and graphical representations of derivative at a given point. They then discussed connections between three aspects of derivative (instantaneous rate of change, the slope of the tangent line to a curve at a particular point and the limit of the difference quotient; see Bingolbali (2008) for more details) and how algebraic, numerical and graphical representations could be linked to relate these aspects of derivative during teaching.

Content for TCK with regard to multiple representations

Technological content introduced to pre-service teachers is a Turkish version of Graphic Calculus software (Blokland, Giessen & Tall, 2006). The software and an activity book in Turkish (Akkoç, 2006) were given to each pre-service teacher. Graphic Calculus software provides graphical and numerical representations of derivative at a point which are dynamically linked as can be seen in Figure 3. As the software calculates the values of rates of change for smaller values of Δx, the secant lines approach to the tangent to the point.

The software also presents slope function by dynamically assigning x values of a function to the slopes of the tangents to the graph of this function at given values of x.

PSMTs were given a worksheet which requires them to evaluate the numerical values of rate of change in the table as seen in Figure 3 and 4. They were also asked to discuss in groups on how the software drew the slope function and the difference between slope function and derivative function.

Content for TPK with regard to multiple representations

Having discovered the technological content of the software with regard to derivative concept, PSMTs discussed TPK with regard to MRs. They were asked to discuss the affordances and limitations of the software

Table 1. The average rate of change of $f(x)=x^2+1$ in the neighborhood of $x=3$

x	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5
Δx	-0.5	-0.4	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.4	0.5
Δx	-2.75	-2.24	-1.71	-1.16	-0.59	0.61	1.24	1.89	2.56	3.25
$\frac{\Delta y}{\Delta x}=\frac{f(x)-f(3)}{x-3}$	5.5	5.6	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.5

in terms of MRs. They were asked to draw y=sin$x$, y=sin2x, y=sin(x/2), y=2sin$x$ and y=(sin$x$)/2 using the software and discuss how technology provides opportunities to make links between representations. The notion of periods of trigonometric functions was introduced to PSMTs and a discussion started on how it differs from paper and pencil techniques to introduce periods of trigonometric functions. TPK content ends with a discussion on the affordances and limitations of the software with regard to the use of MRs with the availability of technological tools.

Content for TPCK with regard to multiple representations

Following the content for TPK with regard to MRs, TPCK of MRs of derivative at a point was introduced. Two main activities as shown in Figure 3 and Figure 4 were re-examined and the following questions were discussed:

- *In each activity, what kinds of representations of derivative at a point are available and what kinds of opportunities are there to make links between representations?*
- *What kinds of opportunities are there to relate three aspects of derivative (derivative-rate of change, derivative-slope and derivative-limit) using the software?*

In addition to these discussion points, PSMTs' attention was drawn to the limitations of the software in terms of rounded values of rate of change in the table produced by the software (For smaller Δx values, the software rounds up the values of rate of change; e.g. 2.000001 is rounded up to 2). PSMTs were asked to discuss how this limitation could be avoided or potentially used to promote student learning.

After PCK and TPCK contents were given as described above, micro-teaching videos of derivative lessons which were performed by pre-service teachers a year ago were watched and discussed in terms of how MRs were used.

The participants

A cohort of 40 PSMTs participated in the research. The PSMTs initially took a three-and-half years mathematics program at the university and then enrolled the secondary mathematics teacher preparation program. The graduates of the program will teach mathematics at secondary level and have a strong mathematical background. The preparation program for the PSMTs involves such courses as Teaching Methods, Educational Psychology and Assessment. The data for this study collected during the courses "Methods for Teaching Mathematics II" and "Technology-Aided Mathematics Teaching." All forty PSMTs enrolled these courses which were designed on the basis of TPCK framework as explained hitherto. The content of PCK with five components was delivered to the PSMTs during workshops. Then, ten PSMTs did microteachings before their peers who took observation notes on the microteachings. Following this, the TPCK content was delivered to the PSMTs with five components each of which was introduced in separate workshops. For the TPCK workshops the Graphic Calculus software was also demonstrated to the PSMTs who were allowed to work independently for the purpose of exploration. Ten PSMTs did micro teachings once again but this time they employed Graphic Calculus software to introduce the concept of derivative.

DATA COLLECTION

During the research, several data collection tools were employed, including: diagnostic test on derivative, lesson plans, detailed teaching notes used during microteachings, video records of micro-teachings, interviews and questionnaires.

Diagnostic test on derivative: Despite the fact that PSMTs spent three-and-half years in pure mathematics courses, it was important to see their conceptual understandings of the notion of derivative. Hence, a test with several items, which aimed to find out PSMTs' understandings and concept images (Tall and Vinner, 1981) of derivative, was applied to all participants.

Lesson plans: The participants were asked to prepare three lesson plans: one before the course started, one after the PCK workshops and the last was after the TCPK workshops. All three lesson plans were on the same topic: introduction of derivative. The lesson plan format had sections on objectives,

Table 2. PSMTs' responses for the meaning of MRs.

	Number of PSMTs (N=40) (Before the course starts)	**Number of PSMTs (N=40)** (After the TPCK workshops)
Graphical representation	2	36
Tabular (numerical) representation	1	38
Algebraic representation	1	37
Different representations of a concept	7	17
Use of different symbols for the expression of a concept	8	0
Unanswered	15	0
Others	6	9

prerequisite knowledge, materials used, classroom organization, outline of teacher and student activities, and assessment during and after the lesson. To prepare the plans, the PSMTs were allowed to make use of any textbook they wish and also required to examine the curriculum scripts.

Detailed teaching notes: Those who were to do microteachings were asked to prepare detailed teaching notes which were later retained by the research team. These notes included PSMTs' suggestions and personal reminders of particular issues to attend to during their teachings.

Video records of micro teachings: Ten PSMTs were asked to do microteachings before their peers in two occasions. The first microteachings were performed just after the completion of the PCK workshops and the second one took place following the TPCK workshops. After the microteaching sessions, the performing teacher candidates made reflections on their approaches and performances with regard to the components of PCK (or TPCK) and also had a chance to hear the reactions and/or observations of their peers.

Interviews: The research team conducted semi-structured interviews with those doing the microteachings. The interviews took place before and after each microteaching sessions. The PSMTs were asked a series of questions regarding their preparations and the lesson plans. After the microteachings, they were interviewed about their performance. Both of the interviews were shaped on the basis of the components of PCK (or TPCK).

Questionnaires: The open-ended questionnaires were also used to find out the PSMTs' initial understandings of the components of PCK in a general manner (e.g., student difficulties, MRs, instructional strategies, assessment and curriculum). The questionnaire was applied twice, at the start and end of the course.

DATA ANALYSIS AND FINDINGS

Analyses of the data will be presented in two sections. In the first one, we present our quantitative analyses on the basis of mainly lesson plans with regard to the use of MRs. In the second one, we present a case study in which microteaching of a pre-service teacher is examined to give the reader a better appreciation of the nature of PSMTs' development. Before going into data analyses, however, we feel it useful to briefly mention about the MRs of derivative which we focused during the course and employed in our analyses.

Multiple representations of derivative

The concept of derivative at a point can be defined in three main ways: (i) the slope of the tangent line to a curve at a particular point, (ii) the limit of the difference quotient and (iii) the instantaneous rate of change (Bingolbali, 2008). Of these three, the limit of the difference quotient aspect lies at heart of the derivative interpretation and helps to understand the other two aspects. It is through the limit of the difference quotient aspect that we can actually make sense of the slopes of secant lines approaching to the slope of tangent line. Similarly, it is through the limit of the difference quotient aspect that we can make sense of average rate of changes approaching to the instantaneous rate of change at a particular point. A conceptual understanding of the derivative and its teaching for such an understanding, therefore, require an understanding of how all these aspects are related and presented in a connected manner in its teaching.

Among many other things, the successful use of such MRs as algebraic, graphical and tabular (numerical) is a way to make links between and among the aspects/interpretations of derivative. The uses of these different representations are considered to pave the way for the conceptual understanding of the derivative in its teaching (Amoah & Laridon, 2004). The uses of graphical and numerical representations are particularly emphasized alongside the common use of algebraic representation (ibid.). Below the function of $f(x)=x^2+1$ and its derivative at a particular point are presented to illustrate how these representations can be used to make sense of the derivative concept (Akkoç, 2008).

The derivative of the function of $f(x)=x^2+1$ is equal to $f\,'(x)=2x$. This derived function can be obtained through the fundamental rule of differentiation or through the limit of difference quotient. After finding out the derived function, the derivative (slope, instantaneous rate of change) at a particular point can be calculated. The derivative of the given function, for instance, at $x=3$ is equal to 6. Calculating the derivative in this manner is an example of finding it out algebraically.

The derivative of the function of $f(x)=x^2+1$at $x=3$ can also be represented numerically as shown in Table 1. From both sides of $x=3$, the average rates of changes approach to 6 as the width of the intervals goes to zero. Note that the value 6 is the derivative of the function at the point $x=3$.

In addition to its algebraic and numerical representations, the derivative of the function of $f(x)=x^2+1$ at $x=3$ can be represented graphically as well. It can graphically be seen that the slopes of secant lines from both sides of $x=3$ approach to the value 6, which is the slope of tangent line to the curve at $x=3$.

What have been presented so far suggests that the three different aspects of derivative can be better appreciated through the use of three MRs.

QUANTITATIVE ANALYSES OF THE DATA

In this section, we provide the results of our analyses of the questionnaires and lesson plans. The first thing that we desired to find out was PSMTs' understanding of MRs. The data for the PSMTs' understanding of MRs came from general pedagogy questionnaire in which PSMTs were asked what the multiple representation of a mathematical concept is. The PSMTs' responses to this item generated following categories as presented in Table 2.

As can be seen in Table 2, PSMTs gave examples of MRs such as "graphical", "tabular (numerical)" and "algebraic" to explain what MRs meant as the first three categories of responses. However, very few PSMTs gave these examples before the course. The number of PSMTs who gave these examples increases considerably after they took TPCK course. One interesting result is concerned with PSMTs' misunderstandings about MRs. Before the course, eight PSMTs considered "symbols" used in mathematics as MRs. On the other hand, none of them had this misunderstanding after TPCK course. Overall, these results indicate that PSMTs' understanding of what MRs meant had dramatically improved.

After the analyses of the PSMTs' responses to the questionnaire item, we turn our attention to their lesson plans and analyze initial two plans: one before the course starts and one after the PCK workshops. Analyses of the lesson plans before the course suggest that 12 PSMTs used only one representation of derivative and the rest used at least two representations. This figure changes after the PCK workshops in that 38 of the PSMTs used two or more representations while introducing derivative. It was interesting to observe that although many PSMTs did not show a solid understanding of the issue of MRs in the questionnaire item, 28 of them were able to use more than one representation in their lesson plans. One reason for this, we believe, is related to the fact that PSMTs examined the curriculum scripts and textbooks, which guided their preparation of lesson plans.

We then decided to examine lesson plans to figure out if the PSMTs make connections between the MRs

Table 3. Frequency analysis of the links established among different representations

	First lesson plans		Second lesson plans	
Categories	**N**	**%**	**N**	**%**
MRs are not linked	34	85.0	9	22.5
One pair linked	3	7.5	5	12.5
Two pairs linked	1	2.5	8	20.0
Three pairs linked	0	0	2	5.0
All three MRs are interconnected	0	0	12	30.0
No response	2	5.0	4	10.0
Total	40	100.0	40	100.0

Table 4. Frequency analysis of the aspects of derivative addressed in the lesson plans

	First lesson plans		Second lesson plans	
Categories	N	%	N	%
None	28	70.0	6	15.0
Only one aspect	8	20.0	6	15.0
Two aspects	1	2.5	6	15.0
All three aspects	0	0	2	5.0
The three aspects are interconnected	0	0	19	47.5
Unanswered	3	7.5	1	2.5
Total	40	100.0	40	100.0

Table 5. The frequency analysis of the use of technology for the MRs of derivative

Categories	**N**	**%**
None	1	2.5
Only one pair	5	12.5
Only two pairs	1	2.5
All three pairs	2	5.0
Three representations are interconnected	27	67.5
Unanswered	4	10.0
Total	40	100.0

used in the lesson plans. Considering that we focus on three common representations of derivative (algebraic, numeric or tabular, and graphical), in our analyses we focused on the categories of possible connections among the MRs of derivative as follows.

- *MRs of derivative (Graphical (G), Numerical (N) and Algebraic (A)) are not linked.*
- *Only one pair of representations are linked (any one of G-N, G-A, or N-A)*
- *Only two pairs of representations are linked (any two of G-N, G-A, and N-A)*
- *Three pairs of representations are linked (pairs of G-N, G-A, and N-A are all present)*
- *All three representations are interconnected to one another (the pairs of G-N, G-A, and N-A as well as G-N-A are present)*

On the basis of these categories, we analyzed the first and second lesson plans and our analyses are presented in Table 3. PSMTs' initial lesson plans prepared before the PCK workshops reveal that 85% of the participants did not link the MRs of derivative used in the lesson plans. However, this figure drops to 22.5% after the PCK workshops. It is also remarkable that among the first plans, there was not a single one that attempted to establish links among all three representations; yet after the PCK workshops there were 12 (30%) plans which explicitly linked all three MRs of derivative. A holistic evaluation of the figures clearly shows that PSMTs gained an awareness of the necessity of establishing links among the MRs of derivative and made an effort to reflect this awareness into their lesson plans.

As mentioned before, there are close relationships between the use of MRs and the different aspects of derivative (the slope of the tangent line to a curve at a particular point, the limit of the difference quotient and the instantaneous rate of change). A true understanding of this concept requires a holistic view of these aspects and a grasp of the relevance of one to the others. Hence we assume that an effective teaching needs to make use of MRs in relating the aspects of derivative to one another. With this assumption in mind, we also analyzed the lesson plans to find out if the PSMTs used MRs to demonstrate the connections between the different aspects of derivative. To this end, we created categories for the aspects of derivative attended to in the lesson plans and carried out our analyses accrodingly. These categories were as follows.

- *None of the aspects of the derivative is introduced.*
- *Only one aspect is addressed: any one of Derivative-Rate of change, Derivative-Limit or Derivative-Slope is focused.*
- *Two aspects are addressed: any two of Derivative-Rate of change, Derivative-Limit and Derivative-Slope relationships are emphasized.*
- *Three aspects are addressed: all the three are emphasized but are not interrelated.*
- *The three aspects are both addressed and interconnected: the three aspects of derivative are related to one another (Derivative-Rate of change-Limit-Slope).*

Our analyses based on these categories show (see Table 4) that while in the initial lesson plans, 70% of the PSMTs did not mention about any aspects of derivative, this figure drops to 15% after the PCK workshops. There is a dramatic increase in the number of those who addressed the three aspects and related them to each other through MRs of derivative: almost half of the second lesson plans (47.5%) did so; compare this with the first plans in which there was none. Generally speaking, in the first lesson plans the aspects of derivative was ignored while in the second plans, except for the 7 PSMTs, at least one aspect was taken into consideration. These figures clearly show that the PSMTs has certainly gained an awareness as to the importance of different aspects of derivative and also gained insights into these aspects. They hence made an effort to prepare the second plans accordingly and reflected their understandings into their approaches.

So far, PSMTs' lesson plans have been analyzed in terms of MRs and different aspects of derivative. We now turn our attention to the use of technology in connecting the MRs and the different aspects of derivative. For this purpose, we analyzed the third lesson plans which were produced after the TPCK workshops. Our initial analyses suggested that 87.5% of the participants used at least two representations of derivative with the help of technology. We further analyzed the lesson plans with a greater detail to see if technology was used to link the MRs of derivative. For this purpose we created the following categories.

- *None: technology was used to link none of the MRs with one other.*
- *Only one pair: any one of the G-N, G-A, or N-A connection was planned with technology.*
- *Only two pairs: any two of G-N, G-A, or N-A connection was planned with technology.*
- *Three pairs: All three pairs of G-N, G-A, and N-A are linked with technology.*
- *Three representations, G-N-A, are interconnected to one another with technology*

The analyses of the third lesson plans along with these categories yield the results as presented in Table 5. As can be seen , a great majority of the PSMTs (67.5%) made use of technology for the purpose of interconnection of MRs. This figure is rather important for PSMTs not only employed the MRs of derivative and made explicit links between and among the MRs but they also integrated technology into their teaching plans and drew on it to establish the links. The importance of this figure becomes even more evident when we consider their first plans where a large number of PSMTs (85%, see Table 3) did not link the representations, let alone doing the links with the help of technology. Hence this analysis indicates PSMTs' developing competence and awareness of using technology.

In order to gain further insights into the development of PSMTs' utilization of technology, we also carried out analyses of the third lesson plans as to how they handled the three aspects of derivative in the lesson plans. With this regard, we sought to set two main issues: 1) if they included any aspect of derivative (slope, limit of the difference quotient and the instantaneous rate of change) in the lesson plans and 2) whether they employed the technology when addressing any of the aspects. Our analyses are presented below as the frequency of the presence of any one of the aspects of derivative and of those who planned to use technology.

As seen in the Table 6 , 75% of the PSMTs aim to establish interconnections among the three aspects of derivative and they planned to do so with the help of technology. This is remarkable in the sense that many of the PSMTs, at the start of the course, were not aware of these aspects; yet, after the TPCK workshops they surely developed insights not only into these aspects and the relations among them but also into the benefits and affordances of technology while making the relations among them explicit. Hence the analyses of PSMTs' third lesson plans provide evidence as to their development for the integration of technology in making connections among the three aspects with the help of MRs of derivative.

Observing the PSMTs' development is important. Yet equally important is the nature of this development. In order to provide the reader with an opportunity to see the nature of PSMTs' developing competences with regard to use of MRs of derivative in technology-rich environments we now present micro-teaching of a pre-service teacher.

QUALITATIVE ANALYSES OF A PSMT'S MICROTEACHING

In this part of the paper, we present the analyses of a PSMT's microteaching. The aim here is to demonstrate the use of MRs with regard to three aspects of derivative through technology. The pre-service teacher (called Arzu) is a female teacher candidate and did microteaching after the PCK workshops. She re-prepared the lesson plan that was produced after the TPCK workshops. In this microteaching she employed technology to introduce the concept of derivative. The analyses of her teaching will be presented in four sections. First we briefly describe her approach to introducing derivative; second detail how she employed

Table 6. The frequency of those addressing the aspects of derivative and using technology for this

Categories	Yes N(%)	No N(%)	Unanswered N(%)	Total N(%)
Do PSMT address the link between the rate of change and slope?	32 (%80)	4 (%10)	4 (%10)	40 (%100)
Do PSMT make use of technology in addressing the link between the rate of change and slope?	32 (%80)	4 (%10)	4 (%10)	40 (%100)
Do PSMT address the link between the limiting process and slope?	34 (%85)	2 (%5)	4 (%10)	40 (%100)
Do PSMT make use of technology in addressing the link between the limiting process and slope?	34 (%85)	2 (%5)	4 (%10)	40 (%100)
Do PSMT address the link between the rate of change and limiting process?	32 (%80)	4 (%10)	4 (%10)	40 (%100)
Do PSMT make use of technology in addressing the link between the rate of change and limiting process?	32 (%80)	4 (%10)	4 (%10)	40 (%100)
Do PSMT address the links among the rate of change, limiting process and slope?	30 (%75)	6 (%15)	4 (%10)	40 (%100)
Do PSMT make use of technology in addressing the links among the rate of change, limiting process and slope?	30 (%75)	6 (%15)	4 (%10)	40 (%100)

Table 7. The tabular representation that Arzu produced

$[t_1, t_2]$	[3, 5]	[4, 5]	[4.5, 5]	[4.9, 5]	[5, 5.1]
$V_{average}$	11	12	12.5	12.9	13.1

the MRs. Third we consider the aspects of derivative on which she focused and finally we present the way in which MRs are used to interconnect the aspects of derivative.

An overview of Arzu's approach to introduction of derivative

Arzu started her teaching with a problem which involved the calculation of average velocity by using the given distance equation which was the function of time. The distance function was $X(t)=t^2+3t$ and average velocity was calculated in the intervals of [1,5] and [2,5]. In her solution, she emphasized that average velocity can be calculated via $\Delta x/\Delta t$. Later she pointed out that if an interval is given, then it is possible to find the average velocity as there can be changes both in distance and time. She asked her peers about the possibility of finding the velocity at a particular point, when $t=5$. To

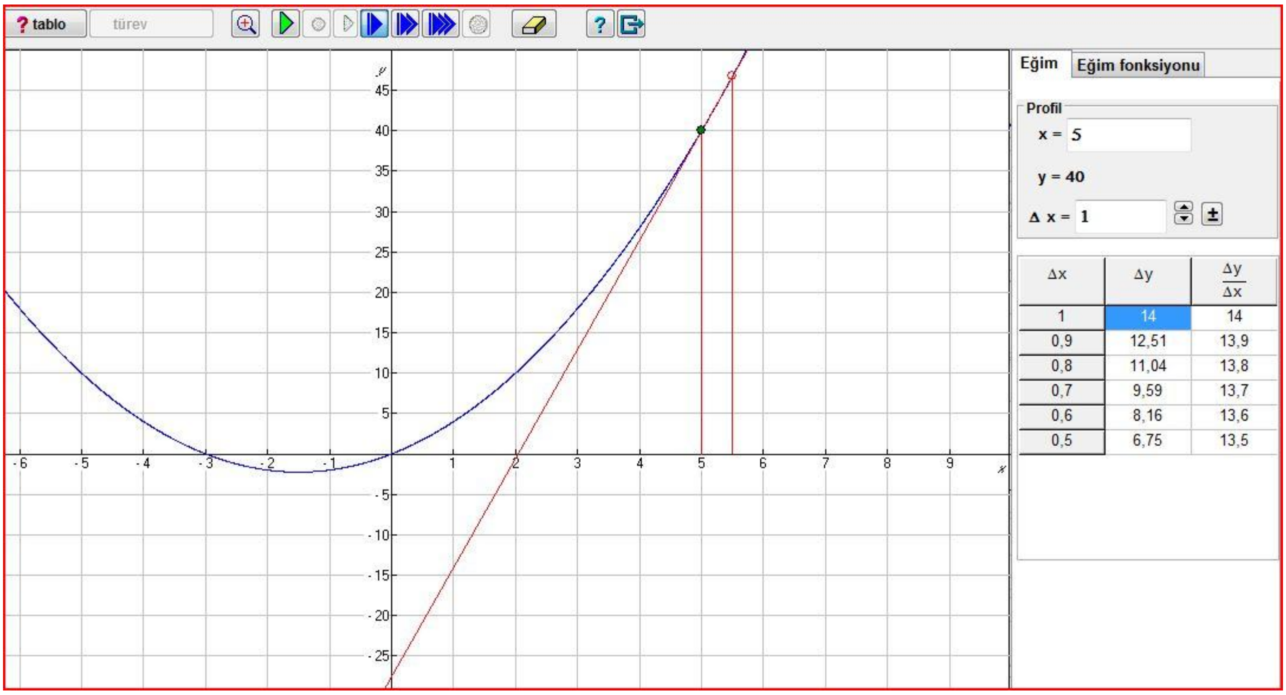

Figure 5. Graphic Calculus window for the function x²+3x with graphical and numerical representations

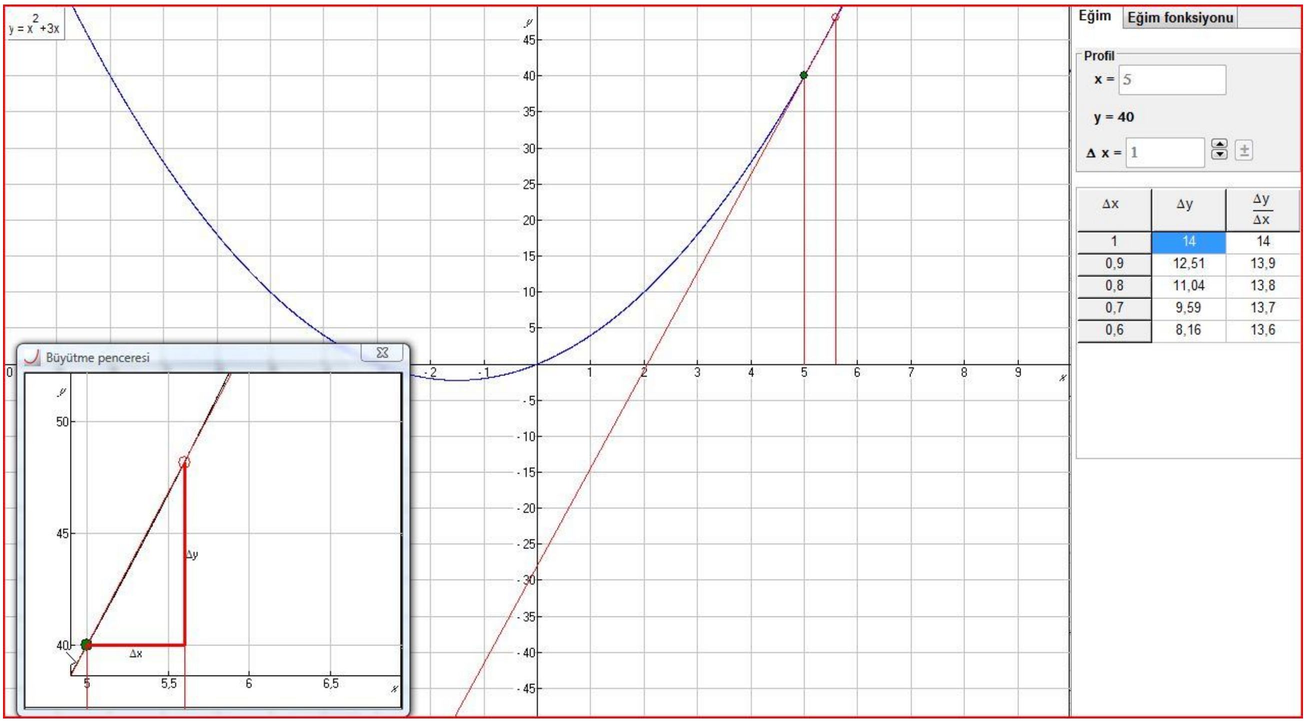

Figure 6. Rate of change and the slope of the secant lines

find out this, she suggested producing a table of values by evaluating average velocity over various intervals in the neighborhood of 5. She produced table 7.

She, based on the graph, commented that as the intervals were getting smaller in the neighborhood of 5, average velocity seemed to be 13; she also noted that with their current knowledge, they could not tell the exact result. She then reminded the concept of limit and noted that if the changes in times in the neighborhood of 5 approach to zero (Δt→0), then it might be possible to find the exact result. She wrote the algebraic representation of limit as $\lim_{\Delta t\to 0}\dfrac{x(t+\Delta t)-x(t)}{t+\Delta t-t}$ and calculated this for t=5 (which yielded the result of 13 for the velocity at t=5).

Following this Arzu got the Graphic Calculus software started. She entered the function and obtained the graph and tabular values for the rate of change (see Figure 5). She then explained how the values for $\Delta y/\Delta x$ were produced and had some of her peers calculate certain values to make sure that the outcomes in the tabular representation were understood.

Arzu later focused on the graphical representation and pointed out that the rate of change (i.e. $\Delta y/\Delta x$) was related to the slope of the secant lines and showed this with the "Zoom-in" tool of the software (see Figure 6). Then she introduced the formal limit definition of derivative and wrote it down on the board.

Having given the formal limit definition, Arzu turned to the software and this time used it to obtain the slope function of x^2+3x. The software dynamically demonstrates the values of slope function in relation to the values of rates of change and represents them graphically (see Figure 7). Arzu explained how the slope function was obtained and related this to the values of rate of changes. Then she articulated that the derivative of the function of x^2+3x was represented by the slope function. She concluded her teaching by explaining the procedure to algebraically obtain the derivative of a polynomial function.

Arzu's use of MRs of derivative

When Arzu' teaching is examined with regard to MRs, it can be said that she employed tabular (or numeric), graphical and algebraic representations during her teaching. Arzu started her teaching by calculating the average velocity in two intervals. Later she raised the issue of finding the velocity of moving object at a particular point in time. As this was the introduction of derivative, she did not use the rules of differentiation to answer this. Hence what she did was to create a table of values for the average velocity in different intervals at the neighborhood of t=5. The tabular representation of the values (see Table 7) certainly helpful in predicting the velocity of the object at t=5. As Ainsworth (1999, p.135) suggests tables tend to "support quicker and more accurate readoff and highlight patterns and regularities across cases or sets of values." In this sense, the function of using table representation here can be considered as constraining and complementing. The values of average velocity in different intervals were computed separately and assembling these values in the table does not convey new information on the part of learner. However, such an assembly and reorganization of the values constrain the learner by giving them a focus and hence directing their attention to the target value of velocity at a particular point in time.

Arzu also used representations for the complementary purposes. For example, having reached to the graph of x^2+3x through the software, she concentrated on both tabular and graphical representations (see Figure 5), each of which was used to explain one another. As seen in Figure 6, table of values as rates of change are complemented by the graphical representation which in turn was used to explain the production of the table of values. To achieve this, Arzu even used the Zoom-in button (see Figure 6) to direct the attention to, and indeed to elucidate, the link between the tabular and graphical representations. Surely each representation carries unique as well as shared information with regard to the meaning of derivative. For instance, graphical representation contains the information that derivative is the limit of the secant lines while the tabular representation relates the slope of the tangent to the rate of change. Hence the advantage of using these two representations was greater than the sum of the parts.

Finally Arzu employed representations to construct deeper understanding of derivative. This we believe is rather valuable and in practice it occurs rarely. Yet Arzu was quite successful in her attempt. She pronounced the derivative while interconnecting the graphical, tabular and algebraic representations (see Figure 6). Having considered the slopes of the secant lines and related them to the tabular representations, she turned her attention to the slope function which Graphic Calculus software produced. The graph of slope function is obtained by matching the values of x with that of y generated via $\dfrac{f(x+\Delta x)-f(x)}{\Delta x}$ (see Figure 7) The tabular representation of the slope function along with the graphical and algebraic one is present on the same window, which gives the teacher a chance to merge them all into a single picture and hence connect them under the concept of derivative. This was the way that Arzu first pronounced the concept of derivative by interrelating the MRs to construct a new understanding, a new concept, derivative.

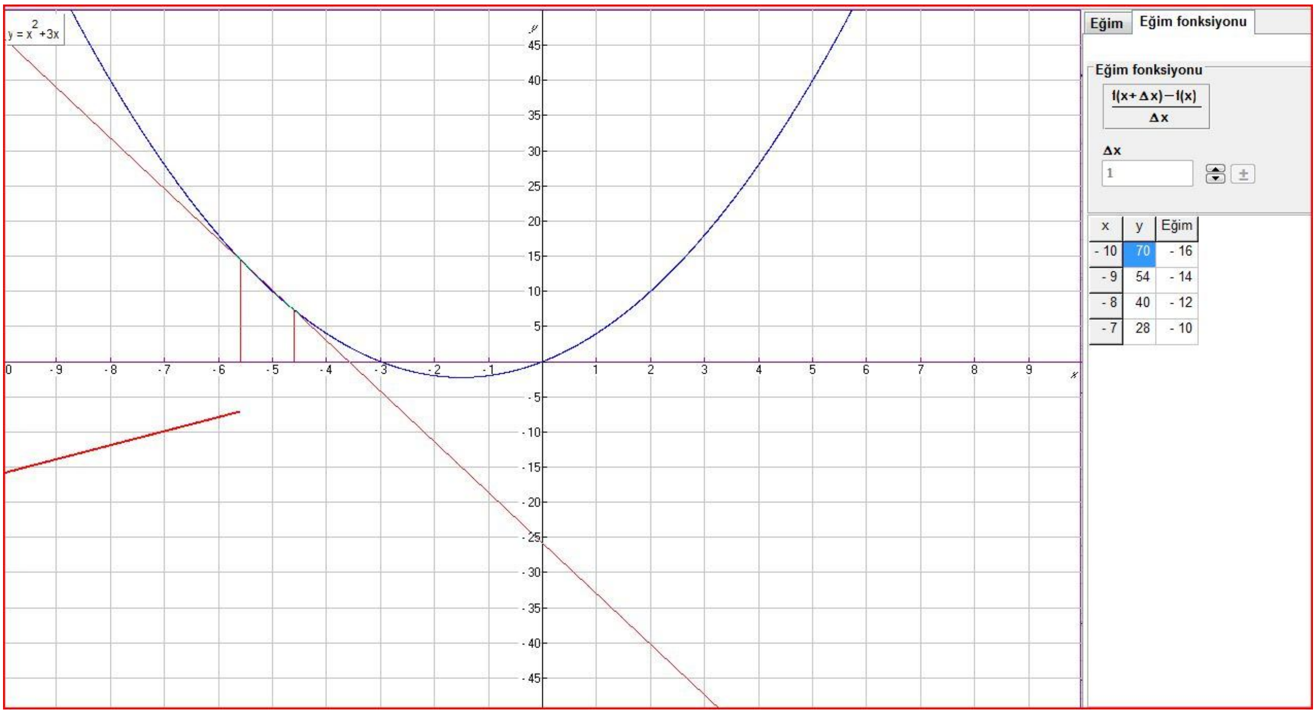

Figure 7. Graphic Calculus shows dynamically occurrence of the slope function

Three aspects of derivative in Arzu's teaching

Arzu incorporated all three aspects of derivative in her teaching. She started her teaching with a problem of average velocity of a moving object. To handle the problem, she made use of rates of change and then problematized the possibility of determining the instantaneous rate of change. To determine the velocity of the object at a particular point in time, Arzu brought the concept of limit into attention. It was through the limiting process that she calculated the instantaneous velocity. Later she used technology to introduce the slopes of secant lines approaching to the slope of tangent line to the graph at the point of 5. She then related the slope of secant lines to the rate of change aspect of derivative. Finally she considered the slope function to emphasize that the derivative of a function is obtained by matching values of x with the instantaneous rate of change at that particular points of x. In doing so, she was not only emphasizing three aspects but also trying to clarify the interrelationships among these aspects of derivative.

The MRs and three aspects of derivative

The first step that Arzu took towards the introduction of derivative was the concept of rate of change, which she brought into consideration through the problem of a moving object. To solve the problem, she employed the algebraic representation which, unlike the other representations, allows the symbolic manipulation and easy and fast calculation with regard to this problem. She then mentioned about the instantaneous rate of change and set off to find out the velocity of a moving object at a particular point in time. To this end, she employed algebraic representation for the calculations but preferred tabular representation to get students sensing the value of velocity. Arzu used tabular representation for the purposes of both constraining and complementing. Tabular representation played constraining role in that it highlighted the regularities across the set of matching values (see Table 7). Tabular representation, unlike the algebraic one, has the potential to evoke the concept of limit and in this sense it also played a complementary role. Following this, Arzu drew on the limit concept and calculated the instantaneous velocity.

She later brought the technology into her teaching. She sketched the graph of x^2+3x with Graphic Calculus software. On the same window, one could see graphical, tabular and algebraic representations. The first thing that Arzu did was to explain and exemplify the relationships between and among these representations. She explained how the tabular values were obtained from the algebraic representations. She also focused on the relationship between the tabular values and the secant lines on the graph and explained how one representation was related to the other. Arzu noted that each value of Δx on the table was used to create a secant line on the graph and when the Δx approached to zero then the secant lines approached to the tangent line at the point under consideration. Based on this, she introduced the limit (formal) definition of derivative and turned the Graphic Calculus to explain this with the help of slope function. In her explanation, she related the tabular representation to the limit of secant lines.

As this brief analysis suggests, Arzu used MRs of derivative for the purpose of constructing: the meaning of derivative by combining the three aspects together into a single picture.

DISCUSSION AND EDUCATIONAL IMPLICATIONS

It is clear from the data that PSMTs taking part in our study has shown great developments in their knowledge of MRs, in their utilization of MRs for teaching, in devising ways to connect the MRs for teaching and in making use of technology for the MRs. First of all, the PSMTs, before the course started, did not have much knowledge about the MRs in mathematics. This is evident in their responses to questionnaire items as 75% of the PSMTs (Table 2) were not able to explain the meaning of MRs. Of course this does not mean that the PSMTs did not have any idea of the MRs. Surely they used different representations in their first lesson plans prepared before the course but their knowledge of MRs was dispersed nor did they appreciate the importance of MRs for teaching and learning mathematics. The way that they used the MRs was lacking in the sense of purpose; that is, they did not relate the representations to one another in the context of derivative. We believe that the PSMTs' use of MRs in the first lesson plans was largely shaped by the textbooks and the curriculum scripts that they were advised to examine for their lesson plans. As we reported elsewhere, the PSMTs tend to follow the approach adopted in the source that they examined (see Ozmantar et al., 2009). Hence their use of MRs in the first lesson plans was as if the MRs employed to introduce derivative were "poured into" their plans without having much thought as to the purpose that those MRs of derivative served. However after the completion of the course the PSMTs were able to explain the meaning of MRs; further to this, they incorporated MRs into their lesson plans purposefully.

The PSMTs' initial deficiency was reflected in their utilization of the MRs for teaching derivative as evidenced in their first lesson plans. It is true that they employed MRs of derivative in the first lesson plans; however, the plans were not structured in such a way that links the representations with the aspects of derivative. However, a change in their approach to utilize MRs is evident in their second lesson plans where the PSMTs' efforts to connect the MRs were all too apparent.

The PSMTs show progresses in the use of technology with regard to the MRs. Arzu's case is exemplary for that matter. In her teaching, she was competent in the utilization of MRs for complementing, constraining and constructing purposes. She was also able to combine different representations to emphasize different aspects of derivative. Arzu's integration of technology for bringing the representations together in relating the aspects of derivative to one another was rather successful. However, Arzu was not alone; as the quantitative analyses show 75% of the PSMTs made use of technology in connecting more than one pairs of the MRs (Table 6). Further to this, 75% of them related the aspects of derivative to one another via MRs with the help of technology.

The question of interest at this point is: why is the cited development of the PSMTs so important? The development of the PSMTs in our study with regard to the use of MRs in technology-rich environment is important for at least four reasons. First of all, one important justification for the use of MRs is that MRs of mathematical concepts provide unique potentials to construct deeper understandings (e.g., Moreno and Mayer, 1999). Further to this, as Berthold et al. (2009, p.346) express, "by combining different representations with different properties, the learners are not limited by the strengths and weaknesses of one particular representation." The literature also provide evidence that the links among the MRs are often not established during instruction by the teachers (Mallet, 2007). It seems that the work of linking the MRs is largely left to the learners. The initial lesson plans that our participants produced provide corroboratory evidence in that 85% of the PSMTs did not relate the MRs with regard to derivative. However, there are many studies showing that the expected outcomes with the use of MRs often do not come about (de Jong et al., 1998) due to the fact that learners find it difficult to relate the MRs to one another and they, more often than not, focus on one type of representation or fail to connect them (Berthold, 2009; Goldenberg, 1988). In fact most students do not spontaneously make an effort to establish connections among the MRs (Yerushalmy, 1991). These findings clearly suggest that unless the links among them is an explicit focus of instruction then the assumed benefits stemming from the use of MRs do not come about. Our participant PSMTs seem to have grasped the importance of linking the representations and hence 67.5% of them linked two or more representations (Table 3) in the context of derivative.

Secondly, the development of the PSMTs informs us about the certain features of successful programs designed for the effective use of MRs with the aid of technology. Three such features that our design implies are the content, method of delivery of the content and hands-on activities (see also Hew and Brush, 2006). First of all, the content of course designed for the PSMTs involved the issue of MRs and particularly focused on the examples of MRs in different topics of mathematics (e.g., limit, function and trigonometry), functions of MRs, strengths and weaknesses of individual representations, representational power of the particular technology chosen for the study (i.e. Graphic Calculus), the importance of connecting the representations and the affordances of the technology for that matter.

We followed certain order in our method to deliver the content in the framework of TPCK. We first considered the definition of MRs, the importance of employing MRs for teaching and examples of MRs from different topics (Pedagogical Knowledge). Then we focused on the ways in which MRs can be employed, on the functions and the importance of interconnecting the particular representations in the context of derivative (Pedagogical Content Knowledge). Following this, we brought the technology dimension into play and discussed the MRs that the particular software (Graphic Calculus) offers (Technological Content Knowledge). Later, the concern was with the questions of how the technology helps in making connections among the MRs, how these connections can be used to achieve a robust understanding of the concepts and what the technology has to offer for teaching with MRs (Technological Pedagogical Knowledge). Finally we concentrated on the particular topic under consideration (derivative) and had the PSMTs devise ways via technology as to how to combine MRs of derivative, how to relate the MRs to three aspects of derivative, what technology has to offer in making explicit the relationships between the MRs and three aspects of derivative, how to employ the technology in making these relations comprehensible to the learners, in what order the aspects should be introduced via MRs (Technological Pedagogical Content Knowledge). Hence the TPCK framework was effectively our design tool for the courses as well as provided us with a framework to shape our method to deliver the course. Considering the development of our participants, we believe that this method of delivering the content was effective.

In our delivery of the content, we paid particular attention to get PSMTs involved in hands-on activities. Our primary aim was to achieve active participation of them into activities as well as to give them a "space" where they can explore the ideas and tools on their own ways. Hence we guide them with discussion questions but largely left the responsibility to the individuals who most of the times worked in groups. We believe that giving the PSMTs a chance to explore the alternatives and individually active involvement into activities are important for them to get acquainted and develop insights and competencies in the integration process of technology. Based on this brief consideration, we argue, the successful integration programs need to have at least these three as features in the design and conduct of the courses.

Thirdly, the research cited the teacher's lack of knowledge and skills in using technology as obstacles to the integration of technology into teaching (Pelgrum, 2001; Hakkarainen et al., 2001). Even though teachers have the necessary skills to use technology, if they are lacking in the knowledge of how to deliver the content by means of technology, this again creates barriers (Hew and Brush, 2006). Such deficiencies in teacher knowledge shape their beliefs as to the usefulness of technology as well. For example, Ertmer et al. (1999) investigated one elementary school in the USA and found that teacher beliefs about the role of technology in the curriculum formed their objectives for the use of technology. Those considering technology just "a way to keep kids busy" (Hew and Brush, 2006) did not appreciate the relevance of technology to the content knowledge. Students were allowed to use computers as a reward of finishing the assigned tasks. The teachers reported that the content knowledge and skills were more important to them. As this study clearly suggests many teachers are not able to see the relation between the use of technology and content dimension of their subject. Further to this they do not believe that technology aid their students for a robust comprehension of the subject matter at hand. For instance, a study carried out in Australia on the perception of computers at secondary level reveal that teachers do not see computers as leading to better understanding or fostering the learning (Newhouse, 2001).

When considered in the context of our study with regard to the TPCK framework, these findings point to the importance of teacher's technological knowledge, technological content knowledge as well as technological pedagogical knowledge (see also Arnold et al., 2009). Our pre-service teachers' development certainly parallels to those areas of knowledge. The PSMTs in our study joined workshops on Graphic Calculus software and performed hands-on activities as described above. Furthermore, they did activities as to the MRs of several mathematical topics, in particular on derivative, via the software. They also participated in the workshops where they developed ideas as to how to make use of technology for connecting and relating the MRs, which in and of itself created the content dimension and gave the PSMTs a sense of purpose in their efforts. All these activities and workshops contribute a great deal to the development of PSMTs with regard to use of MRs. In so doing, we believe, PSMTs overcome some important obstacles to the technology integration. The evidence for this come from the developing competences of our participants both in their lesson plans and the way in which aspects of derivative are interrelated through MRs with the help of technology. This competence was clearly evident in microteachings such as that of Arzu.

Fourthly, there is a tendency among the pre-service teachers that technology functions mainly as a computational device rather than a learning resource (Juersivich et al., 2009). Given that, at least in the case of our research, most PSMTs are "foreigners" to the culture of teaching mathematics with the aid of technology, there is a need for teacher educators to get PSMTs experiencing the contribution of technology to their teaching. MRs provide a venue for the PSMTs to engage in activities where the technology acts as a learning resource and not only paves the way for new possibilities of teaching but also serves to deepen the student understanding of the mathematical concepts. It is important for our PSMTs to experience these features of technology with regard to the use of MRs. The importance does not merely stem from their developing competences in technological knowledge; but also from the fact that our participants' subject matter knowledge has also improved and they themselves experienced the enhancement in their own learning. For example, in our interview on her microteaching, we asked Arzu if she made any changes in the structure of her lesson plan with the involvement of technology. She responded as follows:

[In this process] I got confident, knowledgeable… I mean in this process I corrected my own misconceptions… I knew things [about derivative] but they were shaky… things haven't settled down… [before] ideas were dispersed because I myself couldn't connect them [the representations and three aspects of derivative]… But I learnt the topic [derivative] more… things settled down now.

As Arzu's response clearly suggests, during the TPCK workshops where she did hands-on activities on MRs and three aspects of derivative via technology, she corrected her own misconceptions and she herself "learnt" the derivative. Such remarks were common among the PSMTs that they learnt the relationships among three aspects and among the MRs of derivative during their participation of the workshops. This experience in and of itself was valuable as it convinced many of the usefulness of technology and the necessity of incorporation of it into teaching for the better learning outcomes (Juersivich et al. (2009) also report similar observations).

Having observed PSMTs development, examined their lesson plans and followed their microteachings, we are very much convinced of the importance of MRs for a successful teaching – whatever the teaching medium is (regardless of whether it be chalk-and-board or a technologically rich environment). We believe that in any attempt to design courses for technology integration, the issue of MRs need to be part of the program. Teachers or pre-service teachers need to have a chance to see explicitly the potential of MRs in achieving a robust and deep understanding of the subject at hand. They also need to see the contribution that technology has to offer for that matter.

At this point, we wish to note here that the contribution of technology is often attributed to its power of allowing the visualization. However, our analyses point out that contribution of technology, at least in the case of Graphic Calculus, with regard to MRs goes well beyond its visual power. We do not deny the important effect of visualization that technology offers. Equally important is, we think, the dynamic relations among the MRs that technology is able to put forward. A change in one representation immediately affects the others and all the changes can be seen at the same time on the same window. This dynamic linking makes most of technological tools powerful resources for learning. It is through this feature that the links among the MRs and the aspects of the topic become accessible to the learners. It is one of the features that allows teachers to make the links explicit focus of instruction and to combine MRs with individual unique properties for the purposes of complementing, constraining and constructing deeper understanding.

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Information and Communication Technologies (ICT) in Biology Teaching in Slovenian Secondary Schools

Andrej Šorgo
University of Maribor, Maribor, SLOVENIA

Tatjana Verčkovnik and Slavko Kocijančič
University of Ljubljana, Ljubljana, SLOVENIA

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About two-thirds of Slovene secondary schools received computers equipped with data-loggers and sensors to be used in teaching Physics, Chemistry and Biology. Later it was recognized that only a couple of Biology teachers were using the donated equipment in their classrooms or laboratories. The questionnaire, intended to investigate the situation, was posted to schools which had received a donation. Based on the answers, it was possible to assign computer applications from one of the three groups. In the first group were these applications (word processing, e-mail and internet use) towards which teachers have positive attitudes and that they do use for school work. The common element is that teachers can work at home and then use the materials in the classroom. In the second group were applications (presentations, use of data loggers, computer programmes and virtual laboratory) towards which attitudes are positive, but which teachers do not use because of the overloaded curriculum, lack of equipment, and inappropriate training. In the third group are applications (computer games and programming), about which attitudes are negative and which teachers do not use. The Introduction of such applications into teaching is at the moment far from realistic.

Keywords: Biology; Information and communication technologies; ICT; Secondary schools.

INTRODUCTION

Ability to work with information and communication technologies (ICT) is recognized as one of the key competencies necessary for success in life and competition in the labour market (Levy and Murmane, 2001; Salganik, 2001; Eurydice, 2002) which every citizen should possess (Recommendation of the European Parliament and of the Council, 2006), and term 'computer literacy' was introduced to distinguish between users and non-users of ICT (Bawden, 2001). Concerning ICT, two important roles are assigned to schools. The first is to fulfil the expectations of society for demanding ICT skills, and the second is to raise the quality of education in the schools with the support of ICT. Many scholars, teachers and teacher-trainers have recognized the potential of ICT to enhance teaching and learning, and as a side effect the number of published articles about the use of ICT in school work is enormous (Bell and Bell, 2003). However, despite significant investment in training and resources, in reality schools are still far below the level of ICT use in science, transport, communication, industry, and many other fields (Hawkins 2002; Hepp, Hinostroza, Laval and Rehbein 2004; Machin, McNally and Silva, 2007; Eteokleous, 2008).

Correspondence to: Andrej Šorgo, Ph.D in Biology Education, Department of Biology, Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška cesta *160, 2000 Maribor, SLOVENIA*
E -mail: andrej.sorgo@uni-mb.si

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State of the literature

- Description of new hardware and innovative software applications designed to be used in schools are reported on daily basis;
- In most cases benefits and positive impacts of ICT on educational outcomes are reported;
- Use of computers in schools, even if available, is mosaic, and underpinned with attitudes and opinions of teachers;

Contribution of this paper to the literature

- This study suggests that perceived importance and usage of software by teachers correlate;
- Developing of new teaching tools is almost meaningless if teachers do not recognize their added value for teaching practice.
- An application will be easier transferred into a classroom if teachers can use it, test it, and prepare teaching materials beforehand at home computers.

Usage of ICT in schools is so diverse that it is almost impossible to list all possible applications. Taylor (1980, 2003) recognized three roles of computers in a classroom: as tutor, tool, and tutee. Introduction of ICT in biology lessons can raise not only level of knowledge but students attitudes toward biology as well (Haunsel and Hill, 1989; Kubiatko and Halakova, 2009). As biology (science) teachers we additionally have to distinguish between two groups of applications. In the first group are generic applications used in all subjects, like word-processing, searching for information, communication using e-mails, and multimedia presentations. In this case if a science teacher does not use ICT in a classroom damage to the students is limited because they can achieve missing skills with their work in other subjects, or at home (Kuhlemeier and Hemker, 2007). In the second group are applications adapted or developed to be used in science teaching (McFarlane and Sakellariou, 2002), like imaging systems in microscopy (McLean, 2000; Fiche, Bonvin, and Bosman, 2006), virtual dissections (O'Byrne, Patry, and Carnegie, 2008), simulations (Ramasundaram, Grunwald, Mangeot, Camerford and Bliss, 2005), virtual laboratory (Jenkins, 2004), and real laboratory exercises with data acquisition systems (Šorgo, Hajdinjak and Briški, 2008). The most important difference among these two groups of applications is that if a science teacher does not use such applications in teaching students in most cases they would not be able to compensate loss with work in other subjects or at home.

The introduction of computers into the teaching and learning in Slovenian secondary schools has followed two general tracks. The first one was the introduction of the compulsory subjects, Computer Science and/or Informatics, into the curriculum. The second one involved the use of computers in a rainbow of different subjects. The introduction of computers into student work in other subjects is encouraged by the authorities, but the final decision about their use in teaching is left to the discretion of the teachers. The difference between these two paths is that teachers from the first group are trained professionals in Computer Science and Informatics, while teachers from the second group are more or less enlightened 'computer amateurs'. Occasionally cooperation between a teacher of Informatics and a teacher from some other subject occurs and enhances student work (Šorgo and Logar, 2006).

Purpose of the study

The impetus behind our research was the knowledge that between years 2001 and 2004 about two-thirds (N = 88) of Slovene secondary schools (N = 143) received from the Ministry of Education and Sport a total of 269 computers equipped with data-loggers and a set of probes and sensors to be used in teaching Physics, Chemistry and Biology. Because the community of secondary school Biology teachers in Slovenia is small (about 150 teachers) in subsequent years it was easy to recognize that only few were using the donated equipment in their classrooms or laboratories. Because we have successfully implemented computers in our teaching and laboratory work with equipment also available to other biology teachers (Šorgo and Kocijančič 2004, 2006; Šorgo et. al., 2008) we posed the following questions: How are computers used by our colleagues at other schools and what are the obstacles to their use?' Is non-use of data loggers a special case, or does it only represent collateral damage in the general rejection of computers in school work?

MATERIAL AND METHODS

Our research concerning ICT use was part of the thesis entitled 'The influence of a Computerised Laboratory on the Quality of Biology Teaching, and the Development of Competency in High School Students' (Šorgo, 2007). Research based on the idea that besides equipment availability, which is the most often reported reason for not using computers in the SITES 2 study (Pelgrum, 2001), there must be some other underlying factors which function as barriers. Our predictions were that we should investigate the domains of teacher knowledge, experience, and opportunities. To find answers to our research questions, we prepared an extended questionnaire to be addressed to our colleagues.

Structure of the questionnaire

The questionnaire was based, in some parts, on previously used questionnaires (Computer Attitude Questionnaire; Lavonen, Aksela, Juuti and Meisalo, 2003; Paris, 2004; Nickell and Pinto, 1986; Swain, Monk and Johnson, 2000; Selwyn, 1997; Ediger, 2002). Research questions concerning ICT were addressed to the teachers. These research questions were as follows:

1) Where do teachers have access to computers when these are needed for school work?

2) How many computers and school computer sites are available to teachers for Biology teaching?

3) How often did they use computers at different school sites for Biology teaching over the last year?

4) How important to the teachers were different approaches to acquiring knowledge about computer work?

5) How often had they used different computer applications over the last three years in preparation for school work, classroom work and work with students?

6) From a teacher perspective, how important are different computer applications for teaching Biology?

7) How proficient are the teachers in the use of various computer applications.

There were different methods of answering, what depend on a research question. In first three cases teachers have to circle provided answers or fill in the numbers in blank fields. Last four tables were of the Likert type, with eighteen items each, and teachers have to answer with circling the option on five or six-point scales. In all cases we used the same list of eighteen applications and an option of "other", the difference was recorded on a scales.

First version of the questionnaire was reviewed by five secondary school teachers and according to their comments final version was assembled.

Data collection

A letter of intent was sent out in the 2005/06 school year to the principals at those secondary schools that had received computers with data loggers. After receiving permission from the principals, we sent 317 questionnaires to 56 schools. We received responses from 207 teachers, mostly these from Physics, Chemistry and Biology working at 52 schools. 70 questionnaires were answered by Biology teachers, and these responses are analyzed in our present text. The questionnaires of the Physics and Chemistry teachers are designated for later analysis.

Description of the sample

We received completed questionnaires from 70 Biology teachers. Because we received responses from about 40% of Slovenian secondary school biology teachers, our results can be recognized as representative. 37 of the respondents (52.9 %) taught at grammar schools and 28 (40%) at vocational colleges. Because of anonymity, 5 (7.1 %) teachers did not respond about the type of school. The majority of the teachers taught Biology as a single subject (N = 56; 80 %), but at vocational schools a number of teachers taught Biology in combination with other subjects like Microbiology or Chemistry. In biology teaching female teachers are in the majority (88.6 %). Teachers are, on average, 42 years old, the oldest being 60 and the youngest 24. They had, on average, 15 years of work experience and 15 teachers (21.4 %) had work experience outside schools.

Statistical analysis of the results

Because we were interested in general patterns of ICT usage in schools, we conducted our analyses with our sample as a single group, and we did not break down our group into subgroups to search for differences, for example, between genders. Results are presented as tables. Frequencies are presented as absolute numbers [N] and as percentages [%]. Results of answers measured by scales are presented as mean [M] and standard deviations [SD]. The analyses were performed with the statistical package SPSS 12.0.

RESULTS

Access to computers

All of the biology teachers who responded to the questionnaire (N = 70) have access to computers when they need this for a work: at their homes and schools (N= 61; 87.1%), at home (N = 4; 5.7%), at school (N = 4; 5.7%), and one of them (1, 4%) reported having a portable computer.

Availability of ICT for Biology teaching in schools

Teachers were asked about school sites and number of computers available for their work with students.

From the results presented in Table 1, we can recognize that a sufficient number of computers for using computer applications with a class of students (working individually or in small groups) is, for the majority of teachers, available only in Computer Science or Informatics and Multimedia classrooms. A well recognized problem is that Computer classrooms are not available for teaching Biology at optimal times.

Limitations on the use of data-loggers in such classrooms are safety (use of water, aggressive chemicals, etc.), lack of available space on the desks for experiment assembly, and the near almost impossibility of assembling laboratory equipment for long term experiments because of computer sharing between classes.

Only five teachers reported that they had access to more than four computers in classes/laboratories that can be used for laboratory work or group work. About three-quarters of the teachers have access to a single computer (N = 51; 72.8 %) in their preparatory room. This computer is in most cases shared among all the Biology teachers at the school. Because its main purpose is teachers' work in lesson preparation and administration, student access to this computer is rarely allowed. A little more than half the teachers (N = 36; 51.4 %) have access to a computer on a trolley. This computer most often occupies a staff room and must be shared with all other teachers at the school, a factor which could definitely be a limitation on its use. Less than two-fifths (N = 27; 38.6 %) have computers with a permanent place in a Biology classroom, and only four teachers (5 %) reported having a portable computer. Only the last two groups could use ICT on demand.

Number of lessons with ICT in the last school year teachers were asked, how many lessons they had performed with the support of ICT in the last school year.

Table 1. Number of computers and school locations, where computers are available for biology teaching when required.

	Number of computers					
Location	1	2-3	4-8	9-16	16+	Total
A specialized classroom for teaching biology.	26	1				27
A specialized laboratory for teaching biology.	14		2			16
A preparatory room (office) for biology teachers.	47	2	2			51
A classroom dedicated to teaching Science subjects.	2		1			3
A Science laboratory.	5	1	2			8
Computer on a trolley or portable computer.	30	3	3			36
A Computer Science/Informatics classroom.	1		1	27	12	41
A Multimedia classroom.	9	2	4	8	1	24
Portable computer.	1	2	1			4

Table 2. Location and number of lessons carried out using computers during the last school year.

	Number of lessons				
Location	1-3	4-6	7-9	10+	Total
A specialized classroom for teaching biology.	8	5	1	11	25
A specialized laboratory for teaching biology.			2	3	5
In a preparatory room (office) for biology teachers.	1	1		1	3
In a classroom dedicated to teaching Science subjects.	1	2		2	5
In a Science laboratory.	1				1
Computer on a trolley or portable computer.	7	6	2	1	16
In a Computer Science/Informatics classroom	6	1	1	3	11
In a Multimedia classroom	1			3	4
Other classrooms	3				

Table 3. Importance of different approaches to knowledge gained from their work with computers. The mean and standard deviation on a six-point (0-6) Likert scale are reported.

Approaches to knowledge	M	SD
Self-education	4,5	0.7
At home from children, partners, or friends	3,6	1.3
Through courses offered as in-service training	3,5	1.5
From colleagues at school	2,9	1.6
Through courses offered by institutions outside school system	1,7	1.9
As a subject at university	1,3	1.5
As a subject at high school	0,8	1.2

It is clear from the results presented in Table 2 that teachers most often used ICT in their classrooms. The correlation between computer use and location in a classroom is positive r (49) = 0.44, p = 0.01. We can predict that the use of computers, at least for demonstrations and multimedia presentations, would increase if every Biology classroom were equipped with at least one computer and a projector. Our conclusion is strengthened by the lack of correlation between availability of computer in a preparatory room and their use in the classroom (r (45) = 0.07, p = 0.64) or the availability of a computer on a trolley for all teachers in the school and the number of biology lessons carried out with such computers (r(36) = 0.06, p = 0.72).

Importance of different approaches to knowledge gained from their work with computers

Teachers answered on a six-point scale about the importance of different approaches gained from their work with computers. The scale was: 0 – did not receive; 1 – very unimportant; 2 – unimportant; 3 – partly important; 4 – important; 5 – very important

We can draw conclusions about the importance of each approach from the calculated means [M].

The most important route to the computer proficiency (Table 3) was self education. (M = 4.5). Only two teachers assessed self-education as being unimportant and 42 saw it as very important. Then follows learning from partners and in the family (M = 3.5). We can connect our findings with the knowledge that the majority of the teachers prefer to fulfil obligations that do not require direct contact with students, colleagues or parents (preparation or assessment of students work, etc.) at home, so they can fix a problem with ICT without delay, in most cases by themselves or with family help. School-supported in-service training offered by the Board of Education was

Table 4. Frequency of use (F), perceived importance (I) of and proficiency (P) in computer use for school work.

	F		I		P	
Application	M	SD	M	SD	M	SD
Word processing	4,1	1,1	4,3	0,9	3,9	0,9
Searching for information on the internet	3,9	1,1	4,3	0,7	3,6	1,0
e-mail	3,7	1,3	3,8	1,0	3,9	0,9
Participation in forums or in interest groups	1,4	0,8	1,8	1,5	1,5	0,8
Viewing films, or photos; listening to music	2,1	1,2	2,9	1,3	2,9	1,2
Processing of your own films, pictures, etc.	2,0	1,1	3,2	1,1	2,5	1,2
Statistical packages (SPSS, Statistica, etc.)	1,3	0,5	1,9	1,3	1,6	0,9
Multimedia	2,2	1,1	3,5	1,3	2,6	1,2
Spreadsheets (Excel, Access, etc.)	1,7	0,9	3,1	1,4	2,3	1,2
Maintaining a web page (FrontPage, FTP, etc.)	1,3	0,8	2,6	1,4	1,3	0,8
Presentations (PowerPoint, etc.)	2,8	1,4	4,4	0,7	3,1	1,3
International e-projects (Net Days,etc.)	1,2	0,6	2,6	1,6	1,4	1,0
Computer simulations and virtual laboratory	1,4	0,7	3,5	1,2	1,8	1,0
Programming (Basic, Pascal, C,etc.)	1,0	0,2	1,3	1,2	1,1	0,4
Programmes for drawing (Paint, etc.)	1,3	0,5	2,2	1,4	1,6	0,8
Games	1,2	0,7	1,3	1,0	1,8	1,1
Interactive programmes dedicated to school	2,0	0,9	3,8	1,2	2,9	1,2
Computer based laboratory (data-loggers)	1,4	0,8	4,0	1,1	1,8	1,0

F = Frequency; I = Importance; P = Proficiency

Table 5. Correlations between frequency of using a computer application for school work, perceived importance, and teachers' proficiency in use of application. All correlations are significant at p < 0.001 level.

	Frequency	Importance	Proficiency
Frequency	1	0.737	0.949
Importance	0.737	1	0.765
Proficiency	0.949	0.765	1

assessed more important than help from colleagues. The low importance placed on knowledge gained in schools can be seen in the fact that subjects both in high school and university left teachers almost untouched.

Use of computers for school work

We were interested in the frequency of use, perceived importance of and proficiency in the use of various computer applications. In all three cases we used the same list of eighteen applications and an option of "other", the difference was recorded on a scales.

The first question was: How often have you used the computer in last three years in your preparation for school work, work in the classroom and in work with your students (seminars, homework, communication, etc)? Teachers answered on a five-point scale: 1 – never; 2 – a few times in year; 3 –once or twice a month; 4 – once or twice a month a week; 5 – more than twice a week

The second question was: In your opinion, how important the use of computers in your preparation for school work, work in the classroom and in work with your students (seminars, homework, communication, etc)? Teachers answered on a five-point scale: 1 – very unimportant; 2 – unimportant; 3 –neutral; 4 –important; 5 – very important.

The third question was: How would you grade your proficiency in working with computers? Teachers answered on a five-point scale: 1 – no experience; 2 – satisfactory; 3 – good; 4 – very good; 5 – excellent.

The most often used application in school work (Table 4) is a word processor, which is used at least once a week by 74.3 % (N =52), but never used by two teachers (2.9 %), followed by searching for information on the internet, which is performed at least once a week

Table 6. The difference between the importance (I) given to computers and their usage (U) for school work. Means and difference between the means (D) are reported

Application	I	U	D
Presentations (PowerPoint, etc.)	4.4	2.8	1.6
Searching for the information on the internet	4.3	3.9	0.4
Word processing	4.3	4.1	0.2
Computer based laboratory (data-loggers)	4	1.4	2.6
e-mail	3.8	3.7	0.1
Interactive programmes dedicated to school	3.8	2	1.8
Computer simulations and virtual laboratory	3.5	1.4	2.1
Multimedia	3.5	2.2	1.3
Processing of your own films, pictures, etc.	3.2	2	1.2
Spreadsheets (Excel, Access, etc.)	3.1	1.7	1.4
Viewing films, or photos; listening to the music	2.9	2.1	0.8
Maintaining a web page (FrontPage, FTP, etc.)	2.6	1.3	1.3
International e-projects (Net Days, etc.)	2.6	1.2	1.4
Programmes for drawing (Paint, etc.)	2.2	1.3	0.9
Statistical packages (SPSS, Statistica, etc.)	1.9	1.3	0.6
Participation on forums or in interest groups	1.8	1.4	0.4
Programming (Basic, Pascal, C, etc.)	1.3	1	0.3
Games	1.3	1.2	0.1

I = Importance; U = usage; D = Difference between means

Table 7. Relationship between usage and perceived importance of computer use.

		IMPORTANCE	
		Do use (+)	Do not use (–)
USAGE	Important (+)	+ +	+ –
	Unimportant (–)	– +	– –

by 67.2 % of teachers (N = 47), but never in the case of two teachers (2.9 %). In third place is e-mail which is used at least once a week by 60 % (N=42) of teachers but never used by six teachers (8.6 %).

From the results presented in Table 4, we can conclude that teachers assess the importance of computer applications in a school work in a different order. At the top are presentations (M = 4.4; SD = 0.7), information searches (M = 4.3; SD = 0.7), word processing (M = 4.3; SD = 0.9) and the computer based laboratory (M = 4.0, SD = 1.1). The perceived importance of presentations and information searching is supported by the finding that nobody assessed these two applications as unimportant or very unimportant. At the bottom of the list come programming and games.

According to their own opinion, teachers (Table 4) are most proficient at word processing (M = 3.9, SD = 0.9), use of e-mail (M = 3.9, SD = 0.9), searching for information (M = 3.6, SD = 1.0), and presentations (M = 3.1, SD = 1.3). Only one teacher reported that (s)he had no experience with e-mail, and ten reported that they had no experience in preparing presentations. Any knowledge of computer programming has almost been lost, even though we know that, at least for some of the younger teachers, it formed part of the syllabus in high school Computer Science.

DISCUSSION

From the results of our study we were able to recognize that our biology teachers are in line with the main stream in introduction of ICT into teaching routine around the world and investment in computers does not guarantee their later use inside the classroom (Hawkins, 2002; Resnick, 2002; Hepp et al., 2004).

We can conclude that teachers use computers for school work mainly as typewriters, as a source of information and a communication tool, for their preparation, tests and administration outside the classroom, most often at homes. In the classroom paper copies of work-sheets or tests may be used later but rarely presentations. Additionally the conclusion that teachers only rarely use computers in instruction is supported by the case of programmes for presentation (PowerPoint), which occupy a high fourth place, but which are used more than once a week by only one teacher; twenty teachers (28.6 %) use such programmes a few times in a year, and 49 (70%) never. For all other applications, we should use the word “occasionally”.

Because we were primary interested to find obstacles in introduction of computer supported laboratory, we can make similar conclusion as McFarlane and Sakellariou (2002) for England and Wales ‘that data loggers remains token rather than having found a place in routine science classes’. The situation in Slovenia is quite similar to the situations following the introduction of data-loggers in England (Newton 1999, 2000) or Australia (Ng and Gunstone, 2003). The reason is that the most important factor in the implementation of computers in teaching and learning is whether a teacher can or cannot arrange appropriate teaching opportunities for using ICT in a classroom or laboratory (Pelgrum, 2001; Binlingam, 2009).

Teachers make their decisions about use of ICT applications on the individual basis and use of one application does not mean that some other application will be used, and upgraded version of an application will be welcomed (Zhang, Aikman and Sun, 2008). The correlations between use of computers in a school, its perceived importance for school work and proficiency in such work are highly significant (Table 5). So we can say that teachers will in most cases use ICT for work with students if they recognize an application as important, and are in a same time proficient in its use.

However from the correlations alone we cannot predict use of an application in the classroom. We can gain additional insight into the connection between importance and actual use of an application for teaching if we investigate the difference between the means of its importance for the teachers and its actual use in teaching (Table 6). Theoretically, it was possible to form four main groups of computer applications on the basis of the difference between their perceived importance and their actual use in the classroom (Table 7).

In the first group are applications that are recognized as important and that teachers are using on average at least once in month (values over 3). We put into this group applications where the calculated difference between usage and importance was less than one. In our case members of the first group include work with word processors, use of e-mail, and internet searching for information.

In the second group are applications that are recognized as important or very important and that teachers do not use regularly (values less than 3). We put into this group applications where the calculated value of the difference between importance and usage was more than one. In this second group are computer-based laboratory, work with presentation programmes, computer simulations and virtual laboratory, and specialized programmes dedicated to teaching.

The third group should comprise applications that would be recognized as unimportant or very unimportant and that teachers would use. The difference should be a negative number. We did not find any application that could be assigned to the third group. However we can expect the emergence of such applications in the near future when some applications will became obligatory. Teachers may not find such an application useful but will be obligated to use it (for example, computer-supported administration of absenteeism).

The fourth group comprises applications that are recognized as unimportant and that teachers do not use. The difference between means is, as in the first group, less than one. Games and computer programming are typical members of this group.

Recognition of the difference can be important in the introduction of an application into a school. We can predict that in a case where teachers recognize an application as important and do not use it, there must be underlying barriers and obstacles that must be eliminated. In most cases the barriers are related to overloaded curriculum and lack of computers or appropriate training or support. In cases where teachers do not recognize an application as important, there is no use giving them such an application. They will not use it anyway. So the first step in introducing such an application in a school is to make it important to the teachers. It can be suggested that teachers are likely to adopt practices with computers that are in line with their beliefs about teaching (Tondeur, Hermans, van Braak, Valcke, 2008).

CONCLUSIONS

From the results, we can say that most Slovene biology teachers know how to use computers at least on a basic level and are using them at least occasionally. Here or there some non-users may persist, but with additional compulsory applications (school administration, e-mail contact with parents, etc.), we can predict that such teachers will became an extinct rarity. The majority of teachers have access to computers at home and in their schools. From the results, we can conclude that teachers use computers for school work predominantly as advanced typewriters, for communication and as desktop libraries. Because of the insufficient number of computers in schools, which must be shared between teachers, the major part of computer work is done at home.

The situation is different when computers are to be used in the classroom. Schools are generally well equipped with computers for instruction in Computer Science and Informatics, but not for teaching Biology. The majority of biology teachers have access (besides the school library or staff room) to one computer in a preparatory room, which is normally unavailable to students. Computers situated outside Biology classroom do not guarantee their use in Biology instruction. There is a positive correlation with the use and availability of computers only if they are located in a biology classroom or laboratory. But even then possession of the equipment is only a prerequisite and not a guarantee that it will be used for instructions. At the time of our study data-loggers were available to all biology teachers in the sample, but only a quarter (28.5%) of them ever used the donated equipment.

Knowing this, we can conclude that the number of demonstrations and presentations will increase over time with the installation of additional computers in classrooms, but will increase significantly only in cases when the teachers will be able to prepare materials for instruction at home and use these later on stationary computers with the projector in a classroom. Portable computers and computers on trolleys that must be transported to the classroom and that need to be installed before the class will be used only sporadically. Those applications that are unavailable at home (data-loggers) or that need longer preparation time in school are condemned to disuse.

Providing a sufficient number of computers is only the first step. In our opinion, a more important barrier to the wider use of computers is teacher perception of the importance of an application, as well as teachers' proficiency. The optimal combination is proficiency in using an application and a sense of its importance. This combination applied to teachers' conceptions of word processors, internet searches and e-mail. An additional factor that can enhance use of these applications is help from the family when needed, because such programmes can be used for private purposes as well. For school work, such use of ICT can add value to teacher preparation, the search for information, or administration, but is of limited importance for teaching and learning. For example, it is fine to prepare tests with a word processor, and it is great to have a database of previously used questions, but at the end of the day, the task will be same as if it were written with ink.

The other group includes programmes that are already recognized as important, but that teachers rarely use in the classroom. Beside the buying computers the magic circle what must be broken is this: because they do not use them, they do not feel comfortable using them, so they do not use them. Unfortunately these are programmes that can be used in direct instruction, and can be of help in raising the quality of teaching and learning. There is no need to send apostles to the teachers preaching the importance of such programmes but, instead experts to help with problems. We believe that the best solution can be found in presentations. Teachers will make more frequent use of these when every classroom will be equipped with a computer and an overhead projector. Work with interactive programmes dedicated to school, computer simulations and virtual laboratory, and computer based laboratory (data-loggers) can all be introduced into teaching in the optimal way, when students can work alone, in pairs or small groups. The same is true for sources available online. As long as Biology teachers do not have access to fully equipped computer laboratories on the demand, they will not use them. But even in this case we think that the solution lies with the internet. It is very unlikely that anyone would get help in using of these programmes from family members, and this may help to limit their use.

At the moment, maintaining home pages is within the capacity of only a few teachers, and the introduction of educational computer games or programming into biology teaching is far from realistic.

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The Effectiveness of Computer Supported Versus Real Laboratory Inquiry Learning Environments on the Understanding of Direct Current Electricity among Pre-Service Elementary School Teachers

Mustafa Başer
University of Mustafa Kemal, Antakya, TURKIYE

Soner Durmuş
University of Abant Izzet Baysal, Bolu, TURKIYE

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The purpose of this study was to compare the changes in conceptual understanding of Direct Current Electricity (DCE) in virtual (VLE) and real laboratory environment (RLE) among pre-service elementary school teachers. A pre- and post- test experimental design was used with two different groups. One of the groups was randomly assigned to VLE (n = 42) and the other to RLE (n = 38). Participants in the VLE group used computer simulations to perform the given tasks, whereas those in the RLE group used real laboratory apparatus. Before the treatment, all the students administered the Direct Electric Circuits Concepts Test (DIRECT). Pre-test analyses show that there was no significant difference between the two groups in terms of understanding DCE. After completing three week physics by inquiry based treatment, the DIRECT was re-administered as a post-test. Results showed that both groups showed the same effects on acquisition of scientific concepts.

Keywords: CAL Systems; Virtual Laboratory; Inquiry Learning; Pre-Service Teachers

INTRODUCTION

Many researchers in science education indicated that students from different age groups and levels have difficulties in acquiring the concepts in physics (e.g., Baser, 2006a; Engelhardt & Beichner, 2004; Peters, 1982). These difficulties arise from the fact that students construct their own concepts by interacting with the physical world. In general, these constructions are usually not consistent with scientifically accepted ideas (Vosniadou et al., 2001). Researchers use different names for these scientifically inconsistent ideas, namely preconceptions, misconceptions, alternative conceptions, intuitive conceptions, and so on. (Aguirre, 1998; Tsai & Chou, 2002; Eryilmaz, 2002; Sherin, 2006). In the current study, the term called alternative conceptions is preferred for referring to the mistaken answers given by students, their ideas about particular situations, and to their fundamental beliefs about how the world works (Dykstra, Boyle, & Monarch, 1992).

Correspondence to: Mustafa Başer, Assoc. Professor in Science Education, Mustafa Kemal Universitesi, Egitim Fakultesi, BOTE, Antakya, Hatay-TURKIYE
E -mail: baser.mustafa@yahoo.com

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State of the literature

- Although there are a number of studies in science education literature for evaluating the effect of real laboratory environment and virtual laboratory environment in both of which students perform traditional confirmatory experiments, there only a few studies that compares when inquiry learning is the primary teaching method in both environments.
- On the other hand, most of the studies found in the literature do not include gender comparison in both learning environments.
- Lastly, the comparison of delayed effects of real and virtual learning environments are rare in the current science education literature.

Contribution of this paper to the literature

This study contributes to the current science education literature in three contexts:

- it explores the change in students understanding of electric concepts in technology rich inquiry learning environment,
- it finds out that female students perform better in technology rich learning environment,
- it discloses that conceptual change is durable when inquiry learning environment is implemented by both real and virtual learning environments.

Alternative conceptions related to different subjects of physics have been documented in the literature (e.g., Cepni & Keles, 2006; Ma-Naim, Bar, & Zinn, 2002; Maloney, O'Kuma, & Hieggelke, 2001; Hestenes, Wells, & Swackhamer, 1992). Changing alternative conceptions is not an easy task since these conceptions are very stable, well embedded in students' cognitive domain (Sungur, Tekkaya, & Geban, 2001), and difficult to remove with traditional teaching methods (Eryilmaz, 2002). Thus, physics educators search for new methods to change these alternative conceptions. Although there is a number of perspectives in interpreting student conceptual change in physics (Chi, Slotta, & De Leeuw, 1994; diSessa, 2002; Vosniadou, 2001), the most commonly implemented conceptual change models are mainly based on Piaget's cognitive disequilibrium notion (Tsai, 2003). A well-known conceptual change model is proposed by Posner et al. (Baser & Geban, 2007). In this conceptual change model, students have to be confronted with a cognitive conflict induced by a discrepant event. Inquiry learning can be used to help students solve this cognitive conflict and construct their own conceptions by engaging students in scientific processes that encourage students to build a personal scientific knowledge which they can use to predict and explain their natural world (van Joolingen, de Jong, & Dimitrakopoulou, 2007).

Researchers have revealed that inquiry-based learning could be facilitated effectively through the use of real laboratory experiments and/or the use of virtual laboratory experiments (Zacharia, 2007; Finkelstein et al., 2005). There were a few studies that investigate educational implications of using technology-rich inquiry environments (Waight & Abd-El-Khalick, 2007). Therefore, this study is conducted in an attempt to fill in the gap in this area by investigating the relative effectiveness of inquiry learning through computer simulations and real experimentation on students' understanding of direct current electricity.

Computer Supported Inquiry Learning

Inquiry learning fosters conceptual change by engaging students in exploring the given tasks that are expected to lead them to state hypotheses, carry out experiments, create models and theories, and evaluate them as scientists do. The essence of this process is to carry out experiments that are usually done in real laboratory environment. On the other hand, computer simulations have the potential of giving students the chance to carry out experiments virtually as in the real laboratory environment (Finkelstein et al., 2005).

In the last two decades, computers have been used to create environments that engage learners in scientific inquiry (van Joolingen, de Jang, & Dimitrakopoulou, 2007). They come up to the agreement that computerized inquiry learning has positive effect on students' conceptual understanding (Salovaara, 2005; Taasoobshirazi et al., 2006). However, there are a few studies comparing the achievement of students' performing tasks in real laboratory environment to that in virtual laboratory environment, in both of which inquiry learning is implemented (Zacharia, 2007). These studies support the view that virtual experimental environment has similar or better effect on students' conceptualization of scientific concepts when compared to real experimental environments (van Joolingen, de Jong & Dimitrakopoulou, 2007; Zacharia, 2007).

In spite of the benefit of using computer simulations to enhance inquiry, there are some critical issues implementing computer supported inquiry learning. Although prior knowledge and computer literacy seem to be important for carrying out experiments in virtual learning environment, Wecker, Kohnle, and Fischer (2007) found that there was no significant relations between procedural computer-related knowledge and self-confidence in using the computer for the acquisition of knowledge. The same study also revealed that students that are more literate about computer acquired significantly less knowledge. According to Wecker, Kohnle, and Fischer (2007, p.141), "the dyad with higher familiarity with computers spent less time on the single elements for receptive use, which gave them little opportunity to elaborate on the information provided in these elements". Another issue that science educators should take into consideration is the gender bias in computer supported learning. It is generally accepted that technology is gender-neutral (Plumm, 2008). Contrary to this view, current research findings reveal that there are significant gender-related differences in performance and interaction style in computerized learning environments. Although computer supported learning environments have the potential of offering democratic and equal opportunities, the evidence suggests that this claim is no longer true because of the fact that interaction through electronic channels does not consider the social complexity and gender imbalance which already exists within society (Gunn et al., 2002). However, the findings of Mayer-Smitha, Pedrettib, and Woodrowa (2000) indicate that gender issue should not be seen as one that promotes student engagement and success. More significant than gender are the issues concerning how science and technology-rich learning environments should be structured, and what pedagogical practices need to be used. Hence, computer-supported learning environment facilitating inquiry learning should be designed so as to offer equal opportunities (Gunn, 2003). This kind of learning environment will not be beneficial only to males but also to females (Hakkarainena & Palonen, 2003). Physics by inquiry curriculum is designed with pedagogy to make students active while constructing their own knowledge.

Studies in Direct Current Electricity

Since concepts in direct current electricity such as current, potential difference, complete circuit, and power dissipated within circuit element are abstract (Choi, 2004), students develop many alternative conceptions related to these concepts. There are many studies that investigate these alternative concepts from different countries and for different age groups (Baser, 2006b; Cepni & Keles, 2006; Periago & Bohigas, 2005; Engelhardt & Beichner, 2004; Lee & Law, 2001; Shipstone et al., 1998; McDermott & Shaffer, 1992).

Earlier studies naturally deal with identifying students' alternative conceptions related to electricity. For example, Fredette and Lochhead (1980) found that most young students consider that current can be carried by a single wire from the positive terminal of the battery to a bulb to shine it and thus there is no need to connect another wire from battery to bulb. However, some students consider that current coming from positive and negative terminal of the battery should be met at the bulb to shine it and therefore they consider that two wires are needed (Osborne, 1983). Students having these kinds of alternative conceptions also consider that current flows in one direction around the circuit and is used up so that less is available to other bulbs in the circuit (Shipstone, 1984).

Understanding electric diagrams and interpreting a short circuit are other sources of difficulty for students. For example, they tend to analyze only the modified part of the circuit rather than the whole circuit if they are asked to analyze the circuit in case any change takes place in a part of the circuit (Cohen, Eylon, & Ganiel, 1983; Engelhardt & Beichner, 2004).

A recent study by Engelhardt and Beicher (2004, p.100) provides an extensive list of students' difficulties and alternative conceptions related to direct current electricity. Here is the list of some examples: students are unable i) to consider that there is no potential difference in an open circuit, ii) to understand the functional two-endedness of circuit elements, iii) to interpret pictures and diagrams of a variety of circuits including series, parallel, and combinations of the two, iv) to understand and apply conservation of current (conservation of charge in the steady state) to a variety of circuits, and so on. Even, these misconceptions do exist on in- and pre- service physics teachers (Kucukozer & Demirci, 2008).

Recent studies aim to change these alternative conceptions using different teaching strategies. For example, Tsai (2003) investigate the effectiveness of conflict maps on refining students' alternative conceptions about simple series electric circuits and conclude that conflict maps have positive effect. Chiu and Lin (2005) used analogies for promoting conceptual change and show that the use of analogies helped students refine their misconceptions concerning electricity. Conceptual change texts can also be used to change students' alternative conceptions related to electricity as in the study of Carles and Andre (1992). Science educators started to integrate computer simulations as the new technologies come to scene. Although computer simulations seem to be a good alternative for gaining concepts in electricity (e.g., Ronen & Eliahu, 2000), science educators are aware that students may benefit better from real than virtual laboratory experiments (e.g., Srinivasan et al., 2006). The studies have begun to focus on the effectiveness of computer simulations in enhancing students' conceptual understandings of electric circuits. For example, Baser (2006a) used an open source software, called Qucs, where students were asked to analyze certain electric circuits to produce numerical or qualitative answers to the given questions, and then to use Qucs to simulate the circuit and check their answers. This study revealed that open source software simulations are effective on promoting conceptual change in direct current electricity. On the other hand, if conceptual change strategies are facilitated through computer simulations, they give rise to better acquisition of conceptual change of direct current electricity concepts than the confirmatory simulation (Baser, 2006b). In another study, Olde (2004) concludes that if students are encouraged to finish tasks using computer simulations, these simulations strengthen their domain knowledge by retrieving and explaining problem solving steps, and focusing on the dynamic characteristics of the simulated circuits.

The comparison of real versus virtual experiments is a new issue in science education. Jaakkola, Nurmi, and Lehtinen (2005) used computer-simulation software to compare its effectiveness on the understanding of electric circuits to real laboratory experiments. His results show that the computer simulations improve students' understanding of electric circuits when compared to the laboratory work. According to the results of Finkelstein et al. (2005), students using computer simulations instead of real apparatus perform better on conceptual questions related to simple circuits. Recently, Zacharia (2007) investigated the value of combining real lab experiments with virtual lab experiments with respect to changes in students' conceptual understanding of concepts in electric circuits. He found that this combination enhanced students' conceptual understanding more than the use of real lab experiments alone. Van Joolingen, de Jong, and Dimitrakopoulou (2007) summarize the findings of previous studies regarding the use of computer-supported inquiry learning in science and argue that the comparison of real to virtual is a current issue and that there is a need for further studies comparing real to virtual lab experiments in inquiry learning.

Research Method

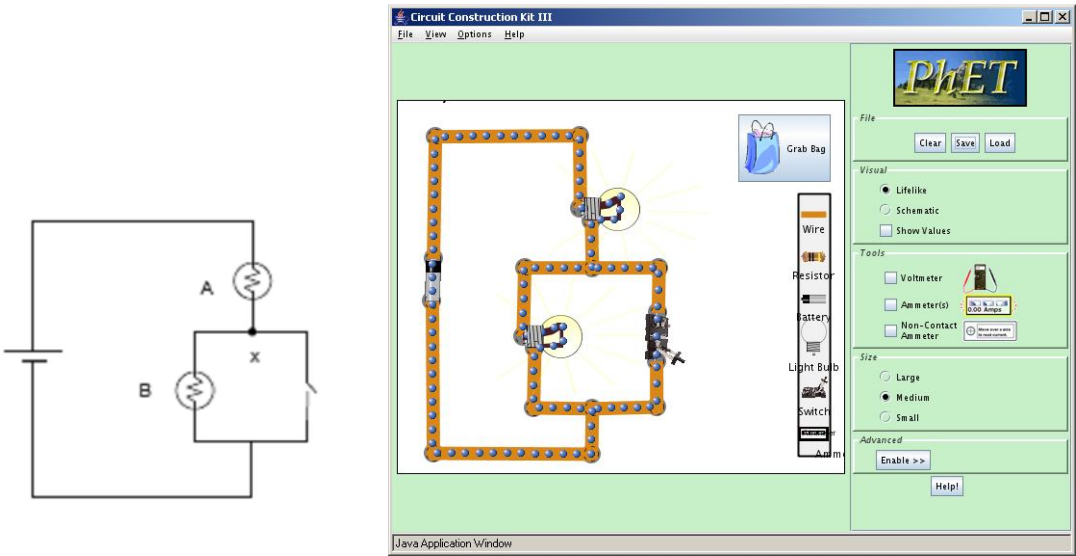
Purpose

The purpose of this study is to investigate the effectiveness of virtual laboratory environment (VLE) when compared to real laboratory environment (RLE) on students' conceptual understanding of electric circuits both implementing physics by inquiry curriculum developed by McDermott et al. (1996). The research questions are as follows:

1. Is there a significant difference between pre-service elementary school teachers' understandings of direct current electricity concepts in VLE and RLE groups?
2. What is the contribution of students' attitudes toward physics and their science process skills to variations in pre-service elementary school teachers' understandings of direct current electricity concepts?
3. Is there a significant contribution of gender and interaction between genders, their attitudes towards physics, and modes of treatments to the variations in pre-service elementary school teachers' understandings of direct current electricity concepts?
4. Is there a significant difference between long-term effects of VLE and RLE on pre-service elementary school teachers' understandings of direct current electricity concepts?

Participants

The participants were 87 pre-service elementary school teachers enrolled in two classes of science education course at Abant Izzet Baysal University in Turkey. Seven participants were excluded from analyses since their data were missing either in the post test or retained test or they missed at least one week of instructions. None of the participants received physics course in electricity at the university. For most of the participants (n=67), it was the first time that they were facing the direct current electricity concepts such as potential difference, current and power dissipation in circuit element. The participants of this study ranged in age from 19 to 22 years. Participants' native language



(A) (B)

Figure 1. (A) Circuit diagram (B) Constructed circuit in CCK

and language of instruction were Turkish. In both groups, students worked in pairs. The study lasted twelve hours in three sessions (one session per week). Each of the two instructional methods was randomly assigned to one class after the participants were already in the class. The VLE group consisted of 42 students (30 female, 12 male) and there were 38 students (23 female, 15 male) in the RLE group. Both groups were instructed by the first author of this study.

Instruments

Determining and Interpreting Resistive Electric Circuit Concepts (DIRECT)

The authors of the present study found few tests on DC electric circuits (e.g., Cohen, Eylon, & Ganiel, 1983; Dupin & Johsua, 1987; Millar & King, 1993) in the related literature, but these tests were mostly developed either for a research tool or curriculum assessment instrument, not for a general assessment tool. Hence, the scope of these tests restricted content, dealing with a single concept such as voltage or resistance. Engelhardt & Beichner (2004) decided to develop DIRECT as to evaluate students' understanding of a variety of direct current resistive electric circuit concepts. In the present study, the authors decided to use DIRECT (v.1.2) to determine conceptual understandings of students in direct current electricity based on the following criteria: i) it is a test that can be used to diagnose both high school and university students' reasoning regarding to direct current resistive electric circuits (Engelhardt & Beichner, 2004), ii) it can be used to evaluate students' progress in learning concepts in direct current electricity (Baser, 2006b), and iii) it is a useful pedagogical tool to assess student learning in an inquiry-based physics course (Ross & Venugopal, 2005).

There are 11 objectives related to four sub-topics of direct current electricity in the test. The test contains 29 five alternative multiple choice (one item has four alternatives) conceptual items. The test is translated and adapted to Turkish by the first author. The translated version of the test is examined and verified by two physics instructors who have English proficiency. Reliability (KR20) of the Turkish version was found to be 0.71. Therefore, the test can be used for group measurements. Some representative items from DIRECT were given in Appendix A. In order to investigate the effect of VLE and RLE on students' understandings of direct electric circuit concepts, DIRECT was administered as a pre and post test to all the participants in the study. Furthermore, DIRECT was given as a delayed post test to determine the delayed effect of the two modes of learning environment after three months.

Physics Attitude Scale (PAS)

Since attitudes toward the subjects investigated in the study are generally related to success (e.g., Chin & Won, 2001; Baser & Geban, 2007), students' attitude toward physics was controlled. This scale was developed by the first author of this study (Baser, 2003.). While the scale was constructed in the previous study, firstly students were asked to write down what they think about physics as a school subject. Then texts written by students were carefully analyzed and classified common ideas. The ideas put together to form the scale which was submitted to field expert. Their recommandations were taken into consideration to make the scale better. Finally 15 Likert type items were constructed and applied to students who tooks physics for determining its reliability. IIts reliability was found as 0.83. This test was applied to students in both groups before the treatment to determine students' attitudes towards physics. Some sample items were given in Appendix B.

Science Process Skill Test (SPST)

Students' science process skills play an important role on inquiry based curriculum for their achievements (Myers & Dyer, 2006), so this measure was taken to control students' science process skills. Burns, Okey and Wise (1985) developed this test and it contains 36 four-alternative multiple-choice questions. Students in both groups took the test prior to the treatment. The reliability of the test was 0.81. It measures basic skills to implement scientific inquiry methods such as identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations and interpreting data. Some items from SPST were given in Appendix C.

The inclusion of covariates can increase statistical power because it accounts for some of the variability (Tabachnick and Fidell, 2001). Both measures of PAS and SPST were used as covariates for ANCOVA statistics to remove the effects of students' attitudes toward physics and their science process skills on their achievement related to concepts in direct current electricity.

Treatment

The module of electric circuits from physics by inquiry curriculum (PBI, McDermott & The Physics Education Group, 1996) was translated and adapted to Turkish by the first author. The consistency of the Turkish form was reviewed by a physicist and two physics students, their recommendations were taken into consideration without changing the structure of PBI. Identical PBI curriculum was implemented in both groups. This study compares the effectiveness of two instructional conditions that differ only in the medium of experimentation. Students in the VLE group performed experiments using computer simulation software (Circuit Construction Kit, CCK), whereas students in the RLE group performed the same experiments using real laboratory instruments.

PBI curriculum was developed considering the basic tenets of constructivist views of cognitive development by McDermott and her colleagues (1996). Students bring some alternative conceptions based on their interactions with their environments to physics classes. PBI curriculum recognizes these conceptions and claims that these prior conceptions can be changed to scientifically accepted conceptions through experimentation. PBI curriculum generally uses discrepant events assuming that these events would induce cognitive conflict. A discrepant event is generally the physical experience that provides students with novel evidence to contradict their existing conceptions (Kang, Scharman, & Taehee, 2004; p.73). Hence, PBI curriculum is specifically designed to be implemented in real laboratory environment. The concepts and relations are investigated in-depth in PBI curriculum rather than in broader sense. Students construct their own knowledge through a process of guided inquiry in which they work with simple experiments to make observations as scientist do by developing critical thinking and scientific reasoning skills. During this process, well-designed questions were asked to students for helping them understand the concepts being taught. The role of instructors is to intervene and ask more probing questions as to reveal what they have learned and to guide for further learning.

It was decided that the experiments in circuit module of PBI curriculum can be implemented with open-ended simulation software as with real laboratory apparatus. The simulation software used in this study to conduct experiments virtually was Circuit Construction Kit (CCK). CCK is developed by the Physics Education Technology project at the University of Colorado (http://phet.colorado.edu/web-pages/index.html). Students can conduct experiments using CCK similar to real-life labs (Perkins et al., 2006). Connecting light bulbs, switches, resistors and wires to create desired direct current electric circuits are possible in CCK. For example, as a part of instruction in one question (see Fig. 1A), students are asked firstly to predict how brightness of the bulb A and B are affected if the switch is closed. Secondly, they are required to set the circuit up and check their answers. In CCK, this experiment can be done as in Fig. 1B.

If the computer simulation experiments are compared to real laboratory experiments, it can be claimed that computer simulation experiments have two advantages over real experiments: 1) Students have difficulties with the basic concept of electric circuits due to the fact that they can not see electric charge carriers (electrons) move through an electric wire (Pfister, 2004). CCK simulations offer opportunities to students to observe the electrons moving explicitly through circuit components. This may enable students to understand charge conservation and to be aware of the fact that the

Table 1. Means (M) and Standard Deviations (SD) of the Pre, Post, and Delayed Post Test Results of the DIRECT, SPST, and PAS

		DIRECT						SPST		PAS	
		Pre		Post		Delayed post		Pre		Pre	
Group	N	M	SD	M	SD	M	SD	M	SD	M	SD
VLE	42	9.31	3.04	15.38	3.72	14.50	2.65	24.57	3.23	2.93	0.78
RLE	38	9.74	2.94	15.45	3.32	13.50	3.44	23.97	3.67	3.07	0.61

Table 2. ANCOVA Summary (Group vs. Achievement)

Source	SS	df	MS	F	*P*
Treatment	10.34	1	10.34	1.15	0.29
Gender	12.02	1	12.02	1.33	0.25
Treatment * Gender	102.52	1	102.52	11.36	0.00*
Covariate (Attitude towards Physics)	49.65	1	49.65	5.50	0.02*
Covariate (Science Process Skills)	77.03	1	77.03	8.54	0.01*
Error					

* Significant ($p < .05$)

brightness of bulb depends on the number and the speed of electrons, which indicates the amount of current flowing through the bulb. 2) Since it is nearly impossible to have identical bulbs (real bulbs with equal resistances), students may encounter unexpected results during real laboratory experiments. For example, they may observe unequal brightness of bulbs in series. This observation may strengthen their alternative conceptions or cause new alternative conceptions. On the other hand, since current and voltage relations are calculated through Kirchhoff's law in computer simulations, students always observed correct brightness of bulbs in series.

Srinivasan et al. (2006) argue that most students perceive computer simulations as fake. In order to convince students that both VLE and RLE experiments yield the same results, at the beginning of the instruction students in the VLE group are given the chance to experience with real bulb, battery and wire as to light the bulb. The same experiment is done with CCK as to compare with real experiment. Hence, students may have a sense that doing experiments in computer environment is not fake.

RESULTS

In order to investigate the effectiveness of the treatments on dependent variable, and to control the students' previous learning in direct current electricity concepts, their science process skills, and attitude toward physics before the treatment, three pre-tests (DIRECT, SPST, PAS) were administered to all of the participants. The descriptive statistics is presented in Table I. The alpha level for all statistical tests was 0.05.

ANOVA statistics implied that there was no significant difference between the two groups in terms of learning direct current electricity concepts ($F(0.41)=0.53$, $p>0.05$), science process skills ($F(0.60)=0.44$ $p>0.05$), and attitude toward physics ($F(0.85)=0.36$ $p>0.05$) at the beginning of treatment.

Contribution of Treatment to Achievement in the Direct Current Electricity Concepts

By controlling the effects of students' science process skills and their attitudes towards physics as covariates, the immediate effects of two different instructions on students' achievement related to direct electricity concepts were determined with ANCOVA after the treatment. The analysis of data is summarized in Table II. The results revealed that the post-test mean scores of the VLE group and RLE groups with respect to the achievement related to direct current electricity concepts were not significantly different ($\overline{X}_{VLE}=15.38$, $\overline{X}_{RLE}=15.45$).

In the light of the findings of this study, it is seen that computer supported inquiry and real laboratory inquiry teaching have the same effect on students' understandings of direct current electricity. The participants both in the VLE and RLE groups showed significant gains in the mean scores of DIRECT. The post-DIRECT scores were significantly higher in both groups when pre-DIRECT scores were compared with post-DIRECT scores.

When all test questions in DIRECT were analyzed using t-test, there was only one question (question number 13) in which the participants in the RLE group outperformed the participants in The VLE group. In question number 13, students were asked to deduce the best schematic diagram for the given realistic circuit. Since the participants in the RLE group played with real batteries, bulbs and wires, they were accustomed to construct real circuit for the given schematic diagram. Also, there was another question (question 22) in which students were asked to infer realistic circuit for the given schematic diagram. The participants in the RLE group did still better on this question, but the difference was not significant. Since simulations enable students to observe movements of charges through circuit, it was assumed that the participants in The VLE group were expected to understand the conservation of charges in the circuit. In question 1, students were asked if charges are converted to light when the bulb lights. However, the participants in The VLE group did not significantly outperform the participants in The RLE group.

Contribution of Attitudes toward Physics and Science Process Skills to Achievement in the Direct Current Electricity Concepts

ANCOVA statistics revealed that the contribution of students' attitudes toward physics and science process skills to the variations in their achievements related to direct current electricity concepts were significant. Hence, it seems that attitudes of the participants toward physics and science process skills are accounted for significant variations in their achievement related to direct current electricity concepts in physics if they receive physics by inquiry curriculum.

Contribution of Gender and Interaction between Gender and Treatment to Achievement in the Direct Current Electricity Concepts

Analyses of data indicated that although interaction between gender and treatment differences significantly contributed to students' understandings of direct current electricity concepts, gender alone was not significantly accounted for students' understandings of direct current electricity concepts. This interaction could

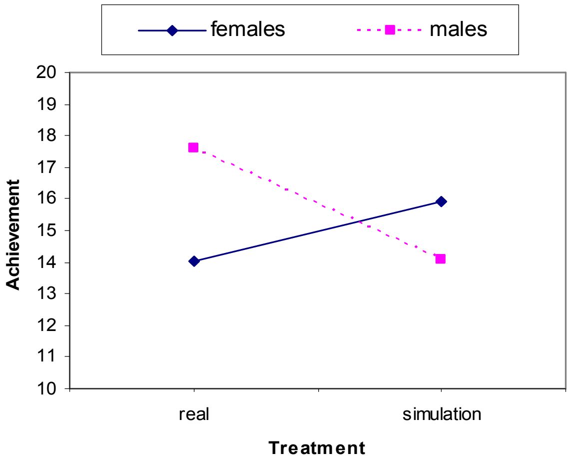


Figure 2. Achievement Test Scores by Gender

come from the gender difference in The RLE group (see Fig. 2).

Regarding gender differences in each group separately, the data indicated that there was a significant difference between the post-DIRECT scores of males and females in The RLE group (t=3.76, df=36, p=0.00, $\overline{X}_{male} = 17.60$, $\overline{X}_{female} = 14.04$) in favor of males, and none in The VLE group (t=1.45, df=40, p=0.16, $\overline{X}_{male} = 14.08$, $\overline{X}_{female} = 15.90$). In the light of the findings of this study, males are observed to be superior in real laboratory experiments. The reason might be that male students might be more familiar to batteries, bulbs and wires than female students.

Delayed Effects of VLE and RLE on Students' Understandings of Direct Current Electric Concepts

DIRECT was re-administered to all participants of this study after three months to determine delayed effects of two modes of instruction on students' understandings of direct current electric concepts. ANOVA statistics indicated that there was no significant difference between the delayed post-test mean scores of the participants in The VLE group and the participants in The RLE group ($F(5.71)=0.02$, $p<0.05$). Although mean scores of students on the delayed post test were slightly less than those of students on the immediate post test, they were still significantly higher than those of pre test for both groups. This finding implies that physics by inquiry-based instruction implemented in this study assures the durability of conceptual change, whether implemented either in virtual or real laboratory environments, at least in the short term.

CONCLUSIONS

The purpose of this study was to compare relative effectiveness of virtual laboratory inquiry learning environment to real laboratory inquiry learning environment on pre-service elementary school teacher' understandings of direct current electrical circuits. The participants in both groups followed the physics by inquiry curriculum in order to learn concepts in direct current electricity. While the participants in The VLE group utilized computer simulations to perform the given tasks, the participants in The RLE group used real laboratory apparatus to perform the same tasks. The analyses show that the achievements of participants in both groups are at the same level in terms of understanding concepts in electricity. Thus as an aswer for the first research questionof this study, it is observed that there is no difference for the participants between computer simulations or real laboratory apparatus. As a ansfer for the second and third research question of this study, it can be concluded that, based on the analyses of data, although science process skills, attitudes toward physics, and interactions between gender and treatment made significant contributions to the variations in achievement, gender difference and treatment did not. Tha last reseacrh question was about long term effect of modes of instruction on pre-service elementary school teachers' understandings of direct current electricity concepts. Analyses of data enable us to conclude that students in both virtual and real expereiments retained their understandings of concepts in direct current electricity at the same level.

DISCUSSIONS

The results showed that computer supported inquiry and real laboratory inquiry teaching had the same effect on students' understandings of concepts in direct current electricity. This finding is consistent with the works of Triona and Klahr (2007), Jaakkola, Nurmi, and Lehtinen (2005), and Choi and Park (2003). All of these studies indicated that computer simulations are as productive a learning tool as hands on equipments, given the same curricula and educational setting (Triona & Klahr, 2003). One plausible explanation of why physical and virtual materials had equivalent effectiveness is that, because computer simulations capture important features of the instruction using real apparatus, physical materials are unnecessary (Triona & Klahr, 2005). On the other hand, the study of Finkelstein et al. (2005) implied that students using computer simulations instead of real equipment perform better on conceptual questions related to simple circuits, and their ability to manipulate real circuits is high. The finding of Srinivasan et al. (2006) revealed that most of the students participated in the study perceived computer simulations as fake. In order to give students the chance to compare real with virtual experimentation in the current study, students in The VLE group were provided real bulb, battery, and wires to light the bulb in the first session of instruction. After that, they run the same experiment using computer simulation. Then, students in The VLE group were asked whether they perceived computer simulation as fake. All students agreed that real apparatus was essentially replaceable by computer simulation rather than seeing it as fake.

Constructivist learning approaches claim that students should be cognitively active while constructing their knowledge (Kitsantas, Baylor, & Hu, 2001). Thus, whether an activity is carried out through computer simulations or real laboratory apparatus, being cognitively active is the main issue. Physics by inquiry curriculum encourages student to be mentally committed by guiding them through the process of constructing their models with which they can explain behaviors of electric circuits (Zacharia, 2007). Hence, it was observed that the participants in the VLE group actively built their knowledge of direct current electricity as similar to the participants in the RLE group. It seems that activities related to direct current electricity in physics by inquiry curriculum enabled students to foster conceptual change either through virtual or real laboratory environment. When the delayed effect of physics by inquiry curriculum is considered, students' success is promised to be durable both for the VLE and RLE groups.

The test used in this study to assess students' achievement related to direct current electricity was DIRECT. This test was used to measure the level of conceptual change in direct current electricity (e.g., Ates, 2005; Baser, 2006b). When the post-DIRECT test scores were compared to pre-DIRECT scores of the participants in both groups, the gains of participants in both groups were significant. Similar to the finding of this study, Ronen and Eliahu (2000) also concluded that simulations provide constructive feedback, help students realize their misconceptions and correct them. Hence, this might suggest that computer simulations promoted conceptual change as opposed to the claims of Finkelstein et al. (2005).

Physics by inquiry curriculum produced significantly higher post-test mean scores on the direct current electric concepts test (DIRECT) for both groups in comparison with their pre-test mean scores. The design of the physics by inquiry curriculum basically meets the conditions of conceptual change model offered by Posner et al. (1982). The conditions were as follows: (i) students should be dissatisfied with their current (alternative) conceptions; the new conception should be (ii) intelligible, (iii) plausible, and (iv) fruitful for students. The experiments usually begin with a contradictory question that enables students to recognize their misconceptions. Students are expected to answer the questions based on their previous experiences. Then, they were asked to construct the given circuit and validate their answers. If the result of the experiment is not the same as what students expected, a cognitive conflict that positions them in a state of reflection and resolution is invoked in them so that they become dissatisfied with their current conception (dissatisfaction). Students search and build a new conception on their own to solve the problem. Since they state their own conception in order to explain the behavior of the circuit, this new conception is not too complicated (intelligibility and plausibility). Afterwards, students are asked to predict the brightness of bulbs by using the newly constructed concept. If the result of the experiment is consistent with their newly constructed prediction, the new concept will be fruitful for them, i.e., will be helpful for explaining future problems. Baser (2006b) concluded that if students run experiments, which are related to simple electric circuits under the conditions of conceptual change model offered by Posner et al. (1982), through computer simulations they will have the opportunity to change their misconceptions. Therefore, as the result revealed, conceptual development of subjects following physics by inquiry curriculum is high regardless of medium of experimentation. However, the success of Posner's approach depends strongly on the wills and abilities of students to recognize and resolve the conflict (Planinic et al., 2005). As Ozdemir and Clark (2007), Dekkers and Thijs (1998), Dreyfus et al. (1990), and Elizabeth and Galloway (1996) argued, instructions based on cognitive conflict do not always promote conceptual change. The reason might be that students often refuse to accept ideas which are in direct conflict with their alternative concepts (Bergquist and Heikkinen, 1990).

Students' attitudes toward physics significantly contributed to their achievement related to direct electricity concepts. Thus, this study revealed that student' attitudes toward physics is a good predictor for the achievement related to direct current electricity concepts, which is consistent with previous studies (e.g., Baser & Geban, 2007; Lightburn & Fraser, 2007). Students' attitudes toward computer were not controlled in this study. Hence, further researchers should take into account students' attitudes toward computer in computer supported inquiry learning since students' achievement strongly depends on their attitude toward computer in computerized instruction. (e.g., Baser 2006b; Akcay et al., 2006; Chang, 2002). Students' science process skills are the other important factor affecting students' achievements. Since identifying variables, identifying and stating the hypotheses, designing experiments and interpreting data are basic skills to implement physics by inquiry curriculum, which are important components of science process skills, it is natural that students' science process skills contribute significantly to their achievement. Therefore, any physics teacher who considers implementing physics by inquiry curriculum should be aware of his/her students' science process skills. Another issue might be to investigate whether students' science process skills are affected by long-term implementation of physics by inquiry curriculum

When the contributions of treatment, gender, and interaction between the treatment and gender are considered, only interaction between the treatment and gender was observed to have made a significant contribution to the variance in achievement related to direct current electricity concepts. When the post-DIRECT scores of males and females in the RLE and VLE groups are analyzed separately, males in The RLE group outperformed females in The RLE group. On the other hand, performances of males and females in The VLE group were the same on the post-DIRECT. Thus, it can be concluded that instruction in The VLE group is superior for females. This finding is supported in previous researches by comparing the success of males to females in inquiry based learning in real laboratory environment (e.g., Thijs & Bosch, 1998; Wang & Andre, 1991). Achievement of males compared to females in The RLE group might be explained with the common notion that males are more familiar to batteries, bulbs and wires than females. Although the difference between performances of males and females were not statistically different in The VLE group, females outperformed males. This finding is supported by the study of Mayer-Smith, Pedretti, and Woodrow (2000) in which they concluded that female students learning science through and with technology perform as well as or better than their male counterparts. As Akpan (2002) also found, virtual laboratory environment provides equal chances for both genders. Hence, this finding should be investigated in detail with larger sample size and with different subjects of physics.

What was it that made females successful in the VLE group? We attribute their success, in part, to the learning environment which provides an equal chance of experimentation with males. Ates (2005) found that achievement scores of male students were higher than those of female students when inquiry learning tasks were implemented through real batteries and bulbs. This result is totally consistent with the one obtained in the current study, that is, achievement scores of male students in RLE group is higher than those of female students, whereas in the VLE Group, contrary to this finding, achievement score of female students is higher than those of male students. This result is similar to the work of Mayer-Smitha, Pedrettib, Woodrowa (2000) who found that females were successful when no explicit intervention strategies were implemented to promote gender equitable learning with computer supported learning.

It is common that not all misconceptions related to direct current electricity can be challenged and hopefully changed through experimentation. Some other pedagogical means of physics education should be utilized. For example, analogies could be used to address some misconceptions in current electricity (Chiu & Lin, 2005). On the other hand, conceptual change texts are one of the alternatives that can be accompanied with the regular classroom instruction for improving acquisition of qualitative concepts about simple electrical circuits (Wang & Andre, 1991).

Contrary to general assumption that physical manipulation improves learning, Triona and Klahr (2007), and Finkelstein et al. (2005) preferred virtual to real manipulation. Based on the findings of our study, we conclude that students' conceptual understandings in electricity can be improved not only by physical manipulation but also by computer simulation.

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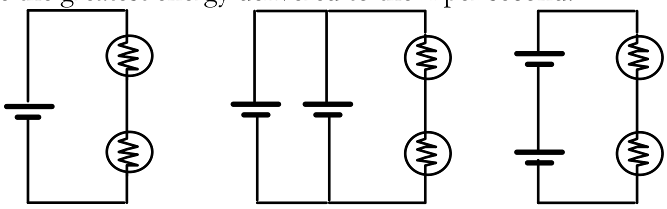
◈◇◈

Appendix-A: Some Items from Direct (Engelhardt And Beichner, 2004)

1) Which circuit or circuits have the greatest energy delivered to them per second?

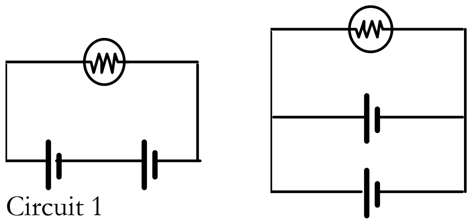
(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuit 1 = Circuit 2
(E) Circuit 2 = Circuit 3



Circuit 1 Circuit 2 Circuit 3

2) Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is brighter?

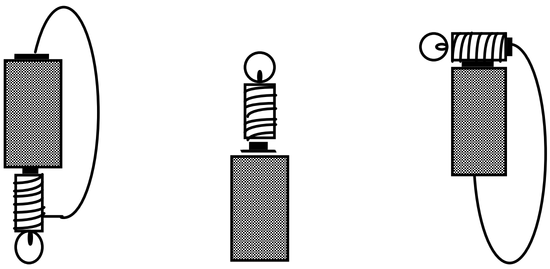
(A) Bulb in circuit 1 because two batteries in series provide less voltage
(B) Bulb in circuit 1 because two batteries in series provide more voltage
(C) Bulb in circuit 2 because two batteries in parallel provide less voltage
(D) Bulb in circuit 2 because two batteries in parallel provide more voltage
(E) Neither, they are the same



Circuit 1 Circuit 2

3) Which circuit(s) will light the bulb? (The other object represents a battery.)

(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuits 1 and 3
(E) Circuits 1, 3, and 4



Circuit 1 Circuit 2 Circuit 3 Circuit 4

Appendix-B: Some Items from Physics Attitude Scale

In the blank provided in front of the statements about physics, please indicate whether you Totally Agree (TA), Agree (A), have no decision (ND), Disagree (D), or Totally Disagree (TD).

___ 1. I like to learn more topics in Physics.
___ 2. I get bored when I study Physics
___ 3. I like to attend physics lessons.
___ 4.I am not interested in participating discussions related to physics subject

Appendix-C: Some Items from Science Process Skill Test (Burns, Okey and Wise, 1985)

1. Jim thinks that the more air pressure in a basketball, the higher it will bounce. To investigate this hypothesis he collects several basketballs and an air pump with a pressure guage. How should Jim test this hypothesis?

A) Bounce basketballs with different amounts of force from the same height.

B) Bounce basketballs having different air pressure from the same height.

C) Bounce basketballs having the same air pressure at different angles from the floor.

D) Bounce basketballs having the same amount of air pressure from different heights.

2. The effect of width of wheel on ease of rolling is being studied by a science class. The class puts wide wheels onto a small cart and lets they roll down an inclined ramp and then across the floor. The investigation is repeated using the same cart but this time fitted with narrow wheels.

How could the class measure ease of rolling?

A) Measure the total distance the cart travels.

B) Measure the angle of the inclined ramp.

C) Measure the width of each of the two sets of wheels.

D) Measure the weight of each of the carts.

http://www.ejmste.com

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Identifying Students' Interests in Biology Using a Decade of Self-Generated Questions

Ayelet Baram-Tsabari
Department of Education in Technology and Science, Haifa, ISRAEL

Ricky J. Sethi
University of California, Riverside, CA, USA

Lynn Bry
Harvard Medical School, Boston, MA, USA

Anat Yarden
Weizmann Institute of Science, Rehovot, ISRAEL

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An identification of students' interests in biology can help teachers better engage their pupils and meet their needs. To this end, over 28,000 self-generated biological questions raised by students from kindergarten through graduate school were analyzed according to age and gender. The sample demonstrated a dominance of female contributions among K-12 students. However, girls' interest in submitting questions dropped as they grew older. Topics popular among different age groups of males and females were identified, and the development of interest was described. Ways in which students' interests can be incorporated into a standard-based curriculum are discussed, mainly as a trigger for the learning of less popular subjects which are required by the curricula.

Keywords: Data mining, Free-choice environment, gender, interest, K- graduate

INTRODUCTION

Teaching students what they want to know can be a very beneficial pedagogical strategy. However, curriculum developers and teachers often lack the necessary knowledge on which to base teaching which is responsive to students' genuine interests and informational needs. In order to create such a lesson, the teacher needs prior knowledge regarding the development of students' interest in biological issues, as well as familiarity with their self-generated questions on the topic he or she are about to teach. The aim of this study is to shed light on both – the development of students' interest, as well as their specific question in biological topics, based on a decade worth of self generated biology questions submitted to an online Ask-A-Scientist site.

Correspondence to: Ayelet Baram-Tsabari, Ph.D. in Science Education, Department of Education in Technology and Science, Technion, Haifa 32000, ISRAEL
E-mail: ayelet@technion.ac.il

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The role of students' interest in science education

Positive relationships have been reported between interest and a wide range of learning indicators (Pintrich & Schunk, 2002; Schiefele, 1998). When allowed to pursue their own interests, students participate more, stay involved for longer periods, and exhibit creative practices in doing science (Seiler, 2006). Interest has also been found to influence future educational training (Krapp, 2000) and career choices (Kahle, Parker, Rennie, & Riley, 1993). Beyond being a useful and

State of the literature

- Positive relationships have been reported between interest and a wide range of learning indicators. However, when aiming at creating interesting and relevant learning materials, developers frequently rely on an adult notion of what should be relevant and interesting to students.
- Biology is the most popular science subject among students and adults, and the only science subject that has escaped a masculine image. Girls are most interested in biological topics dealing with health, mind and well-being.
- Interest in biology is not a constant trait: interest in zoology, for example, decreases with age, while interest in human biology increases.

Contribution of this paper to the literature

- This study investigates the development of K-graduate students' interest in different biological topics, based on a decade's worth of self-generated science questions sent to an Ask-A-Scientist site.
- Male and female students differed significantly in their interest in some of the topics. However, students from both genders used Ask-A-Scientist site to get help with their school-work as well as to satisfy their own curiosity.
- Student interest in various topics differed significantly among the various age groups. Topics which were most popular among young age groups have to do with macroscopic levels of organization and concrete entities, while topics popular among older students have to do with microscopic levels of organization and molecular entities.

pragmatic practice, involving students in decisions about their lives in school is an important moral and educational principle (Davie & Galloway, 1996). Jenkins (1999) examined the implications of “citizen science”, i.e. science which relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday lives, for the form and content of school science education. He suggested constructing science curricula that enable young people to engage in science-related issues that are likely to be of interest and concern to them (Jenkins, 1999). This idea also appears in the recommendations of several organizations, including the National Research Council (1996) and the American Association for the Advancement of Science (1993), which have proposed that science curricula provide a common basis of knowledge while addressing the particular needs and interests of students.

Listening to the students is still a frequently overlooked approach to improving academic success (Conboy & Fonseca, 2009). Many scholars have pointed to the importance of relevance to curriculum development (e.g. Edelson & Joseph, 2004; Kember, Ho, & Hong, 2008) and science teaching (e.g. Darby, 2009).However, when aiming at creating relevant learning materials, developers frequently rely on an adult notion of what should be relevant and interesting to students (e.g. Bulte, Westbroek, de Jong, & Pilot, 2006; Chamany, Allen, & Tanner, 2008; Edelson & Joseph, 2004). However, for science to be relevant to its practitioners, the origin of the questions which are being investigated are of great importance (Tippins & Ritchie, 2006). Therefore, the ability to identify students' own interests in biology may be used to contextualize and personalize some of the formal biology curriculum.

Students' Interest in Biology

Research has provided some insight into students' interest in biology. It is the most popular science subject among students and adults (Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Baram-Tsabari & Yarden, 2005; Baram-Tsabari & Yarden, 2009; Dawson, 2000; Falchetti, Caravita, & Sperduti, 2003; Murray & Reiss, 2005; Osborne & Collins, 2000; Qualter, 1993), and especially among females. Ayalon (1995) describes biology as an emerging "feminine niche" in science. It is the only science subject that has escaped a masculine image. .

Differences exist between the topics that males and females find interesting within biology. According to results from the international project 'Relevance of Science Education' [ROSE] in Denmark (Busch, 2005), England (Jenkins & Nelson, 2005), and Norway (Schreiner, 2006), girls are most interested in biological topics dealing with health, mind and well-being. Moreover, interest in biology is not a constant trait: interest in zoology, for example, decreases with age, while interest in human biology increases. This trend has been identified among young (<14-year-old) Israeli children (Baram-Tsabari & Yarden, 2005) as well as adolescents from various countries (Baram-Tsabari, Sethi, Bry, & Yarden, 2006), and it continues among adults (Baram-Tsabari & Yarden, 2007). The increased interest in human biology among adolescents is probably due to the approach of puberty and the related increasing interest in one's body. Adults seem to be more interested in human biology because they are more concerned with health issues. Older pupils' interest in human biology is well attested to by a number of other studies, including some conducted in England (Osborne & Collins, 2000), Israel (Tamir & Gardner, 1989), and Poland (Stawinski, 1984).

Research Approach

Students' scientific interests are traditionally identified by questionnaire-based methods which involve asking students to tick boxes in response to a series of prepared questions or topics (e.g. Dawson, 2000; Qualter, 1993; Sjøberg, 2000; Sjøberg & Schreiner, 2002; Stark & Gray, 1999). However, the listed topics are based on adult-centric views of what subjects should be meaningful to the students. To overcome this problem, a naturalistic method was developed for using students' self-generated questions as a source of information about their interests (Baram-Tsabari & Kaadni, 2009; Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Baram-Tsabari, Sethi, Bry, & Yarden, 2009; Baram-Tsabari & Yarden, 2005, 2007, 2008; Baram-Tsabari & Yarden, 2009; Cakmakci, Sevindik, Pektas, Uysal, Kole, & Kavak, 2009; Falchetti, Caravita, & Sperduti, 2007; Yerdelen-Damar & Eryılmaz, 2009). By studying students' questions, one can learn about what students are interested in and what they want to know about a given topic (Biddulph, Symington, & Osborne, 1986; Chin & Chia, 2004).

Questions are an important part of the ongoing scientific research process and have an important educational role (Biddulph, Symington, & Osborne, 1986; Brill & Yarden, 2003; Keeling, Polacek, & Ingram, 2009; Scardamalia & Bereiter, 1992). However, it is

Table 1. Examples of questions in biological topics, their frequency and percentage (n = 28,484).

Topic[a]	Frequency	Percent	Example[b] (gender, age group, country)[c]
Biochemistry	3,077	10.8	What is the chemical structure of butter, sunflower oil and olive oil? (f, undergrad); What causes a strand of DNA to twist, giving it a double helix shape? (m, 7-9, US)
General Biology	2,943	10.3	How long does it take for the calories in your body to transform into fat? (f, 7-9); How come cells can split asexually and we [humans] cannot? (m, 7-9, US)
Botany	2,766	9.7	Can we use all of spinach's iron? (m, undergraduate, Turkey); What is the chemical composition of an apple? (f, 7-9, US)
Zoology	2,760	9.7	Can a grasshopper grow back limbs? (m, undergraduate); What do you need to raise a wolf? (f, 4-6, US)
Anatomy	2,177	7.6	Is there any correlation between eye color and how well you see? (f, 4-6, US); Do children's heads stop growing at age three? (f, non-science graduate)
Cell Biology	2,129	7.5	Can stem cells be obtained from a placenta? (f, 10-12, England); Is there any DNA replication during prophase of mitosis? (undergraduate, US)
Environment & Ecology[d]	2,101	7.4	How can I measure the water retention in soil? (f, 7-9, US); Can air pollution affect the size of insects? (m, 7-9, US)
Medicine	2,036	7.1	Is there a high percentage for a boy to get diabetes if his mother has it? (f, 7-9, US); Why does an adult recover from a fracture much slower than a child? (f, undergrad)
Genetics	1,750	6.1	Can a DNA test distinguish paternity between brothers? (f, non-science graduate); Is there a genetic element that determines the sounds of our voices? (m, 10-12, US)
Microbiology	1,676	5.9	Are there bacteria that eat lava and will they destroy the earth? (m, 7-9, US); How fast do bacteria, mold-fungi or viruses grow on your body? (f, 4-6, US)
Neuroscience	1,283	4.5	How do alcohol/drugs lower inhibitions? (m, 7-9, US); how come when I flunk a test food doesn't taste good? (f, undergrad, US)
Agricultural Sciences	1,282	4.5	What are the scientific names of weeds? (f, 10-12); How would I design an experiment about the effects of gray water? (f, 10-12, Australia)
Evolution	774	2.7	What selected for, groups, organisms, or genes? (m, undergraduate, Canada); Could an herbivore evolve from a carnivore?(f, 10-12, US)
Molecular Biology	529	1.9	2 Strands of DNA—do these make 2 different batches of proteins? (f, undergraduate, Australia); Why can't there be more number of binding sequences for the given primer? (m, science graduate, India)
Development	375	1.3	How do cells 'know' how to form a blastula? (10-12); Babies get the food they need from the umbilical cord but how do they receive oxygen? (f, 7-9, US)
Virology	312	1.1	Why sequence Influenza virus genome? (Science graduate); How long does the polio virus usually stay in its host? (m, 7-9, US)
Immunology	266	0.9	What are cytokines, and how do they work? (f, 10-12, Kuwait); where is our immune system's 'memory' stored?(m, 10-12, US)
Biophysics[d]	248	0.9	Can you tan under black lights? (m, undergrad, US); At what temperature does popcorn pop? (m, 4-6, US)

a The topics are listed in order of popularity.
b These are verbatim quotes. In some cases only part of the question is shown.
c Where data are available. m = male; f = female; US = United States.
d Not all of the questions in this topic are strictly "biological".

difficult to use children's questions in a classroom setting, as they are frequently a negligible component of general classroom learning. As Dillon (1988) plainly states "Children qua students do not ask questions. They may be raising questions in their own mind…but they do not ask questions aloud in the classroom." Researchers attribute this situation to a classroom atmosphere in which revealing a misunderstanding may render the student vulnerable, open to embarrassment, censure or ridicule (Pedrosa de Jesus, Teixeira-Dias, & Watts, 2003; Rop, 2003).

However, students do pose science questions in a free-choice science-learning environment, such as the world-wide web. An option open to children trying to find complex answers on the Web, is to submit their questions to asynchronic human-mediated question-and-answer services, which are sometimes referred to as "Ask-A" services, such as "Ask a Scientist". This study is a part of a larger project in which a decade long worth of questions were collected from an Ask-A-Scientist site, in order to use children's self-generated questions as an indication of their interest in science (Baram-Tsabari, Sethi, Bry, & Yarden, 2009). This study focuses on the development of K-graduate students' interest in different biological topics, as it is being mirrored by their questions.

METHODOLOGY

Data source

MadSci Network is an award-winning independent non-profit organization operating from a server in Scottsdale, Arizona, USA (http://www.madsci.org). MadSci Network receives 90 to 150 questions daily, most of which are answered automatically by the site's search engine. Fewer than 20% of the questions are answered by nearly 800 globally distributed volunteer scientists, usually within two weeks.

MadSci Network covers all branches of science. It collects information and stores key demographic information, allowing ready mining of information in the archives. Many other English-language Ask-A-Scientist services are available on the net, but none were found suitable for this study. The reasons for this were varied, among them - sites that did not ask for the age of the asker or did not record all the information in their archives, sites which served a limited age group, or had a rather small database.

The webmasters of MadSci Network, who are two of the authors of this study (R.J.S and L.B), anonymized and provided for analysis the questions submitted to the site between 1995 to mid 2006. This data includes all the questions received in the site, and not only those sent to the scientists or published online.

Sample characteristics

Over 146,000 questions were sent to Madsci Network between its establishment at the end of 1995 and the first half of 2006. Almost 79,000 of the surfers disclosed their grade level, country of origin, and filled in the name and subject fields. An analysis of all of the questions in this sample is reported in another paper (Baram-Tsabari, Sethi, Bry, & Yarden, 2009). This study reports a more comprehensive analysis of questions allocated to the biological topics.

Users submitted their questions under one of 25 topics. Of these, the following 18 were biology topics: Biochemistry, General Biology, Zoology, Botany, Anatomy, Cell Biology, Environment and Ecology, Medicine, Genetics, Microbiology, Neuroscience, Agricultural Sciences, Evolution, Molecular Biology, Development, Virology, Immunology, and Biophysics (for examples of questions see Table 1). The topics 'Environment and Ecology' and 'Biophysics' include some questions which are not biological in nature (e.g. "Can the millions of miles of black roads be increasing global warming?").

Questions on these topics made up 37.65% of the overall sample, making biology the most popular field of interest. Of these 1,205 questions asked by teachers were not included. The resulting sample was made up of 28,484 biology questions asked by students from kindergarten through graduate school. A few questions were missing some of the data, and therefore the n values differ between variables.

Age split: Submission of questions to MadSci Network requires that the user enter a grade level. 28,480 of the inquirers provided their grade level; 68.3% of the surfers were school students: 2.8% were K-3 students, 9.5% 4-6th graders, 26.2% junior-high-school students and 29.8% senior-high-school students. Undergraduates contributed 20% of the questions, science graduates 7.7% and non-science graduates 4%.

Gender split: Gender identification was based on the asker's first name. Initial classification was done semi-automatically using an English name gender finder (epublishing.nademoya.biz/japan/names_in_english.ph p?nid=A). In the next step, the names that were not automatically classified and appeared twice or more in the data were analyzed individually using baby name guesser (www.gpeters.com/names/baby-names.php), which operates by analyzing popular usage on the internet. In this way, we were able to identify the gender of the asker for 17,840 of the questions. The rest were either names that could equally belong to boys or girls, meaningless scrambles, or names that appeared only once in the database. Of the gender-identifiable questions, 55.7% were asked by girls (n = 9,943) and 44.3% were asked by boys (n = 7,897).

Split by country of origin: 28,402 of the inquirers indicated their country of origin. The surfers originated from 126 countries. The great majority of the questions (81%) originated from the USA, UK, and Canada. An additional 10% originated from another five English-speaking countries (not necessarily as mother tongue): Australia, India, Singapore, Philippines, and New Zealand.

Statistical analysis: Unless otherwise indicated, a two-tailed Pearson chi-square test was used to calculate probabilities. Not all the inquirers provided their full details; therefore, sample sizes differ from graph to graph and are indicated by n values. Significant differences within proportions were determined according to a cell chi-square test.

RESULTS AND DISCUSSION

A decade of biology questions sent to an Ask-A-Scientist internet site were analyzed by age and gender in order to learn about the interests of students in biological topics.

Age distribution of female participants

Overall, females used the site more than males to ask biology questions (55.7% vs. 44.3%, respectively). This surprising majority of females should be viewed in the context of females' general reluctance to use media that foster informal learning about science (National Science Foundation [NSF], 2004; Nisbet, Scheufele, Shanahan, Moy, Brossard, & Lewenstein, 2002) or to take part in extracurricular science experiences (Greenfield, 1998), and their relative lack of formal and out-of-school experience in using computers and the worldwide web (Kafai & Sutton, 1999; Shashaani, 1994). Two factors worked together to explain this female majority of contributors, who are traditionally found to be less interested in science than males: the general interest of female students in the field of biology, and the attractive and secure science-learning environment provided by the internet.

This female dominance was not consistent among age groups. Girls participated in the sample more than boys while in school (K-12), especially during the middle-school and high-school years, but their number dropped dramatically upon moving to college and even more so at the graduate level, making the males the more dominant group in this latter sample (Figure 1). Although it is known that students, especially females, tend to lose interest in science as they grow older (Friedler & Tamir, 1990; George, 2006; Greenfield, 1998; Kahle & Lakes, 1983), this decrease usually takes place during the middle-school and high-school years. In this free-choice online setting, the decrease seems to have been postponed (Figure 1).

Identifying interest in biological topics

Not all topics demonstrated the same level of popularity. The most popular biology topics were biochemistry, general biology, botany and zoology, each receiving approximately 10% of the questions. Anatomy, cell biology, environment and ecology, medicine, genetics, and microbiology received 6 to 7.5% of the questions. Questions in neuroscience, agricultural sciences, evolution, and molecular biology received 2 to 4.5% of the questions. The least interesting topics were development, virology, immunology, and biophysics,

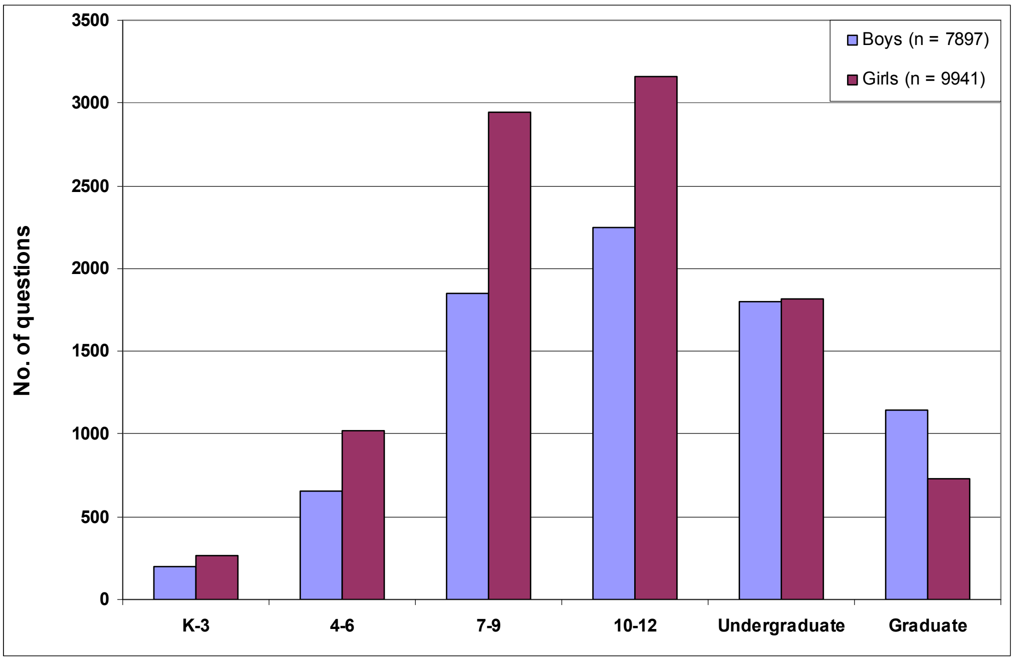

Figure 1. Distribution of biology questions according to gender and age group (n = 17,838)

with around 1% of the questions each (the full list of frequency and percentage of questions for each topic can be seen in Table 1).

Male and female students differed significantly in their interest in some of the topics ($p < 0.0001$). Females were more interested than males in asking questions about botany, cell biology, and genetics, while males were more interested than females in asking questions about medicine, neuroscience, evolution, virology, immunology and biophysics.

Although all of the questions in this sample were self-generated by the askers, it is important to note that some of them were raised by the students as a consequence of a school assignment. In a previous study, we learned that topics such as anatomy and physiology, sickness and medicine, and genetics and reproduction are all characterized by relatively more 'spontaneous' than school-related questions (Baram-Tsabari, Sethi, Bry, & Yarden, 2006). Botany and mycology, microbiology, virology, and cell biology yielded many more teacher- and textbook-generated questions than spontaneous ones. Topics such as

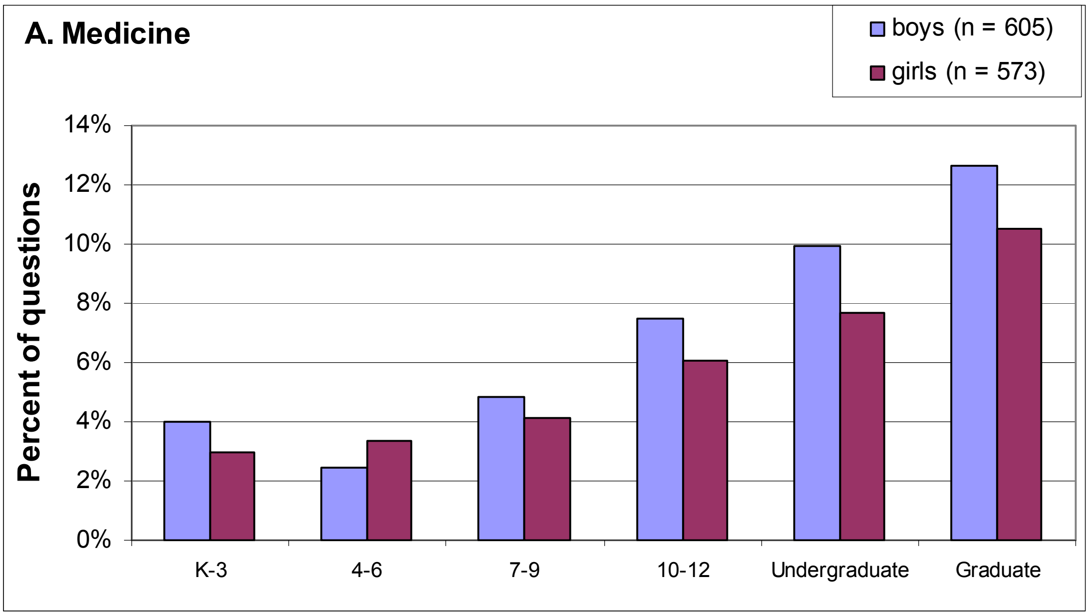

Figure 2. Figure 2: Interest in medicine among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions.

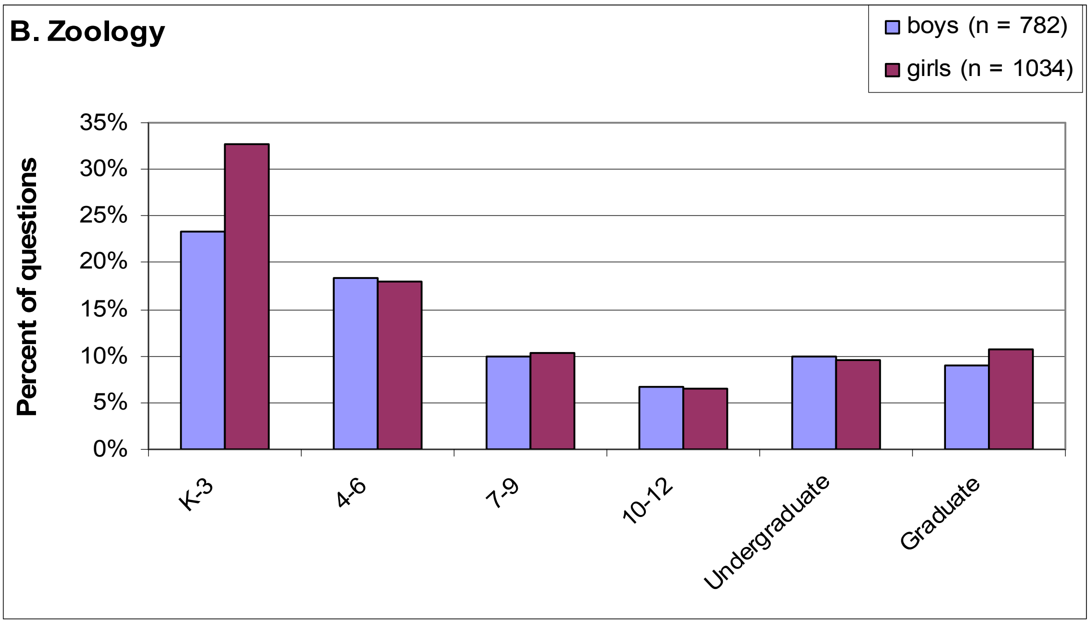

Figure 3. Interest in zoology among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions.

ecology and neurology were almost equally distributed among the two question types (Baram-Tsabari, Sethi, Bry, & Yarden, 2006). From the current analysis, we learned that both males and females used the site to get

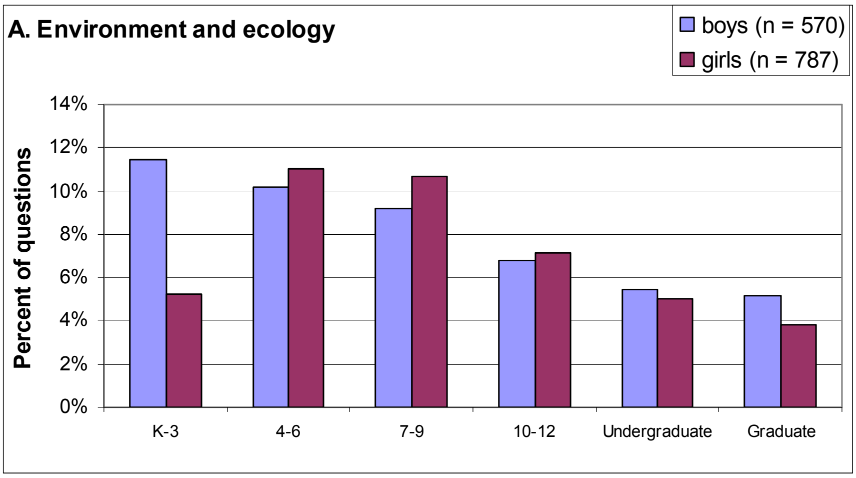

Figure 4. Interest in environment and ecology among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions.

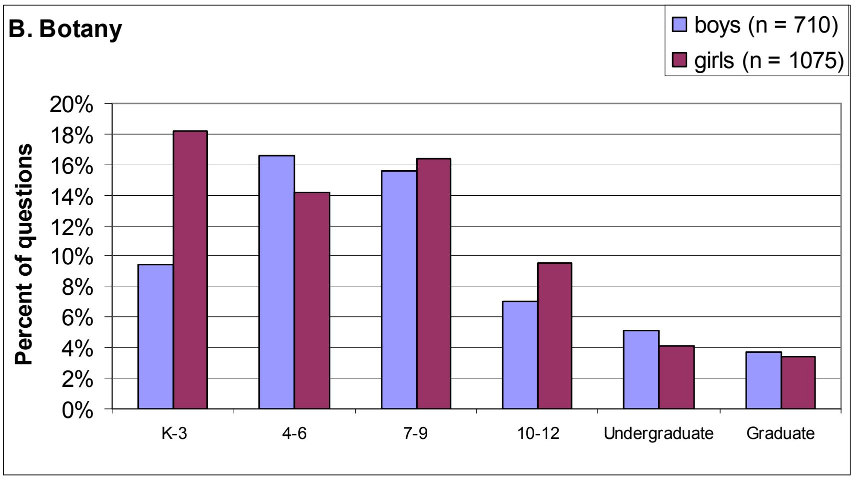

Figure5. Interest in botany among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions.

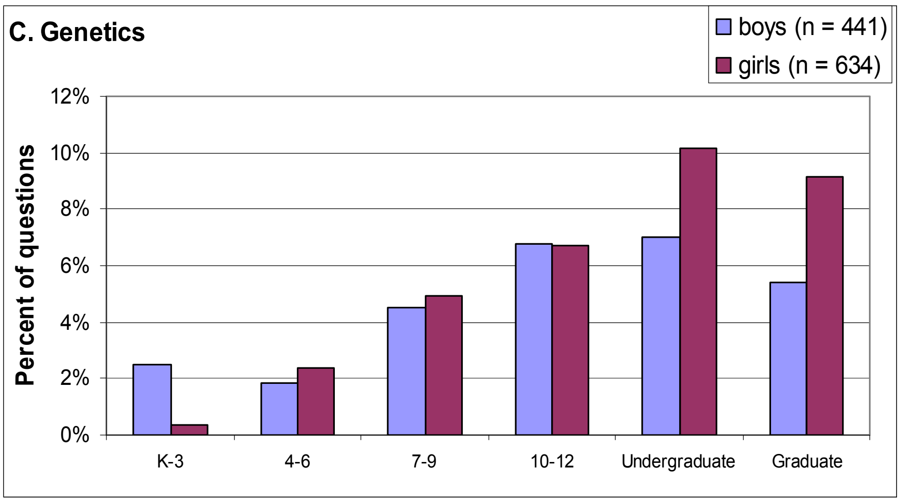

Figure 6. Interest in genetics among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions.

help with their school-work as well as to satisfy their own curiosity, since both spontaneous and school-related topics appear to be more 'masculine' or 'feminine'.

Student interest in the various topics differed significantly among the various age groups ($p < 0.0001$). For example, interest in medicine increased with age (Figure 2), while interest in zoology decreased as students matured (Figure 3). This trend is in agreement with the known pattern of increased interest in human biology and decreased interest in zoology with age, which had been previously identified in several Ask-A-Scientist sites (Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Baram-Tsabari, Sethi, Bry, & Yarden, 2009; Baram-Tsabari & Yarden, 2005).

Other topics which were characterized by a decrease in interest with age were environment and ecology (Figure 4), botany (Figure 5), and agricultural sciences (data not shown). Botany was a relatively popular topic among K-9 students. It was previously found to be a topic that elicits many questions regarding school assignments (Baram-Tsabari, Sethi, Bry, & Yarden, 2006). Thus, it can be assumed that this is the reason for the relatively high percentage of questions on this topic elicited by school children.

Four additional topics showed an increase in the percentage of questions with age: genetics (Figure 6), evolution (Figure 7), neuroscience, and biochemistry (data not shown). The first three were previously found to elicit a large number of children's spontaneous questions (Baram-Tsabari, Sethi, Bry, & Yarden, 2006), therefore the increase is probably not due to school assignments. The increase was not identical for males and females. While females developed an interest in genetics (Figure 6), males asked more about evolution (Figure 7) and neuroscience (data not shown).

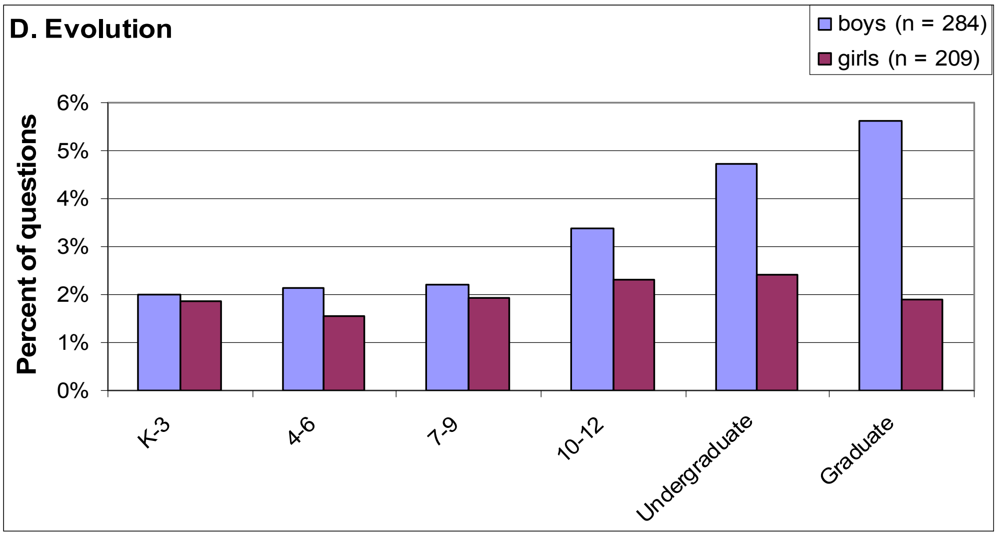

Figure7. Interest in evolution among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions

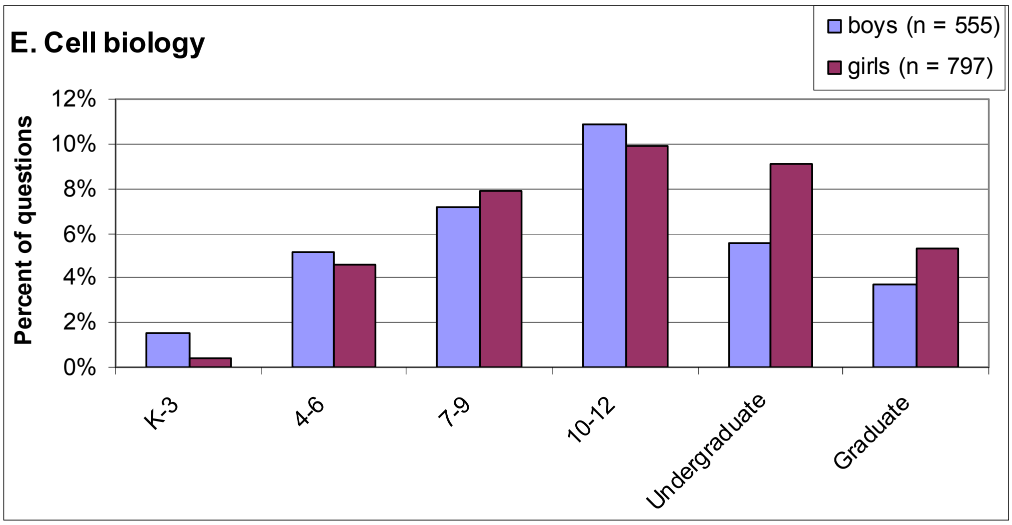

Figure 8. Interest in cell biology among boys and girls in different age groups. Percentage is calculated out of the total boys' or girls' questions

Biochemistry, on the other hand, appealed equally to both genders. It became popular among high-school students and retained its popularity among the older age groups (data not shown). The reason for this increase may be related to the formal study of biochemistry.

Overall, it seems that the topics which were most popular among young age groups have to do with macroscopic levels of organization and concrete entities, such as plants and animals, while topics popular among older students have to do with microscopic levels of organization and molecular entities, such as DNA, neurotransmitters and proteins, and with abstract concepts such as genes and phylogeny.

Cell biology (Figure 8) and microbiology (data not shown) garnered an increase in interest during middle school and high school, followed by a decrease in the older age groups. This finding is in agreement with the results of previous research which found them to be topics that elicit many questions regarding school assignments and less spontaneous questions (Baram-Tsabari, Sethi, Bry, & Yarden, 2006).

Research limitations

As early as the fall of 2003, nearly 100% of public schools in the US had access to the internet (National Center for Education Statistics, 2005). There have been virtually no differences in school access to the Internet by school characteristics since 1999 (National Center for Education Statistics, 2006), theoretically allowing all students to be part of the sample. In 2009, there are over 172 million active home users (users who have logged on from home in the previous 30 days) in the US alone (Marshall, 2009). As access to and use of the Internet becomes more widely and representatively distributed worldwide, new opportunities exist for data collection online (Rhodes, Bowie, & Hergenrather, 2003). Massive multi-player online games, for example, are used as a platform for science education research (Bainbridge, 2007), such as evaluation of scientific habits of the mind (Steinkuehler & Chmiel, 2006), and infecting avatars with virtual epidemic as a model of educational intervention (Kafai, Feldon, Fields, Giang, & Quintero, 2007). However, online data mining also has methodological drawbacks, which will be discussed here.

Non-representative sample: This research made use of a self-selected, non-control sample. There is a positive correlation between knowing about science and being interested in it (Ziman, 1991). Therefore, students who send questions to science web sites are probably more interested in and more knowledgeable about science than the general student population. Furthermore, there is also a marked difference in ease of access for children from different socioeconomic statuses to the internet, which was our source for the questions.

The validity of the study can be supported by the notion of using data that originates from the researched population itself, not as a response to a stimulus from a researcher, thus ensuring high ecological validity. Another way to achieve validation is by comparing any conclusions drawn with other independent observations. Reliability may be assured by the use of a very large sample (Reid, 2006).

Potential of multiple questions from the same user. Surfers in MadSci Networks are not provided with userIDs. As a result, multiple questions from the same user would have been recorded as arriving from different users. We assume that the number of multiple questions does not differ between genders and age groups; however, this uncertainty is a setback of our research.

Gosling, Vazire, Srivastava, and John (2004), found that internet samples are relatively diverse, generalize across presentation formats, are not adversely affected by nonserious or repeat responders, and are consistent with findings from traditional methods (Gosling, Vazire, Srivastava, & John, 2004). It is also true that a surfer can fake his identity online, or ask a question he or she are not really interested in, a key issue, then, is whether the subject would have a good reason to want to fake (Anderson, Ball, & Murphy, 1975). Rhodes, Bowie et al. (2003) conclude that many of the criticisms of online data collection are common to other survey research methodologies.

Allocation to topics: The classification of the questions to the various topics was performed by the surfers. In some cases questions were misplaced, either because the surfer did not recognize the right topic or did not pay attention to the process. We assume that most of these misplacements were distributed evenly among the topics, and therefore did not cause a major bias.

Although web-based experiments of the kind used here are more difficult to control than are experiments conducted in formal setting, they present an important methodological advantage for studying interest-driven science learning, taking into consideration that this kind and amount of data does not exist anywhere outside the web (Baram-Tsabari, Sethi, Bry, & Yarden, 2009). Other limitations, however, are not exclusively related to the data collection approach used in this study, but rather to its pedagogical implications.

Formalizing free-choice learning: Asking a question in a free-choice environment does not guarantee willingness to invest time and effort in learning the answer in a school setting. It is not clear what would happen if students' interests were implemented into the school science curriculum. Would free-choice learning lose all of its appeal once it became compulsory?

The role of students' interests in determining the curriculum: Even if we had a clear-cut understanding of what students really wish to know, the biology curriculum would not rely solely on students' interests. Principles in biology should be taught, even if they do not spontaneously elicit questions from the students. On the other hand, how can a curriculum claim to be 'relevant' to the students if it does not incorporate any of their interests?

Implications for teaching

There are several ways in which students' interests can be incorporated into a standard-based curriculum. To list a few: a teacher can present a new principle or concept using a context which is relatively engaging rather than alienating for the target audience (e.g. in biology: zoology vs. human health, (in physics see: Haussler & Hoffmann, 2002)); allow students to create their own research questions within a given topic in project-based learning or use their questions as a starting point for inquiry-based learning (Yerrick, 2000); construct a lesson based on students' questions, or even teach a whole topic using a tailor-made question-based curriculum (Gallas, 1995). Knowledge regarding the development of students' interests in different topics may be used for choosing an engaging context for different groups of learners (Baram-Tsabari & Yarden, 2007). In the following, we discuss another way of using students' individual interests in class, as a trigger for the learning of less popular subjects which are required by the curricula.

Let us imagine a novice biology teacher. Her goal for the lesson is to teach the fundamental classification of cells into prokaryotes and eukaryotes, but she is unexpectedly being asked about a very daily-life aspect of reproduction in birds: "Is it true that if you leave an egg outside the fridge a chick will hatch from it?". This seemingly unrelated question can be used as a trigger for discussing some of the differences between prokaryotes and eukaryotes—the former are simply uni-cellular creatures that usually reproduce by division, while the latter are the building blocks of all multi-cellular creatures, many of which use sexual reproduction, and ultimately, this is why unfertilized eggs do not hatch. Thus, a spontaneous question about reproduction in the context of zoology could have been converted into a formal discussion on cell biology. Seiler (2006) notes that many students' connections with science take the form of questions that a teacher might consider offhanded or even off-task, but they represent significant intellectual efforts by the students to connect science with their lives and experiences. These questions may be used as student input for the development of a student-interest-focused curriculum (Seiler, 2006).

The teacher could also have planned in advance. Since she knows that students at this age are increasingly interested in medicine, she could have started by asking the students why they think antibiotics kill bacteria, but not the person who takes it. The students would probably not be able to answer the question at that point in their education, but the question may engage and interest them.

Teachers who are attentive listeners are able to recognize and extract their students' questions and interests (Seiler, 2006), but ideas for triggering questions can be found using the "frequently asked questions" (FAQs) section presented by some of the Ask-A-Scientist sites, or just by browsing their archives. Questions such as: Where does the fat go when a person loses weight? Why do males have nipples? Can lions become vegetarians? Are dogs color-blind?, all asked by students at Ask-A-Scientist sites, may serve as triggers for standard biology-curriculum issues, such as nutrition, evolution, ecology and the senses (respectively). When choosing questions, the age of the target audience should be taken into consideration, since topic popularity varies with age. Ask-A-Scientist sites seem to be an attractive environment for girls, allowing the teacher to choose from a variety of girls' questions, which are usually rare in a school-science setting.

At Ask-A-Scientist sites the questions are asked by the learners, but the locus of control over the learning process is external, since the answers are given by asynchronic human experts (Nachmias & Tuvi, 2001). When used in class, the locus of control over the learning process is transferred to the teacher. If the questions which are used originate from the students themselves, then they receive some control over their learning, along with the engagement and interest that characterize the process of learning something that one really wants to know.

Acknowledgment

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The Role of Qualitative Research in Science Education

Iztok Devetak, Saša A. Glažar and Janez Vogrinc
University of Ljubljana, Ljubljana, SLOVENIA

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In the paper the qualitative research in which the researcher has been directly involved, and has himself been examining the research phenomenon in the studied environment, is presented. The aim of this qualitative study is to gather data in the form of rich content–based descriptions of people, events, and situations by using different, especially non–structural, techniques to discover the stakeholders' views and similar, to orally analyze the gathered data, and finally to interpret the findings in the form of a concept or contextually dependent grounded theory. The main purpose of the paper is to identify research approaches used by authors who have published in respected international science education journals in the last three years. It can be concluded from the results that authors have been using qualitative and mixed research approaches in more than half of the published papers in the last three years in order to address the research questions in their studies.

Keywords: Qualitative research, Science education, Document analysis, Journal analysis.

INTRODUCTION

Authors who publish papers in respected science education research journals always try to make some efforts to bridge the gap between science education research results and conclusions and their applications in the educational process at all levels of education. This paper presents some methodological aspects that are important for the field of science education research. The selection of the appropriate methodological approach is always an important step in the science education planning process. The science education researcher should, before choosing the method, precisely address or identify the research problem. According to the identified research problem the researcher should ask research questions about it.

The research questions asked should be researchable, take into account the subjects who are participating in the study, ought to address the research problem, and measure the variables that you wish to measure, and should also give some clear answers or - in other words - should have a clear »take home« message (Bunce, 2008).

Correspondence to: Iztok Devetak,
Ph.D in Chemistry Education, University of Ljubljana
Faculty of Education, Kardeljeva pl. 161000 Ljubljana
SLOVENIA
E-mail: iztok.devetak@pef.uni-lj.si

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Research problems and research questions provide an important guideline for the researcher in selecting the appropriate research methodology or methods designs: quantitative, qualitative and mixed methods designs.

For the purposes of this paper only the qualitative approach to science education research will be described in more detail, and the methodology approaches used by the authors who publish in respected science education journals will be analysed. At the end, some insight for future science education research will be placed into the perspective of where science education research is heading.

CHARACTERISTICS OF QUALITATIVE RESEARCH

Qualitative research, regarding its ontological, epistemological and methodological aspect, is not a consistent phenomenon; namely, it combines different kinds of research, e.g. a case study, life history, action research and the like. Bogdan and Biklen (2003) use the term »qualitative research« as the superordinate concept, joining different research approaches with certain common characteristics as well. With the expression

State of the literature

- There are not many papers about methodological approaches in science education research published in respected journals.
- Some aspects of qualitative paradigm of pedagogical research seem to be an important approach recently, but there have not been done a systematic analysis of the methods used in the published papers.
- Three research questions were addressed in this paper, were about methodological approaches that prevail in papers published in the last three years in the field of science education research, about data gathering methods in the qualitative and mixed research papers and was a triangulation of methods used in there papers?

Contribution of this paper to the literature

- The largest part of the analyzed papers was about science in general, rather than biology, chemistry or physics.
- The qualitative research approach was used most frequently, following by quantitative and mixed approach. The authors most frequently use interviews for gathering data following by observations and document analysis. The authors used triangulation of qualitative data gathering methods in only 39.2% of the published qualitative or mixed research papers.
- It can be concluded from the analysis of the papers published in three respected science education journals that, similarly as in the field of general sociological and pedagogical research, the qualitative research approach for gathering data prevails.

»qualitative research«, the research is denoted as consisting of the basic empirical material, collected in the research process, which is verbally described or narrated. Furthermore, the collected material is worked on and analyzed in words without numerical operations (Mesec, 1998). In other authors, (e.g. Denzin & Lincoln, 2000; Creswell 1998) similar definitions of qualitative research are found. According to Creswell, qualitative research is the research process designed according to a clear methodological tradition of research, whereby researchers build up a complex, holistic framework by analyzing narratives and observations, conducting the research work in the habitat (Creswell, 1998). Fraenkel and Wallen (2006) draw attention to the fact that qualitative researchers mainly focus on the examination of characteristic traits or properties of a certain activity, group, situation, or materials, respectively, but they are not much interested in the frequency of appearance of this activity, group, situation, or material. »Qualitative« research is an exploratory approach emphasizing words rather than quantification in gathering and analyzing the data. It is a matter of the inductive, constructivist and interpretative exploratory approach with the following main stresses: to view the world with the eyes of the examinees, to describe and take into account the context, to emphasize the process and not only the final results, to be flexible and develop the concepts and theories as outcomes of the research process (Bryman, 2004).

To summarize, for qualitative research it is characteristic that data are gathered more in a verbal and visual than in a numeric form. When analyzing the gathered data, statistical procedures are also not used, but instead predominantly qualitative analysis, the essence of which is searching for codes in the analyzed materials (Bryman, 2004). The main part of the qualitative analysis of the material is formed by the coding process, i.e. interpreting the analyzed text and attributing the meaning (of key words, notions, codes) to its individual parts (Charmaz, 2006; Bryman, 2004; Flick, 1998), respectively. Qualitative analysis of the material starts with defining the coding units, followed by the appropriate phenomena records according to our judgment and analyzing the characteristics of these phenomena, and ends with the development of the grounded theory (Glaser & Strauss, 1967). The grounded theory is read out as a narrative about the phenomenon which was the subject of the study. It is characteristic for the theory to be constructed from the collected data and to develop in the course of the entire research process. The grounded theory is contextually bound, i.e. it is not a general theory (the findings cannot be generalized without additional definitions), but a theory of narrower scope, valid only in certain environments and in certain conditions.

Qualitative empirical research is oriented towards examining individual cases (idiographic approach). The study is mostly conducted as a study of one case only or a smaller number of cases, therefore the techniques of data collection are adjusted to a small scale analysis, enabling the researcher to get to know the social environment. In data collection one is not limited to one source or one technique only. Apart from the data acquired by interviews and observation, usually also different documentary sources are used, such as personal documents (a birth certificate, an employment record, a passport, letters, photos etc), different records produced in the process of data collecting, transcriptions of tape recordings, video shots, etc. Only the triangulation – the pluralism of data collection techniques and their mutual combination - can provide for linking the findings of individual phenomena or aspects into a meaningful integrity. According to the conventionally accepted definition, triangulation is the use of multiple methods in the study of the same object (Denzin, 1978; Richardson, 2003; Bryman, 2004). Triangulation was first used as a technique for checking the validity of the research findings (Flick 1998; Tashakkori & Teddlie, 1998; Neuman, 2003; Bogdan & Biklen, 2003; Richardson, 2003; Bryman, 2004; Stake, 2005), based on the belief that we could reject or acknowledge the research hypotheses only if we had come to the same conclusions by means of different methods. Nevertheless, later, the importance of triangulation, as well as its employment, increased significantly. Denzin (1978) extended the notion of triangulation, saying that triangulation of methods is only one form of triangulation. In his opinion there are also data sources triangulation, the investigator triangulation and the theory triangulation (about this, see also: Flick, 1998; Tashakkori & Teddlie, 1998; Neuman, 2003; Janesick, 1998). Janesick (1998) added the fifth triangulation form, namely the scientific discipline triangulation. The comprehension that triangulation is not merely a technique for validating the scientific findings, but that it also provides for a more thorough understanding of each researched phenomenon, was increasingly extended. Triangulation is not a tool or a strategy of validation, but an alternative to validation. The combination of multiple methodological practices, empirical materials, perspectives, and observers in a single study is best understood as a strategy that adds rigor, breadth, complexity, richness, and depth to any inquiry (Flick, 1998; Denzin & Lincoln, 2005). Triangulation is a strategy enabling researchers to understand the observational object significantly better and in a more comprehensive manner. Multiple triangulation, assuming the combination of multiple triangulation forms, i.e. the triangulation of investigators, theories, data sources, methods and/or disciplines, provides for the exhaustive data interpretation.

Qualitative research is carried out in line with the principles of the interpretative paradigm, i.e. the focus is on examining the subjective experiences of an individual and on recognizing the importance which the individual attaches to specific events, whereby not even the subjective views of the researcher of the studied situation are neglected. The aim is to active integrated and detailed cognition of phenomena, preferably in natural and concrete circumstances, for the researcher is interested in the context of the pursued activities. As part of the environment, not only is the researcher able to understand what the person is conveying in the form of a rational message and standardized speech, but also the indirect implications of this speech with a specific syntax, contextual lapses, hidden meanings and speech breaks are perceived. Wishes, expectations, interests, needs and personal opinions of the people included into the research should help the researchers to better comprehend the examined phenomena. In this context, the researcher should be aware of the fact that with their participation - and with the researched situation itself – they are influencing the events they are observing, and the discursive reality, as their research object.

Purpose and research questions

The analysis of the research papers published in three major science education research journals is presented in this paper. It was hypothesised that the qualitative research paradigm was used in the papers published in the last three years as often as was s quantitative or mixed one. The research questions addressed in this paper were: (1) which research approaches prevail in papers published in the last three years in the field of science education research?, (2) which data gathering methods were used by the researchers in the qualitative and mixed research papers?, and (3) how often was a triangulation of methods used in the qualitative and mixed researches?

METHOD

Sample

This section of the paper presents results of the analysis of methodology used in the research papers published in three major science education research journals; International Journal of Science Education (IJSE), Journal of Research in Science Teaching (JRST) and Science Education (SE). These three journals are also included in the Social Science Citation Index and they had impact factors as released by the Institute for Scientific Information, Thomson Reuters (USA), Journal Citation Reports for the year 2007 as follows: JRST 1.148, SE 0.936 and IJSE 0.541. Special issues of the journals and books reviews were excluded from the analysis.

Research design, data collection and analysis

The research was a non-experimental, cross-sectional and descriptive study (Bryman, 2004). In the first step of analysis, the full text papers' methodology was read by two authors of this paper. Two authors, trained to analyze the text and code the data by using the designed coding sheet, independently coded the selected data. The analysis and coding process were performed in several steps. According to the first step of analysis, the categories of research approaches used by the authors in selected published papers were identified. Both authors gave consent about the derived codes, and a coding sheet was developed. The data obtained by the document analysis were entered into the excel file and additionally coded and added into the coding sheet. The

Table 1. Number of published pages in the selected journals.

Journal	*2006*	*2007*	*2008**	*Sum by Journal*
JRST	1109	1478	970	*3557*
SE	1143	1030	1126	*3299*
IJSE	1904	1929	1835	*5668*
Sum by year	*4156*	*4437*	*3931*	*12524*

** - not all issues have been published yet in the current publication year*

derived codes were divided into categories according to the qualitative research approaches (e.g. interview, observation, document analysis). If the coding scheme was modified when new codes emerged from the data as the data analysis proceeded, consent about the new code was given by both authors. The agreement on the methodology approaches identified in the published papers in the selected respected journals was calculated at 96 %. The codes derived from the coding sheet were counted, and frequencies and percentages were used to present the results.

RESULTS

Altogether 12,524 pages of research reports were published in three years in the selected journals. More than 4100 pages of research material were published each year, and more than 3200 pages in JRST and SE, and even more than 5600 pages in IJSE (Table 1).

JRST published 146 papers, SE 127 and IJSE 188 papers in the last three years. According to these data, IJSE published 42 papers more than JRSE and 61 research reports more than SE.

Analysis of the scientific fields to which papers were dedicated in JRST shows that in the JRST there were altogether 64.8% of papers dedicated to science in general, 10.3% specifically to biology, 12.4% to chemistry, 10.3% to physics and 2.8% to other fields (biochemistry, geography or other fields).

Analysis shows that 73.2% of all papers in SE covered general science education problems. 11.8% of papers were dedicated to biology, 7.9% to chemistry, 6.3% to physics and 0.8% to other fields.

Results show that 105 (55.9%) of all papers published in IJSE discussed general problems in science education, while 35 papers (18.6%) researched biology education, 24 chemistry and 23 papers physics, that is 12.8% and 12.2% respectively of all papers published in this journal in the last three years.

Figure 1 shows the percentages of scientific fields in all three analyzed journals according to publication years.

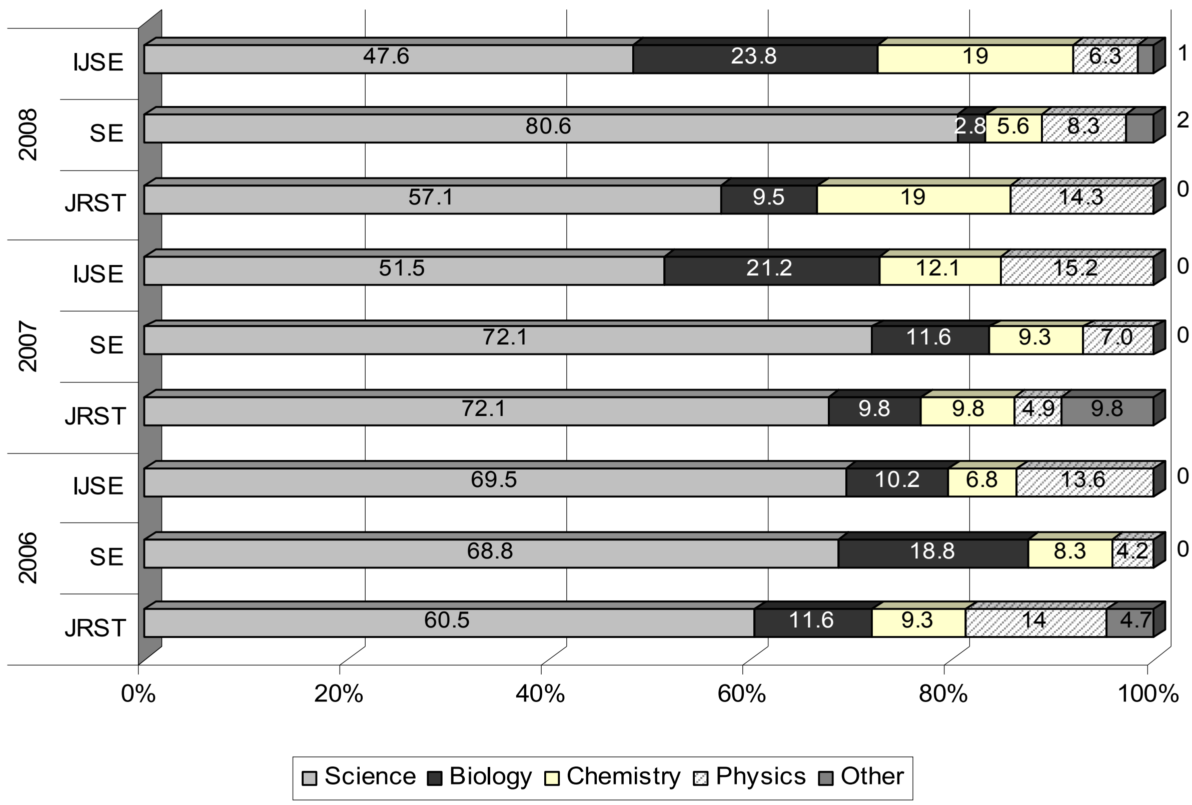

Figure 1. Scientific fields discussed in papers published in analyzed journals each year.

From the analysis of the methodology used in the papers published in JRST from 2006 to 2008 it can be concluded that authors from 65 papers (44.83%) used the qualitative research approach. Authors of 36 papers (24.83%) used mixed methods design, and 43 papers (29.66%) used quantitative methods to answer the research questions. Only two papers (1.38%) were theoretical in nature.

From analysis of the methodological approaches used in papers published in SE, it can be seen that more papers (68 or 53.54%) used qualitative research to answer the research questions than in JRST. According to these data it can be expected that mixed or quantitative research approaches were used in fewer papers than in JRSE. The data show that 20.47% of papers used mixed methodology, and only 13.39% of papers published in SE used some form of quantitative research approach. It can be also concluded from the results that 16 papers published in SE (12.6%) were theoretical or review papers.

Data analysis shows that a greater number of quantitative methodology research papers were published in all three years in IJSE than in SE. A similar number of papers with specific methodological approaches were published in JRST: 75 papers (39.89%) discussed research quantitative in nature and 62 papers (32.98%) presented qualitative research in IJSE. Authors that published papers in IJSE used mixed methodology on average in fewer studies (37 papers or 19.68%) than authors that published in SE or JRSE. There were also 14 (7.45%) theoretical or review papers published in the last three years in IJSE.

It can be summarized from Table 2 that JRST published a similar number of papers using different research methodologies in the last year. Qualitative research approaches predominate over quantitative and mixed methods in publication year 2006, but there were similar percentages of papers published using qualitative and quantitative research methods in year 2007. The results also show that mixed research approaches represent the lowest percentages of methods used by authors of all papers published in JRST.

It can be concluded from Table 2 that SE published a similar percentage of papers which used qualitative or mixed methodology in years 2006 and 2007 as did JRSE. There were about 21% fewer papers with quantitative

Table 2. Results of the analysis; type of research methodology used in selected journals.

Journal	Research methodology	Publication year 2006 f	2006 f%	2007 f	2007 f%	2008 f	2008 f%	Sum f
JRST	Quantitative	6	13.95	23	37.70	14	33.33	43
	Qualitative	24	55.81	26	42.62	15	35.71	65
	Mixed	12	27.91	12	19.67	12	28.57	36
	Theoretical or review	1	2.33	0	0	1	2.38	2
SE	Quantitative	7	14.58	7	16.28	3	8.33	17
	Qualitative	25	52.08	20	46.51	23	63.89	68
	Mixed	9	18.75	8	18.60	9	25.00	26
	Theoretical or review	7	14.58	8	18.60	1	2.78	16
IJSE	Quantitative	22	37.29	20	30.30	20	31.75	62
	Qualitative	21	35.59	26	39.39	28	44.44	75
	Mixed	8	13.56	17	25.76	12	19.05	37
	Theoretical or review	8	13.56	3	4.55	3	4.76	14

Table 3. Results of the analysis; type of data collection in qualitative and mixed research methodology approach in selected journals.

Journal	Data gathering methods	Publication year 2006 f	2006 f%	2007 f	2007 f%	2008 f	2008 f%	Sum f
JRST	Interview	26	72.2	25	51.0	19	70.4	70
	Observation	18	50.0	22	44.9	13	48.2	53
	Document analysis	8	22.2	15	30.6	8	29.6	31
SE	Interview	23	67.7	16	57.1	23	71.9	71
	Observation	18	52.9	20	71.4	19	59.4	57
	Document analysis	13	38.2	7	25.0	14	43.8	34
IJSE	Interview	24	82.8	29	67.4	20	50.0	73
	Observation	11	37.9	14	32.6	20	50.0	45
	Document analysis	8	27.6	14	32.6	15	37.5	37

research approaches published in SE than in JRSE, but there were over 18% more theoretical papers in SE than in JRST in 2007. The most obvious difference between the JRST and SE is in the number of theoretical or review papers published in each journal in years 2006 and 2007. The SE published more theoretical papers than did JRST. But comparing the type of methodology used in papers published in the last year in SE and JRST, it can be seen that SE published 28.18% more papers using qualitative research than JRST. The percentage of papers using mixed methodology or theoretical papers is similar in both journals, so it can be concluded that SE published 25% fewer papers with quantitative methods than JRST.

Further analysis of the methods for gathering data in papers published in JRST revealed that the authors of qualitative researches most frequently used interviews: 70 papers or 69.31%. The next type of data - gathering methods are observations that were used by authors in 53 (52.48%) published papers. The last method of qualitative approach, document analysis, was used in 31 (30.69%) papers. Authors used different ways of recording the data, the most frequently used being video and audio recordings and fieldnotes.

Similar results were obtained by analyzing the qualitative data - gathering approaches that were used in papers published in SE: 62 (65.96%) of papers revealed that the authors gather data using interviews, 57 (60.64%) observations and 34 (36.17%) document analysis. It can be also summarized that authors used video or audio recordings of classroom situations, or some other students' or teachers' activities, in 18.9% of all papers published in SE in the last three years.

More than 65% (73 papers) of all qualitative methodology papers published in IJSE used interviews for gathering data. Fewer papers (45 papers or 40.18%) published in IJSE than in JRSE and SE used observations, and about the same percentage of published papers (37 or 33.04%) used document analysis.

More detailed results of different qualitative methods used by the authors regarding the publication year of the analyzed journals are presented in Table 3.

The analysis of the number of different qualitative approaches used in the papers by the researcher revealed that, in the papers published in the JRST, 63 papers (63.38%) used only one qualitative research approach to gather the data. Two different qualitative methods to gather data were used by the researchers in 23 (22.77%) of the papers, and in only 15 (14.85%) did the authors use all three methods (interview, observation and document analysis) to gather data in their research. It can be concluded that only 38 qualitative research papers published in JRST were reports of research that used triangulation of different qualitative methods in the data collection process.

On the other hand, in 49 (52.13%) published papers in SE only one method of qualitative research was used; 30 (31.91%) of papers present two qualitative methods and only 15 (15.96%) of papers used all three methods of qualitative research to answer the research questions. The results show that there are a few more papers published in SE that use more than one method for collecting qualitative data than in JRSE.

Again, similar results are to be found by analyzing the qualitative papers published in IJSE to those in JRSE regarding the triangulation of qualitative methods for collecting data: 74 papers or 66.07% used only one method, 31 papers (27.68%) two and only 6 papers (5.36%) used all three methods for collecting qualitative data.

Comparing the results of analysis of all three journals, it can be concluded that authors publishing in IJSE rarely use the triangulation of interview, observations and document analysis in one study.

CONCLUSION

Two paradigms of scientific research were developed in the past. Regarding their attributes, they are called quantitative and qualitative. In the presented paper, the expression »paradigm« is used in the sense of Kuhn´s contemporary definition of scientific paradigm. According to Kuhn, paradigms are »the series of reciprocally connected assumptions about social phenomena, providing the philosophical and notional frame for studying them« (Kuhn 1974, p. 39). Therefore, the paradigm is the sum of values, convictions, assumptions telling us which values, beliefs, convictions, assumptions, laws etc., regarding research in the scientific discipline, are shared by the adherents of a certain scientific paradigm. In accordance to them, they form their tradition of scientific research.

The main aim of quantitative research is to obtain reliable, exact, precise, measurable, objective and valid results. The use of the standardized research instruments, distinction between the research subject and the research object, use of statistical methods, forming hypotheses and their reliable verification are some of the major methodological principles of the empirical-analytical methodology.

In qualitative research, the collected data are more in a verbal and pictorial form than in a numerical one. There is also a tendency to incorporate an integral and in-depth comprehension of phenomena in as natural a setting as possible, as well as in the context of concrete circumstances (Mesec, 1998). The crucial instrument of the empirical research is the researcher, since he/she is directly included into the environment, which helps him/her to observe the object of the research.

From the analysis of the papers published in selected journals, it can be concluded that altogether 12,524 pages of research reports were published in three years. Journal of Research in Science Teaching published 146 papers, Science Education 127 and International Journal of Science Education 188 papers.

It can be also summarized that the largest part of the papers were dedicated to science in general, rather than to biology, chemistry, and physics. Pedagogical research into other fields of science (e.g. biochemistry, geography) was published only in a few papers.

In answering the first research question, concerning which research approaches prevail in papers published in the last three years in the field of science education research, it can be concluded that the qualitative research approach was used most frequently by the authors. In all three analysed journals, qualitative research was used in 45.1% papers, quantitative research was used in 26.5% papers, mixed approach (combination of qualitative and quantitative research) was used in 21.5% papers, and 6.9% of papers were theoretical.

From the analysis of the methods for gathering data in papers published in a selected journal - in response to the second research question - it can be concluded that authors most frequently use interviews (in about 45.7% papers). The other two methods of qualitative data gathering - observations (32.9%) and document analysis (21.7%) - were used in fewer papers.

The third research question concerns the quantity of a triangulation used in the qualitative and mixed researches. It can be summarised that authors used triangulation of qualitative data gathering methods in only 40 (39.2%) of the published qualitative or mixed research papers, and 62 (60.8%) of the papers used only one method to gather qualitative data. Two qualitative methods were used by authors of 28 papers, and only 12 authors triangulated all three qualitative methods to answer in depth to their research questions.

It can be concluded from the analysis of the papers published in three respected science education journals that in science education, research similarly as in the field of general sociological and pedagogical research, the qualitative research approach prevails.

A major strength of the qualitative approach is the depth in which explorations are conducted and descriptions are written, usually resulting in sufficient details for the reader to grasp the idiosyncracies of the situation. The ultimate aim of qualitative research is to offer a perspective of a situation and to provide well-written research reports that reflect the researcher's ability to illustrate or describe the corresponding phenomenon. It can be expected that the majority of the research is going to be based upon the qualitative research paradigm in the future, because of the advantages that the qualitative approach introduce into science education research. The disadvantages of the qualitative research approach (e.g. inability to generalize the research findings from the sample to the population, pure objectivity etc.) could be diminished by using the combination of qualitative and quantitative research approaches in so called mixed researches.

In conclusion it can be recommended that the researcher, when selecting the research approach (e.g. qualitative, quantitative or mixed), should always set out from the concrete research problem and research questions or hypothesis. On the basis of the research problem, the researcher should decide which research approach is going to lead him/her easily, swiftly and most efficiently to the most reliable findings that adequately answer the research questions.

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