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# EURASIA
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# CONTENTS

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# LEARNING TO TEACH ARGUMENTATION: CASE STUDIES OF PRE-SERVICE SECONDARY SCIENCE TEACHERS

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**ABSTRACT.** The article presents a case for the promotion of argumentation in science in preservice teacher education. In recent years, argumentation has emerged as a significant goal for teaching and learning of science. As an important aspect of scientific inquiry, argumentation plays a role in the generation and justification of knowledge claims. The theoretical background on the role of argumentation is reviewed and an empirical study is reported on the ways in which teacher training can be supported in the use of argumentation in science classrooms. Case studies of two Turkish teachers are used to illustrate how teachers structure lessons and support argumentation in secondary science classrooms after a series of training sessions. Results indicate that the teachers incorporated those features of pedagogical strategies (e.g. group discussions and presentations) targeted by the training.

**KEYWORDS.** Argumentation, Teacher Education, Case Studies.

## INTRODUCTION

Argumentation is nothing new under the sun. Some of the great thinkers in the history of humanity, such as Plato and Aristotle, have been engaged in argumentation. Many domains, including many world religions, politics and law have relied on the use of argumentation. When we turn to science, we witness that the very establishment that we call 'science' is based on argument. Scientists use arguments to establish theories, models and explanations about the natural world. Consider a recent piece of news about a previously undiscovered feature of the Solar System observed by astronomers using California's Palomar Observatory. A new planet has been given the name 'Sedna' after the Inuit goddess of the ocean. Astronomers now say they have evidence that Sedna has its own moon, although this needs to be confirmed. There is likely to be some debate about whether Sedna really qualifies as a true planet but some scientists are already saying it re-defines our Solar System. The emergence of new evidence prompts scientists to reconsider our models, theories and explanations and to argue for the revision or the abandonment of existing knowledge.

When we turn to science education, we are faced with the fact that we don't do enough


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justice to the teaching and learning of argumentation and as such, even graduates of science programmes are typically unable to provide evidence and justification to some of their claims about the natural world. Try asking any group of people the reasons for believing in the following fundamental tenets of contemporary science: that day and night are caused by a spinning Earth; that matter is made of atoms; that diseases are caused by tiny living microbes. Few, if any, are able to provide the seminal piece of evidence for the first about day and night (Durant, Evans & Thomas, 1989) let alone the evidence for the other axiomatic beliefs of science.

Such failings expose the weakness of a science education, a science education that has placed its emphasis on what should be believed in rather than why something should be believed in. Without question, arguments from authority are a justified and legitimate form of argument. However, the predominance of such forms of argument in the science classroom undermines the rationale for a discipline that is distinguished by its central commitment to evidence as the basis of justified belief and the rational means of resolving difference and controversy (Siegel, 1989). Failure to emphasise and foreground the distinctive hallmark of science is ultimately self-defeating leaving students with beliefs that they are unable to justify to others.

In the science classroom, argument often becomes a monologue, a one-way conversation where the pupil cannot engage in genuine questioning of their teacher because they lack the resources to challenge or question the assertions of the teacher. The result is that the world is portrayed as a set of absolutes, characterised by 'right' and 'wrong' answers with the origins of scientific ideas, their metaphorical roots, and any element of uncertainty simply excised. Restoring the consideration of evidence, reasoning and argument requires instead the recognition of a contemporary model of science.

Giere's model is an attempt to capture the fact that scientists are involved in studying the material world (Giere, 1991). In that process they gather data from instruments and measurements and they develop models of how they think the world behaves. These models allow them to make predictions that they then test. What Giere's model demonstrates is that observation and experiment are the handmaidens to generating arguments about the fit, or lack of it, between theory and data. For data lead to models and theories, models lead to arguments about which evidence is significant, and data, in turn lead to arguments about the success or failure of theories. In short, there is a complex cyclical and reflexive interaction between models and evidence to which evaluative argument makes a central contribution.

Are our efforts for changing the curriculum consistent with such views on science? Science education curriculum innovations in science like those sponsored by the Nuffield Foundation in the UK and the National Science Foundation in the USA in the 60s and 70s, have had little impact on the practices of science teachers (Welch, 1979). Four decades after Joseph Schwab's argument that science should be taught as an 'enquiry into enquiry', and almost a century since John Dewey advocated classroom learning be a student-centred process of enquiry, we still find ourselves struggling to achieve such practices in the science classroom. Witness the publication of Inquiry and the National Science Education Standards (National Research Council, 2000), and the inclusion of 'scientific enquiry' as a separate strand in the English and Welsh science national curriculum (DfEE, 1999).

Such recent policy level arguments serve as signposts to an ideological commitment that teaching science needs to accomplish much more than simply detailing what we know. In addition to teaching the content of science, of growing importance is the need to educate our students and citizens about how we know, and why we believe in the scientific world view e.g., science as a way of knowing (Duschl, 1990; Driver et al., 1996). Such a shift requires a new focus on (1) how evidence is used in science for the construction of explanations – that is on the arguments that form the links between data and the theories that science has constructed; and (2) the development of an understanding of the criteria used in science to evaluate evidence and construct explanations.

In this paper, we present a case that argumentation should be a central aspect of science teaching and learning. Like any unfamiliar or relatively underemphasized strategy, the execution of argumentation in real science classroom will demand more than rhetoric. It will necessitate long-term and supportive professional development of science teachers. We begin our discussion by first establishing the status of research in science education in recent years. Here we visit the theoretical and empirical aspects of the work on argumentation. The emphasis will be on teaching and in particular on professional development of science teachers to facilitate the teaching and learning of argumentation in science classrooms. We then turn our attention to some research outcomes from a project that involved the training of preservice science teachers to implement argumentation in their classrooms. We conclude with some implications for future studies in argumentation in science.

## ROLE OF ARGUMENTATION IN SCIENCE EDUCATION

Over the past few decades numerous studies have focused on the analysis of argumentation discourse in educational contexts (e.g, Driver, Newton, & Osborne, 2000; Duschl, Ellenbogen & Erduran, 1999; Erduran, & Jiménez-Aleixandre, in press; Erduran, 2006;Kelly & Takao, 2002; Jiménez-Aleixandre, Rodríguez, & Duschl, 2000). These studies have highlighted the importance of discourse in the acquisition of scientific knowledge (Boulter & Gilbert, 1995; Pontecorvo, 1987; Schwarz, Neuman, Gil, & Ilya, 2003) and the development of habits of mind in science (e.g. Kuhn, 1970). The implication is that argumentation is a form of discourse that needs to be appropriated by children and explicitly taught through suitable instruction, task structuring and modelling (e.g. Mason, 1996).

Recent approaches have thus framed science learning in terms of the appropriation of community practices that provide the structure, motivation and modes of communication required to sustain scientific discourse (Kelly & Chen, 1999; Lemke,1990). These approaches stand in sharp contrast to the traditional views of science learning that focus on outcomes such as problem solving (Gable & Bunce, 1984), concept learning (Cros, Chastrette & Fayol, 1987) and science-process skills (Heeren, 1990). Science learning is thus considered to involve the construction and use of tools which are instrumental in the generation of knowledge about the natural world. In this framework, argumentation is a significant tool instrumental in the growth of scientific knowledge (Kitcher, 1988) as well as a vital component of scientific discourse (Pera, 1994). Argumentation plays a central role in the building of explanations, models and theories (Siegel, 1991) as scientists use arguments to relate the evidence they select to the claims they reach through use of warrants and backings (Toulmin, 1958).

The philosophical and cognitive foundations of argumentation have played a central role in the justification of research in argumentation in science education (e.g. Duschl & Osborne, 2002; Erduran & Osborne, 2005). Contemporary perspectives in philosophy of science (e.g. Giere, 1991; Kitcher, 1988) emphasize that science is not simply the accumulation of facts about how the world is. Science involves the construction of theories that provide explanations for how the world may be. In proposing provisional explanations for the underlying causes of events, theories are open to challenge and refutation (e.g., Popper, 1959). Science often progresses through dispute, conflict and argumentation rather than through general agreement (e.g, Kuhn, 1970, Latour & Woolgar, 1986). Thus, arguments concerning the appropriateness of experimental design, the interpretation of evidence and the validity of knowledge claims are at the heart of science, and are central to the everyday discourse of scientists. Scientists engage in argumentation and it is through this process of argumentation within the scientific community that quality control in science is maintained (Kuhn, 1992).

Beyond coherence with current philosophies of science, there are cognitive values of argumentation in science education. From the cognitive perspective, to the extent that argument involves the public exercise of reasoning (Kuhn, 1992; Billig, 1996), lessons involving argument will require children to externalise their thinking. Such externalisation requires a move from the intra-psychological plane, and rhetorical argument, to the inter-psychological and dialogic argument (Vygotsky, 1978). When children engage in such a process, and support each other in high quality argument, the interaction between the personal and the social dimensions promotes reflexivity, appropriation and the development of knowledge, beliefs and values. Furthermore, to grasp the connection between evidence and claim is to understand the relationship between claims and warrants and to sharpen children's ability to think critically in a scientific context, preventing them from becoming blinded by unwarranted commitments (Quinn, 1997).

From the sociocultural perspectives on cognition, argumentation is a critical tool for science learning since it enables within learners the appropriation of community practices including scientific discourse (Kelly & Chen, 1999). If enculturation into scientific discourse is significant to science learning, then it becomes imperative to study such discourse to understand how the teaching and learning of argumentation can be traced, assessed and supported. In this sense, the improvement and development of tools for capturing implementation of significant features of argumentation becomes a major concern for science education research.

## SCHOOL-BASED RESEARCH IN ARGUMENTATION

In our work with secondary teachers and students in the United Kingdom, we investigated strategies and resources for promoting and sustaining argumentation in the science classroom (Erduran, Simon & Osborne, 2004; Osborne, Erduran & Simon, 2004a; Simon, Erduran & Osborne, 2006). As a result of a 2-1/2 year school-based research project funded by the Economic and Social Research Council, we have seen that (a) it is possible to train teachers to adapt their teaching to place more emphasis on the construction of argument; (b) children's skills at argument do improve with practice. Furthermore, we were able to develop an analytical framework for studying argumentation in the classroom (Erduran et al., 2004).

The resources produced by teachers during the project work were useful instructional tools. For example in one activity, pupils were presented with a scenario where they were asked to decide about whether a moving, unicellular organism was a plant or an animal cell. The organism called euglena is in fact neither. It has features of both plants (e.g. chlorophyll) and animals (e.g. it moves). Children were then given cards that had factual statements about euglena, and they were asked to use the evidence from the cards to reach a conclusion about whether or not euglena was a plant cell or an animal cell. Some of the pedagogical strategies that would complement these activities included coordination of group discussions, presentations as well as asking questions that would stimulate argumentation such as "What is your evidence? How do you know?"

Our work with the ESRC funded research project led to the development of a training resources on argumentation. We were encouraged by the results given that 8 of the 12 teachers had displayed significantly higher quality arguments in their lessons after one year of training (Osborne et al., 2004). The IDEAS Project, funded by the Nuffield Foundation is a culmination of our efforts for professional development of teachers (Osborne, Erduran & Simon, 2004b). The IDEAS (Ideas, Evidence and Argument in Science Education) pack, first published in 2004 and reprinted in 2005, consists of 28 clips of ordinary teachers dealing with how to structure and approach the teaching of argument in science.

The pack also contains materials to support 6 half day workshops exploring aspects of teaching argument: (1) how to introduce argument; (2) how to manage small group discussions; (3) how to teach argument; (4) what resources can be used to support argumentation by students; (5) how to evaluate arguments; and (6) how to model them for pupils. The materials come on CD ROM as Word and Powerpoint files. In addition, there is a set of resource materials to support the teaching of ideas, evidence and argument in school science education. This consists of 15 sample lessons which teachers can use to try out some or all of the approaches in the IDEAS CPD sessions. Each of the activities comes with an introduction which provides: (a) the aims; (b) the learning goals of the activity; (c) teaching points which highlight aspects of background knowledge or what knowledge the students may need for the activity; (d) a teaching sequence which suggests how the materials might be implemented in the classroom; and (e) background notes for activities that require further elaboration on the science background some of the background science needs further elaboration.

*Training of Pre-service Science Teachers in Argumentation*

The IDEAS pack was used in the training of chemistry pre-service teachers (Ardac, Erduran & Yakmaci-Guzel, 2005) in an ongoing research project based in Istanbul, Turkey. The participants consisted of 17 trainee teachers (12 females and 5 males) enrolled in a science teacher certification course at an English medium university. The pre-service teachers were trained using the IDEAS pack over a 6 weeks period during the spring term of the 2005-2006 academic year. The sessions took place as an integral part of the "practice teaching in chemistry course" that is offered during the final term of the training program. The course requires pre-service teachers to plan, revise and teach a minimum of three chemistry lessons during their field practice. For the purposes of the present study, the pre-service teachers were expected to plan and implement at least one out of the three lessons as an argument lesson derived from the IDEAs pack. Each training session included a 90-minutes workshop based on the IDEAs workshop agenda where teacher training included some recommendations for encouraging students' use of evidence to support their claims as well as the video exemplars of good practice illustrated in the IDEAs video (Osborne et al., 2004). Pre-service teachers were further familiarized with Toulmin's Argument Pattern (TAP) (1958) which is subsequently used to identify the structure of arguments manifested throughout each lesson. Following the training sessions, the participants were given two weeks to prepare an argumentation lesson around a chemistry topic that would agree with the regular school curriculum. During the planning phase, pre-service teachers were expected to use the feedback and suggestions from their instructor to come up with a lesson plan that used major components of an argumentation lesson. During the three weeks that followed the planning phase, pre-service teachers implemented their lesson plans in actual classrooms.

Informed by literature on educational change (e.g. Fullan, 1991), and the failures of the past, we were conscious of a careful consideration of how teacher development could result in sustained change particularly when the production of the training resources did not involve them. Current thinking has recognised that a centrally important concept for any curriculum innovation is that of 'ownership' (Ogborn, 2002). Innovations succeed when teachers have a sense that new approaches belong to them, at least in part. As Ogborn (2002) argues, there 'has to be something of real novel value for teachers to identify with'. However, the need for ownership requires that teachers are a central feature of the process of development and not marginalized to becoming deliverers of someone else's innovations. They must be free to adapt, transform and develop the ideas to their own context and, if necessary, change their aim, function or implementation. Only in this manner can teachers begin to own new practice and to incorporate it into their regular repertory of strategies and approaches to the teaching of science.

Hence, even though the training resources were adapted from one national context (United Kingdom) to another (Turkey), the work proceeded collaboratively with a small group of teachers, in through drawing on theoretical ideas and putting these into practice in order to develop materials and strategies that can be adopted and owned by them. As such, the pre-service teachers had the freedom to pick and choose whatever strategy they found useful for their purposes in teaching an argument lesson.

Lessons from each teacher implementing lessons in Istanbul secondary schools were audiotaped. Selection of topics (e.g. Periodic Table, Acid Rain, Mercury: metal or non-metal?, Radioactivity) to adapt for argument lessons was done by trainees. The data sources in this project were teacher talk, student group talk, students' written work, teacher lesson plans, teacher interviews after training and teacher written responses to argument questions. This work particularly addressed the following research questions: (1) How are pre-service teachers interpreting argument lessons in their teaching? Are they using the strategies promoted in the training sessions? (2) What are the argument outcomes in students' learning? What is the nature of their arguments and argumentation? Here the focus is on the teaching strategies used by the trainees.

## TEACHING STRATEGIES AND STUDENT OUTCOMES

In examining the teachers' strategies, the focus was on how the teachers (a) structured the task, (b) used group discussions, (c) questioned for evidence and justifications, (c) modelled argument, (d) used presentations and peer review, (e) established the norms of argumentation, and (f) provided feedback during group discussions. These features were implicit in the training resources and were investigated with the original teachers in the ESRC project (Simon, Erduran & Osborne, 2005). Here we will present case studies of two Turkish female trainee teachers in their 20s to illustrate their teaching relative to these criteria. Our investigation into student outcomes have concentrated on the (a) nature of arguments, (b) nature of questions, (c) criteria for evaluating evidence, and (d) use of opposition including how counterarguments are ruled out.

The latter, result on students' argumantation will appear in a subsegment publication in more detail.

Case 1: Hulya

Table 1: Teaching strategies used by Hulya

| Teaching Strategy | Example |
|---|---|
| Task structure | Competing theories |
| Questioning | "How do you know? What's your evidence? |
| Modeling | "If you look at this one, it can't be a metal because…" |
| Use of presentations | "You will swap seats and tell your friends what you have done and how you reached your conclusions." |
| Establishing norms of argumentation | "I know that you know this by heart but what I want is for you to find out why it's there." |

Hulya did a lesson on the Periodic Table where she began the lesson with an introduction to the history of the Periodic Table. She used group activities and writing frames to support students' engagement in argumentation. Another strategy she used was the use of "envoys to groups" where representative students from each group was sent to another group to present results of group discussions. Subsequently all of the groups made presentations and the lesson ended with a summary. The primary teaching strategies used by Hulya are summarized in Table 1.

The main task in this lesson was framed in terms of 'competing theories' where students were asked to place missing element in the Periodic Table and decide whether or not it is a metal or a non-metal. Hulya outlined the task clearly indicating that "You need to judge the evidence to decide whether this can be a metal or not." During this lesson, Hulya asked many open-ended questions that were included as argument prompts in the training pack. For instance, she asked "How did you classify this element? Why?", "How do you know that?" Hulya provided much support to students by modeling what would be a good argument. For example, she used the statement stems as "If you look at this one, it can't be a metal because…" Hulya made use of presentations by using envoys across groups. She established the norms of argumentation by highlighting the significance of why it's important to provide justifications for our knowledge.

In terms of student outcomes, there is evidence from Hulya's lesson that students were able to construct a range of arguments. For instance, students related data to claims (e.g. "It could be aluminium because it dissolves in water.") as well as more complex arguments involving warrants and backings as well (e.g. "We are sure about this one because it has all the properties. It's soft and it's close to these so this one also is…"). The nature of the questions asked by students tended to be clarification questions (e.g. "Are we considering the rows or the columns?") while the criteria used for evaluating evidence included the idea of classification (e.g. "We could see if it's a metal, non-metal or semi-metal."). Students tended to discount others' ideas by proposing alternative claims (e.g. "I said this but he said something else.").

Case 2: Nil

Nil conducted a lesson where she presented mercury as an instance to be argued about. She introduced the lesson by asking the main question: Is mercury a metal or a non-metal?. She used group work and presentations, and the lesson ended with a summary. The teaching strategies relevant for promoting argumentation employed by Nil are summarized in Table 2.

Table 2: Teaching strategies used by Nil.

| Teaching Strategy | Example |
|---|---|
| Task structure | Competing theories |
| Questioning | "How do you know that it forms compounds with non-metals?"<br>"What sort of an experiment can you do?" |
| Modeling | "You are presenting a strong argument. Mercury is a metal because it conducts electricity, because metals conduct electricity." |
| Use of presentations | "You have to convince us through your presentations." |
| Establishing norms of argumentation | "You can say it reacts with noble gases but you have to have evidence."<br>"If you cannot provide evidence then you have to be careful about your claims. I heard it's like that is not enough." |

Nil's lesson presented the task of arguing for mercury being a metal or not. The main assumption behind this issue is that children often think of metals in terms of solids. Hence the liquid nature of mercury could potentially provide the stimulus for discussion. Nil used questioning, modeling and presentations as strategies to promote and support argumentation as well as explicit statements on the norms of argumentation.

Nil's students generated a range of arguments including claims supported with data (e.g. "It is a metal because all its properties are consistent." and claims supported with data, warrant and backing: (e.g. "We think mercury is a metal because it has a d- orbital and it can conduct electricity. It has a shiny appearance"). Like Hulya's students, Nil's students mainly asked clarification questions (e.g."Is the boiling point of mercury $14^0$C?"). They were able to generate criteria for evaluating evidence (e.g. "You think it being a liquid is not a physical property. Its being a liquid is because its melting point is low and that's a chemical property."). There was also evidence for the use of rebuttals and oppositions (e.g. "The only property that suggests it's a non-metal is its liquid state but this can be changed. We can turn it into a solid but we can't play around with the number of electrons in its orbitals").

## RESULTS

The results briefly summarized in the case studies here extend to all the 14 trainee teachers. There is evidence on all aspects of teaching strategies investigated that the trainees are using argumentation techniques in their classrooms. The extent of difference between the trainees relied on their use of meta-talk and the quality of the feedback provided to the students. Consider the following from a trainee's use of meta-talk:

> What did you tell me to oppose this point of view? You showed me evidence. During a discussion, what do you need to do in order to make a claim acceptable? You have to base your claim on real evidence. Definitions can be right or wrong. Whichever definition you are supporting or not supporting, you will have to decide. For that position you think is right, you can provide extra evidence. Let's say one definition is right and another wrong. You will prove to me using evidence or your knowledge how this position is right. This is right because…I want you to make me believe in what's right. Whoever reads this will have to be convinced.

Such instances of meta-talk were infrequent and there were also numerous missed opportunities for giving feedback to students in scenarios such as the following:

> In the gaseous state, the amount of energy required to pull out an electron from the outer orbital is less because in the gaseous state, the atoms are further apart.

In this instance, even though the piece of data appealed to is correct (ie. "in the gaseous state, the atoms are further apart"), the claim or the conclusion reached by using this piece of data is incorrect. In other instances (e.g. "Why should I spend more energy in a solid? When you pull out an electron from an atom, the orbit does not disappear, therefore there is no difference in the circumference") the data used might not support the conclusion reached. Such instances suggest that formative feedback in argumentation might be challenging to beginning teachers although other advanced skills such as modeling and questioning did not seem to present as much difficulty. These are preliminary results only. However we are encouraged by the level of engagement by the pre-service teachers, their commitment to the use of some key strategies such as group discussions and presentations, and the outcomes displayed by their pupils.

## CONCLUSIONS & IMPLICATIONS

Our work in school-based research in the teaching and learning of argumentation has provided us with some guidelines for training teachers to promote and support argumentation in science lessons. However, the coordination of current curricular goals with new strategies such as argumentation places extra demands on teachers. If the curriculum emphasizes content outcomes, it will be very difficult for science teachers to open up the discussion space in their classrooms to allow argumentation to take place. Furthermore, without a shift in what gets assessed in terms of teaching and learning performances, it is unlikely that some of the encouraging results observed in our research could be sustainable in the long term. However, even the short-term training of pre-service teachers resulted in attainment of intended pedagogical and learning goals, an encouraging outcome indeed.

Methodological considerations illustrate the need to further develop tools that would be sensitive to identifying not only the structure but the content of arguments. Our work has focused on the process of argumentation not as an ideological preference over content of argument but rather as a pragmatic need to instill both in teachers and students the mechanisms of arguing. Without a sense of the need for providing evidence to justify claims, we wonder how students could see the need for presenting an argument at all, let alone an argument that has internal consistency in terms of its content. Our intention is to extent the line of work on argumentation to develop new tools that would be effective in capturing the quality of content as well as the process.

Implications for future studies in teacher education include the need to trace the developmental stages in the learning to teach argumentation - from novice to expert. What are the learning trajectories for science teachers in getting to know how to teach argumentation? This area of research in argumentation remains relatively uncharted (e.g. Erduran, 2006; Simon, Erduran & Osborne, 2005). The nature of the contribution of argumentation studies to other aspects of science teaching is equally unknown. It will be imperative to situate argumentation in other aspects of science teaching if argumentation is to have systemic validity in professional development. It is when we, as teacher educators, figure out how we can help teachers in their mediation of disagreement with reason that argumentation studies will truly extend the historical precedence of argument embodied for centuries in Plato and Aristotle.

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# LEARNING MATHEMATICAL RULES WITH REASONING

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**ABSTRACT.** This research focused on students learning of mathematical rules with reasoning. A small group of students (age 11-12 yrs) was observed closely by the first author as she taught them fraction rules. The area of focus was fractions and activities were designed pertaining to the four rules of fractions: addition, subtraction, multiplication, and division. The study was undertaken from a constructivist perspective of learning according to which students' learn through active participation in the construction of knowledge (Glasersfeld, 1995). This was significant in the context of mathematics classrooms in Pakistan which usually subscribe to the objectivist epistemology i.e. knowledge of the ultimate reality is possible. An implication of adhering to this epistemology is the knowledge transmission view of teaching and learning (Halai, 2000). Key findings of the study were that there were two significant factors that enabled students to learn rules with reasoning were: Teachers questions and opportunities for students to explain thinking; and opportunity for students to engage with concrete and semi concrete materials. The study also provides some useful insights into the sequence of teaching the fraction rules and raises implications for mathematics teaching and teacher education.

**KEYWORDS.** Reasoning, Mathematical Rules, Understanding, Process of Learning Mathematics.

## THEORETICAL FRAME WORK

A perspective which has greatly influenced the understanding of how students learn comes from Piaget's constructivism. Piaget (1959), provided a radical shift in the outlook toward the learners as active participants in the process of coming to know as opposed to passive recipients of knowledge. The ideas discussed above regarding learners as active participants in knowledge construction from Piaget (1959, 1969) were useful for me in making sense of students' learning and provided underpinnings for the teaching that I undertook as part of my research classroom.

Following from the work of Piaget, von Glasersfeld (1995, p.51) proposed the following two tenets of radical constructivism which claim:

1. knowledge is not passively received but is actively built up by cognising subject,


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2. the function of cognition is adaptive and serves the organisation of the experiential world, and not discovery of ontological reality.

A consequence of taking this view of learning is that individual learners construct unique and idiosyncratic personal knowledge when exposed to identical stimuli. There can be no transfer of knowledge from outside. The notion of personally constructed knowledge or constructivism offers a new set of assumptions about learning and adherents to this radical constructivist theory have interpreted it, and drawn from it, principles to set up teaching and learning situations in classrooms e.g. Cobb, Wood and Yackel (1995). On the basis of my experience as a mathematics teacher, and subsequently, as a researcher in mathematics classrooms, I found Glasersfeld's first tenet helpful to explain why individual students responded differently to the same teaching experience in the classroom.

The second tenet is radical in the sense that relinquishing the belief that knowledge must represent a reality that lies out side our experience is an enormous and frightening step (Glasersfeld, 1995). The enormity of considering the nature of knowledge as not fixed and objective was even more so for mathematics learning because the discipline of mathematics has been imbued with certainty. Acknowledging constructivist principles of knowledge and of coming to know would imply acknowledging the fallible nature of mathematics (Lakatos, 1976) with implications for classroom teaching and learning. For me an understanding of these theoretical perspectives and their practical manifestations meant, that, as a researcher I could recognise and appreciate the dilemmas arising during my teaching: for example, when students tried to construct their own meaning of mathematics while subscribing to the objectivist epistemology of mathematics i.e. there lies an objective body of (mathematical) knowledge which it is their aim to learn. An issue was that radical constructivism does not overtly emphasise the power of negotiation and social interaction on individual construction.

Confrey (1995), says that constructivism has the 'social' implicit in its theoretical position so that it is not necessary to have alternate theories to explain how the social and cultural elements are incorporated in its theory. For example she says that, "knowing is justified belief" (Confrey, 2000, p.12) i.e. for it to be regarded as knowledge the belief has to be justifiable to oneself and others which is in the essence of 'fit'. As students in my research engaged in their mathematics work and I observed them, I had some problems with the practical manifestation of the tenets of constructivism in settings where the genesis of learning was in the social interaction. For example, as students in my research classroom worked at mathematics problem solving tasks in small group settings and constructed their own mathematical understandings, they did not do so in isolation. Interactions with both other students and teacher gave rise to crucial learning opportunities. Thus, I found that collaborative work involved developing explanations that could be understood by others and trying to interpret and make sense of another's ideas and solution attempts as they evolved. I provided students with opportunities to give coherent explanations of their problems, interpretations, and solutions, and to respond to questions and challenges by their peers. They were also expected to listen to and try to make sense of explanations given by others, to pose appropriate questions, and to ask for clarifications. When students engaged in such a discourse, the nature of their mathematical activity was extended to encompass learning opportunities that had their roots and beginnings in social interaction. I reckoned that there was no contradiction here with radical constructivism.

*Research Process*

As part of the research process I taught and observed four boys Asif, Basit, Farhan and Rizwan (age 11-12 yrs.). Students stayed behind after school and the teaching took place in eight one hour sessions outside the routine classroom. I designed my lessons on four rules of fractions, pertaining to addition, subtraction, multiplication and division of fractions, and the order of dealing with operations, because fractions is an important topic included in the national curriculum of Pakistan.

I audio taped all the eight teaching sessions, and alter transcribed them. I also maintained a research journal where I described my observation, identified issues and emerging questions and planned further teaching in light of the ongoing analysis as a result of the journal recording.

## INTRODUCTION OF FRACTIONS

I undertook the teaching of fraction rules from a constructivist perspective as discussed above. However, I wanted to look at the process of learning rules with reasons. Skemp (1991) makes a distinction between instrumental learning and relational learning.

Before starting with the rules of the four basic operations on fractions, I tried to create a conducive environment in the group through introductory sessions. These sessions helped me to know about the children's prior knowledge of fractions. These sessions provided me a ground to build the later sessions, and helped me for further planning. These sessions also helped me to create an atmosphere of trust and relationships between the researcher and the participants. I think building relationships and creating an atmosphere of trust are the nuts and bolts between the researcher and the research participant, because with-out a conducive environment in the group research is difficult to carry out.

According to Piaget's theory of constructivism, using manipulative is physical knowledge and fraction pies and strips are often recommended to teach fractions, and students are also given paper strips to fold to see that $3/4 > 2/3$. (Kamii,1999). To introduce fractions to the children, I selected a task taken from Burn (1992), to introduce fractions as part of a whole and to enable students to see patterns and relationships in fractions. They had to make fraction strips and manipulate them to discover the above mentioned four rules of fractions by themselves, rather then memorizing them. For example, the children were asked to work on paper strips and see how 1/2 +1/4 +1/4 = 1 or how many 1/8 are in one 1/2. I provided five 3-by-18 inch strips in five different colors, and a pair of scissors to each student. Having students cut and label the pieces helped them to relate the fractional notation to the concrete pieces, and to compare the sizes of fractional parts. For example, they could easily see that 1/4, is larger then 1/16, and they could measure to prove that two of the 1/8 pieces are equivalent to 1/4.

| | |
|---|---|
| 1/2 | 1/2 |

| | | | |
|---|---|---|---|
| 1/4 | 1/4 | 1/4 | 1/4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 |

| |
|---|
| **1** |

(Description about the fraction strips is provided in Appendix G).

After preparing the fraction strips, I provided worksheets (see Appendix H) to the children to complete by using fraction strips. The worksheets contained different questions related to fractions. For example, there were questions about equivalent fractions, concept of greater and smaller fractions. While doing these tasks, I observed that at the beginning students did not use fraction strips to solve the worksheet. They were doing the tasks mentally. I requested a number of times to explain their answers with the help of strips because I found that they were not able to explain how they got the answers through their mental work. As I was interested in their reasoning I wanted them to explain and believed that with the help of those strips they would be able to see and talk about the patterns and relationships among fractions.

A sample of the transcription is provided in box 1.

Box 1.

Shahida: How many 1/4 s are equal to one S ?
Farhan: 2.
Shahida: How?
Farhan: Miss, because, these two j are equal to one 1/2. When we multiply S Ч S then we get j.
Shahida: Why are we multiplying here?
Farhan: (silence).

(*Audio transcript*)

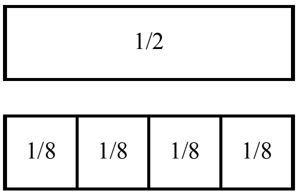
It is visible in the above mentioned conversation, that Farhan was able to give the correct answer. But when Basit used the fraction strips for the same question, he was not only able to give the correct answer but he was also able to justify his answer. He showed two strips of j and said, "when we join these two 1/4s, it is equal to one S". So, the possibility of joining the strips helped Basit. I was asking the children to put their strips in order on the table to enable them to see the different patterns, because my focus was also to see the process of learning mathematical rules with reasoning. I was observing that fraction strips were very helpful in giving reasons. In the following conversation, described in box 2, it is visible that fraction strips helped Rizwan to understand his question.

Box 2.

Shahida: Rizwan, how many eighths in S?
Rizwan: 8 no, no 2.
Shahida: Can you explain us how 2 or how 8 strips of 1/8 are equal to 1/2?
Rizwan: O.k. miss, four 1/8 s are equal to one 1/2.

(*Audio transcript*)

When I asked Rizwan to arrange paper strips according to the questions and see the arrangement of strips, he did so, and finally reached to the correct answer. He arranged his strips like this:




On the basis of my observation, I inferred that strips of fractions helped him to give a reason for his answer, and it also helped him to understand how four 1/8 s are equal to 1/2 because the strips were giving him a clear picture.

When the children were solving the tasks, I was trying to infer their understanding about fractions because I did not have much information about the children's prior knowledge of fractions. For example, the following conversation (Box 3) provided me information about Farhan's understanding of addition of fractions.

Box 3.

Shahida: Yes Farhan, can you explain us with the help of strips?
Farhan: These two 1/4 are making one 1/2.
Shahida: How?
Farhan: Because, these two 1/4 are equal to one 1/2. when we multiply 1/2 x 1/2 then we get 1/4.
(*Audio transcript*)

It was helpful making plans for further sessions.

I was asking them frequent questions to get the idea of fractions. Some of the questions were like the following:

- How many 1/2 strips are equal to 1 whole?
- How many 1/8 strips are equal to 1/4?
- Which is bigger 1/8 or 1/2?

This session provided me sufficient information about the children's understanding of fractions. I felt ready to move ahead and deal with the rule regarding addition of fractions.

## ADDITION OF FRACTIONS $\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}$

I designed a worksheet in order to know about the students' learning of the rule "addition of fractions" (see Appendix I). I designed the worksheet in such a manner that it would enable me to see the children's learning process easily. Specially, how the children learn with reasoning when they are involve in the rule $\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}$

The worksheet was systematically designed from easy to complex. It consisted of three types of addition of fractions, such as addition of fractions with the same denominator, addition of fractions with different denominators, and the addition of improper fractions.

When the children were adding fractions of the same denominator, they did not find any difficulty. Their prior knowledge was very strong in this case. They were even able to justify their work. An example is quoted in box 4.

Box 4.

> Shahida: What is 1/2 + 1/2 ?
> Farhan: 1.
> Shahida: How?
> Farhan: Miss, if we put two halves together it is equal to 1.
> (*Audio transcript*)

The children did not have much trouble with adding fractions with different denominators. Their justifications were based on figures.

I was looking at the process, that is, how they were arriving at the answer. They were solving on the paper very quickly. At that time it was difficult for me to see the process. When they finished, I posed different questions and asked them to explain the solution of their tasks. The children described the process as given in box 5.

Box 5.

> Basit: 3/5 + 2/3 = 5/8 because we add the fractions with different denominators and in the answer there will be different denominator as well. So, the answer will be 5/8. Because 3 + 2 = 5 and 5 + 3 = 8 there fore it will be 5/8.
> Shahida: Can you show me with figure?
> Basit: First we plus 3 and 2. So, it will be 5, then we plus 5 and 3 and it will be 8. So, answer will be 5/8. It means that there are total 8 boxes and 5 out of them are shaded.
> (*Audio transcript*)

When Asif used multi link cubes for his solutions, he described it in the following conversation, given in box 6.

Box 6.

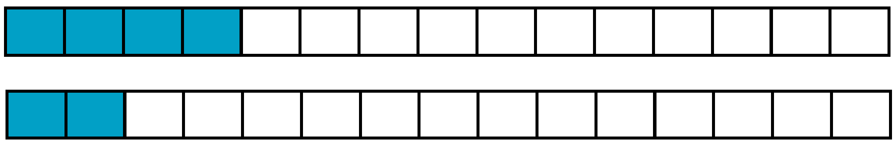
Shahida: Asif! Please can you explain your solution of the question 3/8 + 1/ 8?
Asif: White cubes are denominators and dark green cubes are numerators. I make 8 parts and 3 out of 8 are green. In second, their is 1 out of 8 is green.
Shahida: How many total greens do you have?
Asif: I have total 4 green cubes. So, 4/8 is answer.
(*Audio transcript*)

## SUBTRACTION OF FRACTIONS $\frac{a}{b} - \frac{c}{d} = \frac{ad - bc}{bd}$

The next topic of the session was subtraction of fractions. I designed the worksheet for this session with a similar idea in my mind as I had for addition of fractions. I mean, the tasks started with the subtraction of fractions with the same denominators, with different denominator, and the subtraction of improper fractions respectively (see Appendix J).

In this session, I noticed a slight change in the students' explanations for justifications. For example, Asif started his explanations with drawings. I am reproducing a part of the conversation, while Asif was explaining the solution of the question 4/15 – 2/15 with drawing, as follows:

Asif: In my question 4/15 – 2/15. I minus 2 from 4 and the denominator is same. Therefore, 15 will be the same in answer. And the answer will be 2/15. I make figure like this:

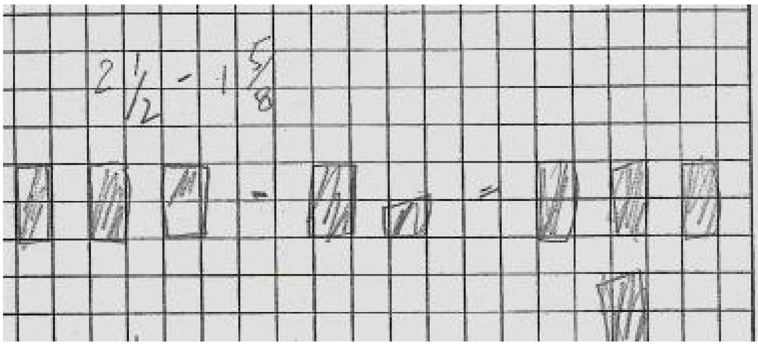


In first figure, I make 15 parts and shade four parts. in second figure, I make 15 parts and shade 2 parts. Miss is it minus? Oh, it's wrong. I added it. I take this 2 and minus from 4. I did mathematically right but on figure it is wrong.
(*Audio transcript*)

Here, it is apparent that the drawing helped Asif to understand the question and he himself realized his mistake with of the help of the drawing. It was difficult for him to describe with figures.

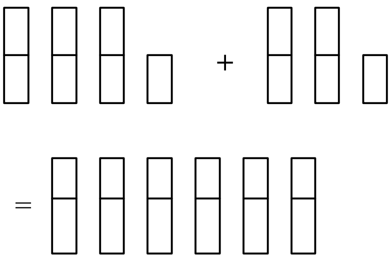
I asked the other children to describe their questions of subtraction of fraction of improper fractions with figures. For example, Basit's work (refer to figure 1). It was difficult for him to show 1 $^{5}/8$ even before showing the process of subtraction. He also had difficulty in the process of subtraction. Instead of subtracting, he was adding the fraction. So, it was quite difficult for children to subtract the improper fractions.

Figure 1.



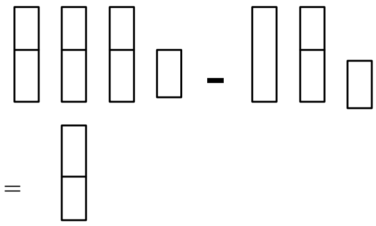
Kamii (1999) also shares the same idea and says, “adding and subtracting fractions tend to be quite difficult for children when unlike denominators are involved” (p.86). When I observed this issue, I tried to create a situation which would help them to show pictorial representations of subtraction of fractions, because I believed that pictorial representation would be helpful in order to learn the rule of subtraction of fractions with reasoning. I tried to relate subtraction of fractions with addition of fractions, because I noticed in the earlier session of addition of fractions that children were quite comfortable with the pictorial representation of addition of fractions. Burns (1992) also suggests, “classroom instruction should build on children’s previous experiences and help children clarify the ideas they have encountered” (p.212). I instructed the children to use the sign of subtraction instead of addition and solve accordingly. For example, I asked Basit to illustrate $3\ ^1/2 + 2\ ^1/2$. He illustrated the process as described in figure 2.

Figure 2.



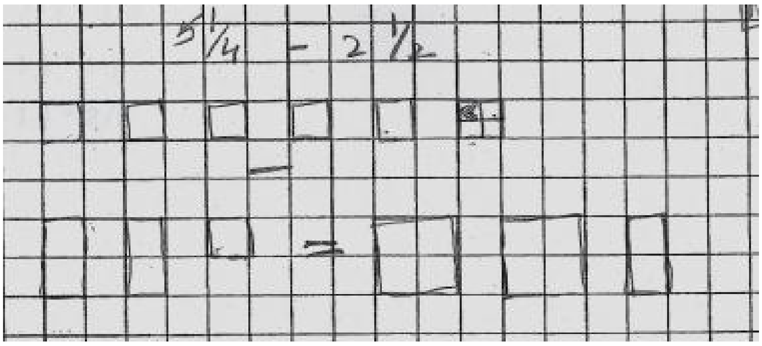
I told Basit to put the sign of minus instead of plus and solve. He did as I instructed.

Figure 3.



I asked the children to think and use other alternatives to solve the problems. I noticed that they started doing it with multi link cubes. Multi links cubes were available for them to use. The children put the cubes as shown in figure 4.

Figure 4.




It was a good exposure for children to check whether the use of manipulative and pictorial representations was workable for all rules of fractions or not. Burns (1992) also emphasizes the use of diverse traditions to introduce fractions, and says, " it is important to provide a variety of ways students can learn about fractions – with concrete materials, from a geometric perspective, with a numerical focus, and related to real life situations" (p. 213). It was also easy for me to explain to them with the help of manipulatives because it was quite visible for them to see the size of the cubes, which were not same for 2 $^{1}/_{2}$ and 1 $^{5}/_{8}$. Then I explained to them that the sizes of all cubes should be equal.

I noticed that meaningful interaction in the mathematics class also helped the children to clarify their arguments. In the particular session about subtraction of fractions, when the children were involved in the process of doing mathematics, they were discussing with each other. They were putting cubes in different manners to do subtraction of fractions. They were arguing with each other and at times they were looking for my help when they needed it. As Lindquist et al, m (1995) say, "… interaction allows students opportunities to talk about their ideas, get feedback for their thinking, and hear other points of view. Thus, students learn from one another as well as from teacher" (p.24).

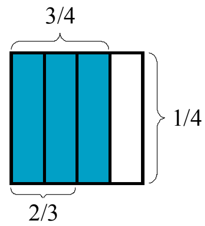
## MULTIPLICATION OF FRACTIONS $\frac{a}{b} \times \frac{c}{d} = \frac{a \times c}{b \times d}$

The next rule was "multiplication of fractions". In this session, the students worked with the formula of multiplication, i.e. $\frac{a}{b} \times \frac{c}{d} = \frac{a \times c}{b \times d}$. I planned some tasks (see Appendix K) to see the students' learning of the rule of multiplication of fractions with reasoning.

In this session, I observed a change. Students were solving the work sheet with pictures or by using multi link cubes, instead of solving mentally. They were trying to prove their solutions. Asif was working on the task 2/3 x 3/4. He explained it as follows (box 7).

Box 7.

Shahida: Can you explain your solution of the question (2/3 x 3/4)?
Asif : I have colored three boxes out of four.
Shahida: For 3/4, how many total parts have you made in the figure?
Asif : Four.
Shahida: How many you are taking from four?
Asif : Three.
Shahida: Yes, from these three parts what do you need?
Asif : 2/3 because it is 2/3 of 3/4.
Shahida: What is the remaining here?
Asif : One fourth and I also got 1/4 by doing mathematically.
Like : 2/3 x 3/4
= 6 /12
= 1/4.



(Asif's diagram)

(*Audio transcript*)

This scenario helped me to understand that Asif already had prior knowledge of symbolic representation of multiplication of fractions. At this step, he was relating that previous knowledge with the current one and justifying his solution with the figure. So, he explained his mathematical solution through pictorial representation.

I was thinking that children could easily make pictorial representations of all tasks related to fractions. But, I found that this claim was not always true. In a later session, children got stuck when they reached the question (1 $^{1}/2$ x 1 $^{1}/2$). It was difficult for them to make pictorial representation, as well as present concretely. I quote apart of the conversation in box 8.

Box 8.

Basit: Can you help me teacher for the question 1/2 x 1/2 ?
Shahida: Your question is 1 and 1/2 x 1 and 1/2.
Basit: 1 and 1/2 x 1 and 1/2.
Shahida: It means you have something one whole and half of that.
Basit: In this question we will take 1 and 1/2 and another 1 and 1/2.
Shahida: Why another? Are we going to add ?
Basit: Yes, miss.
Shahida: O.K. tell me that how will you add this?
Basit: We will multiply the denominators. So, 1/2 =2 and add 1. it will be 3. So, it will be 3/2.

(*Audio transcript*)

Another response to the same question was in the following form:

Shahida: Asif, what do you think about 1 1/2 and 1 1/2?
Asif : I will make one whole and one half of that. When I will put these join, it will become half and half. One whole and I will also add two wholes. Then it will be total 3 wholes. But they easily solved the question mathematically. (Asif solved the question like this):

1 1/2 x 1 1/2
= 3/2 x 3/2
= 9/4
= 2 1/4.

(*Audio transcript*)

Here, I realized that the children did not have a clear concept of multiplication of fractions. They followed the rule of multiplication of fractions but could not explain its meaning. Burns (1992) describes the same idea and says, "giving students rules to help them develop facility with fractions will not help them understand the concepts. The risk is that when students forget a rule, they have no way to reason out through a process" (p.213).

When I was reflecting on the session, I was frequently asking myself, "Is teaching the rule of multiplication of fractions not appropriate for grade six children? Or there is any problem with my teaching?" Later, literature helped me to understand the problem. Kamii (1999) describes, "when teaching multiplication, we do not say "multiply" or use the symbol 'Ч' until well into our instruction. We believe that saying "of means to multiply" imposes words on children that do not make sense to them" (pp. 89-90). So, as teacher we do not start using the symbols at the beginning. Teachers have to make simple stories to explain mathematical concepts and the stories should be according to the children's age and interest. When children get enough understanding then the teachers should use signs related to the concepts such as 2/3 of 3/4 or 3/4 x 4/5.

When the children were stuck, they asked me for help. I started to work it out in the class but the time was over. After the class, I sat down and tried to do pictorial representation of $1\ ^{1}/_{2} \times 1^{1}/_{2}$. It was not easy as the other questions. I spent more then one hour but I could not find the solution. Then I consulted my colleagues, who were interested. They also tried but were not able to work it out through pictures. After all these efforts, I found out that not all the rules can be explained by pictorial representation and not all rules can be explained by materials.

## DIVISION OF FRACTIONS $\frac{a}{b} \div \frac{c}{d} = \frac{a \times d}{b \times c}$

For the rule of division of fractions, I designed some tasks according to the level of grade six students. (see Appendix L). These were simple tasks, because in previous sessions I had found out that students faced difficulty in doing complex tasks. Through these tasks I wanted to know the children's understanding of division of fractions. When I tried to know about their prior knowledge about division of fractions, the following response was received box 9.

Box 9.

Researcher: What do you mean by divide?
Asif: Making parts.
Researcher: So, what is 1/2 ÷ 3?
Asif: It means that how many parts will make three?

(*Audio transcript*)

It was essential for children to have a clear concept of division with whole numbers before they moved to the division of fractions. Kamii (1999) says, "to teach division with fraction, we begin with the simplest of problems. It is important to clarify the students' conceptual understanding of division with whole numbers before asking them to apply it to fractions" (p.88).

So, I tried to pick up a concept which was familiar to them. I asked them to share their understanding of 4 2. They provided me a clear explanation. For explaining 3/7, it was useful to relate it with 1/2 because the children were easily understanding the meaning of 1/2, and these could easily be represented by figures and by concrete materials. I used the strategy of 'known to unknown' in the beginning sessions, which was quite helpful in moving further, or helping the students to understand the concept. In the following box 10, it is apparent that the concept of 1/2 helped Basit to understand 3/7.

Box 10.

Shahida: What do you mean by 3/7 of this shape?
Basit: (……….) silence.
Shahida: What do you mean by 1/2?(Basit drew  this figure).
Shahida: Now, you have to do the same for 3/7. How many parts will you make?
Basit: 7 and I am shading 3 parts out of 7.
Shahida: How many parts are left?
Basit: 4 parts.
Shahida: Can you write this fraction?
Basit: Yes, it is 3/7.
= 2 1/4.
(*Audio transcript*)

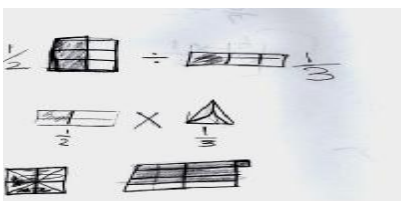
For example, one of the students said that it means four apples divided between two. Even in the conversation described in box 8, the children's knowledge about division was clear to some extent. I mean, Asif's response about division was: making parts of a thing. After having the students' knowledge about division of fractions, I provided them questions about simple division of fractions. At the beginning, I noticed that the children were able to symbolize division of fractions. For example, Basit described as shown in box 11.

Box 11.

Basit: 1/2 ÷ 1/3.
Shahida: How have you solved it, show me here?
Basit: Miss, I have divided 1/2 by 1/3 and then I came to the formulae and I changed it in to multiplication. I have done like this:
1/2 x 3/1. then 1 x 3 = 3 and 2 x 1 = 2. so, it is 3/2.
(*Audio transcript*)

When Basit described his solution, I asked him to show me with pictures, as it was difficult for me to see his understanding from his conversation. He tried to explain his solution with the following pictorial representation, shown in figure 5.

Figure 5.



In the mentioned figure, it is apparent that it was tricky for Basit to picturize the solution of the question with a figure. I found that he described symbolically but it was not easy for him to picturize. Wu (1999) says,

> *But we should not make students feel that the only problems they can do are those they can visualize… but this does not mean they cannot do the problem! Or that more complex problems like this one are not essential (p. 2).*

It is not necessary that children can draw figures for all the problems. Teachers can start with simple fractions for division to make pictorial representations easier because it will give children practice for the particular concept. As Wu (1999) states, "it is good to start with simple fractions that children can visualize, and they should do many such problems, until they have a firm grasp of what they are doing when they divide fractions" (p.1).

But they need to have a deeper understanding of division and it needs lots of practice in mathematics.

Many times children were referring to their prior knowledge in order to relate with the current one. For example,

Box 12.

Shahida: Can you explain us that how you divide it into 15 parts?
Asif: First I, make these five lines. Then I think about five table, and it is 3 x 5 is 15. Then I cut the five parts into three and get 15 parts.
Rizwan: I think that 1, 2, 3, ….10 and 3 x 10 = 30. Half of the 30 is 15. I have made two parts, two parts and two parts. it is equal to fifteen and now shaded two. Because 1, 1, 1, 1,1…..1 equals to 15.
(*Audio transcript*)

While working with the children on the four rules of fraction, I found out that teachers need to start explaining mathematical concepts with concrete material because of the abstract nature of mathematics. They can move to the pictorial representations and then the symbolic representations. Teachers also have to arrange activities from easy to complex. Before starting a new concept, teachers have to be sure that the children have understood the current concept very well. For example, before going to do division of fractions , children must be competent with the concept of multiplication of fractions.

In this chapter, I described the activities which lead me to next write about the factors which enhanced the students' learning of mathematical rules with reasoning.

## LEARNING MATHEMATICAL RULES WITH REASONING

Field data shared above led to several key conclusions about the process of students' learning mathematical rules with reasoning. These are discussed below.

*Mathematical Reasoning: Role of Teacher's Questions & Student Talk*

"Questions are a vital element of the learning process" (Lindquist et.al, 1995, p.25). During my field work I found what Lindquist and other researchers have described as true. I found that questions were significant in a number of ways. First, questions that the teacher raised played a key role in students' learning by providing an opportunity to explain their thinking and provide the teacher with some evidence of what they did or did not know. Second, it was the talk with peers that the students engaged in questions that students raised themselves.

While working in particular sessions, which I designed for the children, I found that different types of questioning was very helpful in providing them opportunities to justify their work. I mostly asked questions like: Why do you think so? How did you come to this answer? Could you elaborate on it? Why do you agree with him? The students were reluctant at the beginning and were unable to answer these questions because the 'why' and 'how' were somehow challenging words for them. But later, they were explaining and justifying their work. And these 'how' and 'why' questions helped them to think about their work. As it was evident in the previous chapter, in box 4.11, I asked Asif to elaborate his question, and his explanation specified his understanding.

However, I recognized that my own questioning skills had to be developed for them to be effective for students' learning. At the beginning of the sessions, I asked questions but was not very clear why I asked those questions. As I engaged for the purpose of the research in focused and deliberate reflection I found out that questioning is a good way of eliciting students' ideas, and it also helped me to know about the student's prior knowledge. It was very helpful to construct new ideas on the basis of that prior knowledge. In the later sessions, I tried to ask more critical and well organized questions. During the ongoing analysis of data, I noticed that in all the sessions pre planned and well organized questions played a key role in learning mathematical rules with reasoning. For example, the questions mentioned in box 4.4, helped Farhan to explain the process of solving the problem. While working with the four students, evidence suggested that my questions helped them think about their work, and because of questioning they started giving justifications for their work, and these justifications led the children to learn with understanding.

Second dimension of the questions were those questions which emerged as a result of students talk among themselves, and between students and teacher. For example, when students got stuck, others helped him. For example, when I asked Asif to explain his solution of the question to the whole group and he did so. There were some mistakes in his solution, and the other children confidently raised questions like, why did you say this?

During this study one of my strategies in the group was to ask children to explain their solutions to the whole group, as I mentioned earlier. By doing so, I realized that I was giving them a chance to share their ideas and thinking. As Hart (1993) says, "we tend often to assess the progress of a child by stating what he does that is correct and what he does that is incorrect rather than asking ourselves why he is correct or why he is wrong" (p.213).

However, it was not easy to engage the students so that they asked questions. Initially, students responded to my questions with silence or with one word answers. I recognized that as a new teacher I needed to set up an environment based on trust and friendliness, so that the emotional environment was that of confidence. I observed that this friendly environment helped children to reason their work. For example, children were asking questions without any hesitation. They were not feeling shy to ask questions. While working in the group, they were arguing with each other and raising questions when they needed clarifications. I tried to create a desirable atmosphere for learning with understanding.

I reflected on the reasons that made it difficult for me to ask open questions that would lead to learning with reasoning, and which made it difficult for students to engage with questions in a meaningful way. I do not have direct evidence to substantiate, but it is likely that students' and teacher's difficulty in dealing with questions which were open and broad could be because classrooms in Pakistan are characterized by mathematics teaching which focuses on memorization and rote learning (----). Students do not necessarily have opportunities to engage in open ended questions. Hence, a strong implication is that teacher education courses need to focus more strongly on the role that good open questions can play in enabling learning of mathematics where students learn rules with reasons and through rote memorisation.

*Learning by doing: Role of Concrete and Semi concrete Materials*

Askey (1999) says, "Having students work with concrete objects or drawings is helpful as students develop and deepen their understanding of operations" (p.7). During the particular sessions, which I designed for my study, I found the above mentioned quote true to some extent.

During my field work, I observed that concrete materials and semi concrete materials such as pictures and paper cutouts played a significant role in learning mathematical rules with reasoning. On many occasions, when children were not able to justify their solutions, concrete materials helped them a lot. For example, in the introductory sessions, I prepared paper strips to help children to understand 'fractions as a whole'. During those sessions I noticed that fraction strips were helpful to the children in providing reasons for their work. I also found out that if teachers were to provide multiple opportunities to the children, it could be helpful for their learning and more children could benefit from it. I also found that concrete materials were very useful for students to learn fractions because I observed on many occasions, that when children were unable to understand mathematics, because of its abstractness, then concrete materials provided them with a physical manifestation of the abstract ideas.

*Difficulty with Improper Fractions and Issues in the Rule of Multiplication of Fractions*

Working with the students, using innovative styles, and a focus in mind created a different picture about the rules of fractions in my mind. For example, during this study I found two major issues while observing the process of students' learning. The first one was about difficulty with improper fractions, and secondly, dealing with the rule of multiplication of fractions.

The difficulty with improper fractions was that students were having difficulty in showing the solutions of improper fractions through pictorial representation, as well as through use of concrete material. In the previous chapter, figure 4.1 is evidence of the statement. In the question 2S - 15/8, children faced difficulty in representing 15/8. The same in figure 4.4. The children had problems with putting cubes in order to show 5j. But they easily showed the pictorial representations of proper fractions, and they were quite confident in showing the same with cubes. Research also indicates the similar and I observed that they could easily solve the questions symbolically. I thought, may be, the problem was that they were not used to presenting fractions through figures or materials. I decided to support their thinking by posing questions, and created situations which facilitated them to find the solutions on their own. According to Kamii (1999),

> *The teacher's job is not to explain mathematics but to facilitate critical thinking and the honest, respectful exchange of ideas among the students. When students explain their reasoning to others, they clarify their own thinking and learn to communicate clearly". (p.88)*

So, children must be aware of multiple ways of solving problems. They should not stick just to one way while dealing with a variety of problems.

Another issue arose when I was observing the process of rule of multiplication of fractions. Asif perceived it as a multiplication of whole numbers. This could be because children in elementary grades are taught that multiplication is repeated addition. Usually, mathematics teachers relate multiplication with addition like 3 x 3 is same as 3 + 3 + 3. Hart (1993) acknowledges the same situation in these words,

The meaning of multiplication is firmly rooted in the child's experience of whole numbers where the operation can always be replaced by repeated addition. If the child sees 4 x 3 as four groups of three subjects … the meaning he attaches to 1/3 x 6/7 is unclear (p.80).

When I read the relevant literature, I found the same situation mentioned in a number of books. In addition to the one quoted above, another similar comment has been made by Skemp (1991), who says,

> *Multiplication is often taught to young children as repeated addition. For the natural number this causes no problem, and is probably the easiest for them to understand. But it causes problems later, for example, when we ask them to learn how to multiply fractions. Here, the concept of repeated addition has no meaning" (p.84).*

As I found the same issue in different contexts, I started thinking that children, and their level of thinking, is more or less the same, not completely but to some extent. Even though their environment and other factors are different, which enhance or hinder their learning, their level of understanding is the same the world over.

It was somehow challenging to explain the rule of multiplication of fractions with reasoning. In the limited time, I found 'rule learning' most suitable for teaching multiplication of fractions. As Hart (1993) acknowledges, "Multiplication of fractions cannot be dealt with by the use of naпve and intuitive methods and is therefore based very much more on 'rule learning' than some other aspects of mathematics" (p.80).

Students learn the basic facts in three stages: the manipulative stage, the pictorial stage, and the symbolic stage. Teachers need to start teaching mathematics from concrete materials, then pictorial representations and then help them to symbolize, because of the abstract nature of mathematics. Each stage builds upon the previous stage to help students master their basic facts.

## CONCLUDING REFLECTIONS

As I was looking at the process of students' learning mathematical rules with reasoning, I found out some factors which enhance the process of reasoning. There are a number of ways which enhance students' learning of mathematical rules with reasoning. In order to develop the reasoning ability in students, teachers must design such questions which may help the children to think and justify their answers. Another strategy can be creation of a conducive environment in the class, which can help children to express themselves without any hesitation. Students' prior knowledge is very helpful in order to reason. Teachers' guidance and interactions with peers also enables children's ability of reasoning.

My study provided me precious insights, which can enhance students reasoning ability, and guidelines for the teachers to practice in their mathematics classrooms, to adopt learning with reasoning.

Because of the abstract nature of mathematics, role of concrete materials is obvious. It helped children to proceed from concrete to abstract. The concrete materials played a vital role in enhancing the students' mathematical reasoning. As per the old Chinese saying, "when I see I forget, when I hear I remember and when I touch I understand". It is the same in mathematics.

While conducting my study, I found that the role of teachers questioning is very important. As teachers ask questions, children explain their ideas. By doing this teacher get an awareness of their student understands. Questioning can also be considered as a tool for assessment i.e. in order to see how much the children understand. When children explain their thinking the teachers easily evaluate them.

Friendly environment in the class was also supportive to reasoning, because in such an environment children argue, raise questions, and describe their thinking without any hesitation. A friendly environment creates a good relationship among teachers and students, and amongst students themselves. By doing so, they learn from each other. In a conducive environment a teacher's guidance is also taken positively. So, a friendly environment in the class is an essential element for learning with understanding.

While conducting this small scale study, I found that teachers play a major role in enabling student's learning of mathematics. The teacher must choose activities which provide opportunities for children to communicate their understanding. I found out that children learn better if they learn to solve problems, to communicate mathematically and to demonstrate reasoning abilities. These attributes will improve the children's understanding of mathematics and will enhance their interest in math concepts and thinking. It is obligatory for all mathematics teachers to always think of innovative strategies of teaching, and to create situations in the classrooms which may enhance learning with conceptual understanding.

Findings of the study raise significant implications for teacher education and for mathematics teachers. One, for students to learn in this case fraction rules with reasons, students need opportunities to talk about their mathematical thinking and explain it to others. Second, to be able to cope with the abstract mathematical concepts, pictures, paper cutouts and other concrete materials help learning by providing opportunities to manipulate, and see. Third, planning tasks and teaching based on constructivist principles of learning by doing and through social interaction had limitations as the mathematics became more complex.

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## APPENDIX G

### PURPOSE

- This activity introduces students to fractions as part of a whole.
- Students will prepare their own fraction kit for a number of fraction activities.

**Instructions for fraction strips**

Give students 6 strips of five different colors (white, blue, red, yellow and green).

Ask students to take a strip, fold it and then cut it into halves. Then ask them to label each piece 1/2.

Ask students to take a strip, fold that strip into halves and again fold that folded strip. Cut the strip into four. Ask students to label each piece j.

Ask students to take another strip, repeat the previous action of folding. This time fold one time more. You will get eight folded pieces. Cut the strips into eight equal parts. Ask students to label each part 1/8.

Ask students to take another strip and fold and cut the strip into sixteen equal parts. Then ask students to label each part 1/16.

Ask students to keep the last strip in rows and then compare the fractional parts.

e.g. 1/2 and 1/4. Find which fractional part is larger and smaller then the other.

Give everyone an envelope to keep their stripe and these will be the students' fractional kits.

## APPENDIX H

Name --------------------

Date ---------------------

The purpose of the activity was to introduce fractions as part of a whole.

Use your fraction strips to complete the following tasks:-

1. Place a ‘greater than’ sign ‘>’ or a ‘less than’ sign ‘<’ between each set of two fractions.

a. 1/2 ☐ 1/4

b. 1/4 ☐ 1

c. 1/4 ☐ 1/8

d. 1/16 ☐ 1

e. 1/8 ☐ 1/4

2. Use fraction stripe and solve the following questions:

a. 1/2 + 1/2 = ---------

b. 1/2 +1/4 + 1/4 = --------

c. 1/2 + 1/4 + 1/8 + 1/8 = -------

d. 1/2 + 1/4 + 1/8 + 1/16 + 1/16 = -------

3. Write five equivalent fractions of 1/2.

1/2 = ------- = ------- = ------- = ------ = --------

## APPENDIX I

## ADDING FRACTIONS

Name: _____________

Date: ______________

**PURPOSE**

The main objective of the session was to develop a situation where the students deal with tasks related to the addition of fractions, which will be helpful in order to enhance students' understanding of the topic, and will help me to generate data for my study.

Add the fractions with the same denominator:

1. 3/7 + 1/7
2. 3/8 + 1/8
3. 1/5 + 3/5

Add the fractions with different denominators:

1. 3/5 + 2/3
2. 5/8 + 1/10
3. 1/3 + 1/6

Add the improper fractions:

1. $1\ {}^{1}/_{2} + 1\ {}^{1}/_{3}$
2. $1\ {}^{3}/_{4} + 2\ {}^{1}/_{2}$
3. $4\ {}^{2}/_{5} + 3\ {}^{1}/_{2}$

## APPENDIX J

## SUBTRATION OF FRACTIONS

Name: _____________

Date: ______________

**PURPOSE**

To help students justify their solutions for subtraction of fractions.

Subtract the fractions with the different denominators:

1. 9/10 – 7/10
2. 4/7 – 3/7
3. 4/15 – 2/15

Subtract the fractions with different denominators:

1. 5/6 – $^{1}/_{2}$
2. 8/9 – $^{3}/_{4}$
3. 4/5 – $^{3}/_{4}$

Subtract the improper fractions:

1. 2 $^{1}/_{2}$ - 1 5/8
2. 3 $^{1}/_{2}$ - 1 $^{3}/_{4}$
3. 5 $^{1}/_{4}$ - 2 $^{1}/_{2}$

## APPENDIX K

## MULTIPLYING FRACTIONS

Name: _________

Date: __________

**PURPOSE**

Students will be able to understand the rule of multiplication of fractions.

Multiply the following and use cubes to solve the problems:

1. 3/7 x 15
2. 7/8 x 16
3. 4/5 x 30
4. 5/7 x 21
5. 1/8 x 32
6. $^{1/}2$ x 1/3
7. 2/3 x 3/4
8. 1 $^{1/}2$ x 1$^{1/}2$
9. 1 $^{3/}4$ x 2/5

## APPENDIX L

## DIVIDING FRACTIONS

Name: -----------

Date: ------------

**PURPOSE**

Students will be able to understand the rule of division of fractions.

Divide the following:

1. 1/2 ÷ 3
2. 3/4 ÷ 4
3. 6/7 ÷ 3
4. 4/5 ÷ 9
5. 1/2 ÷ 3
6. 3/4 ÷ 4
7. 6/7 ÷ 3
8. 4/5 ÷ 9

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# ALIGNING PRESERVICE TEACHER BASIC SCIENCE KNOWLEDGE WITH INTASC I AND NSTA CORE CONTENT STANDARDS

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**Sharon Dotger**

**ABSTRACT.** Training preservice teachers to develop a predisposition toward constructivist instruction is a major goal for many faculty in teacher education. One critical attribute of a constructivist teacher is a strong hold on pedagogical content knowledge. This study examined the prior knowledge of preservice science teachers and how that knowledge aligned with INTASC Standard I and the NSTA Core Knowledge Standards for science teachers. Basic content knowledge of twenty-four preservice teachers in an introductory science education course was assessed through released items from the grade 8 Trends in International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP) tests. Kruskal-Wallis analysis showed no significant differences in content knowledge across 3 content domains.

**KEYWORDS.** Teacher Training, Science Content Knowledge, Standards, Non-parametric Statistics, Misconceptions.

## INTRODUCTION

Ausubel (1968, p.406) stated, "The most important single factor influencing learning is what the learner already knows." Ascertain this and teach him accordingly. This statement has been the driving force for those advocating constructivist teaching methods. Constructivist learning theory suggests that people construct personal understanding by modifying their existing concepts (or schema) when new evidence and an experience is presented. This implies that students do not simply accept what has been taught, but rather shift their understanding in response to what has been taught.

If teachers are to embody the constructivist learning theory, than they need to discard their naпve conceptions of scientific phenomena and relearn the currently accepted explanations of scientific phenomena so they can teach their students accordingly. Teachers need to know and accept content, evaluate student ideas and understandings, and provide learning experiences to align students' conceptions with scientific explanations. This is particularly true in the domain of earth science as more states are requiring earth science in their curricula with less formally trained earth science teachers (Dickerson, 2002; Veal, 2002). Many agencies and organizations have set benchmarks for tackling this problem.


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*Purpose of the study*

The purpose of this study was to examine the basic content knowledge of preservice middle and secondary science teachers on 3 broad stratifications of science (life, physical and earth science) and how their existing knowledge aligned with INTASC Standard I and the NSTA Core Knowledge Standards. Preservice teachers are operationally defined as those students who do not yet have license to teach. This group of students consists of undergraduates (freshman-senior) and alternative licensure students (students with an earned bachelors degree returning to earn licensure). In North Carolina for example, teacher education programs are graduating students with the fulfilled requirements for a comprehensive science teacher license. However, the lack of emphasis on earth science during their training can pose a problem if preservice teachers are to someday instruct students on the basics of earth science and ultimately meet the standards set forth by federal and state agencies. It has been assumed that those with a richer background in specific science content domains would know and teach that content more effectively (Borko, 1996). The research question thus became: Do alternative licensure students possess greater earth science content knowledge according to INTASC standard I and the NSTA core knowledge standards than undergraduate preservice students?

## BACKGROUND

Since the 1980's, secondary school preservice teacher education has focused on pedagogy with the assumption students already possess strong content knowledge. However, with teacher shortages in critical areas such as science and mathematics, preservice teacher graduates are often hired by school systems to teach subjects in which they are not domain experts. Recent legislation in the form of No Child Left Behind is requiring teachers to be highly qualified and therefore teacher educators must prepare preservice teachers to be just that. Teachers cannot effectively educate students on subjects they themselves aren't comfortable with or confident in (Ball, 1990). Borko (1996) reported that most teachers' content knowledge comes from what they absorbed from their disciplinary fields, while their pedagogy and understanding of communication comes from the field of education. This only emphasizes the literature that science educators approach problems differently than pure scientists due in part to the science educators pedagogical knowledge and understanding of the implications of learning science (Borko, 1996). If future teachers are misinformed or have poor understanding of specific concepts, it is quite likely they will perpetuate these naiive conceptions to their students (Boyes, 1995).

*INTASC Standard I and the NSTA Core Knowledge Standards*

Licensing teachers to instruct students in basic science content has been a challenge for colleges and schools of education. There is never-ending discussion about the depth of content knowledge students should learn across the content areas and how this should be balanced with pedagogy. What do teachers need to know in terms of content knowledge and pedagogy is often debatable. The Interstate New Teacher Assessment and Support Consortium (INTASC) and the National Science Teachers Association have set out to make these objectives clear for teachers of all grade levels and with all types of certification. What follows is an overview of the vision of these two agencies.

The Interstate New Teacher Assessment and Support Consortium (INTASC) is a collaboration of state and national educational organizations dedicated to reform the preparation, licensing, and professional development of teachers. The first INTASC principle focuses on teacher content knowledge and describes this knowledge as "…the central concepts, tools of inquiry, and structures of the discipline…" (p. 1). The principle is separated into knowledge, dispositions, and performances the teachers should be able to demonstrate. While the content-based standards are still under development, teachers should know the most important concepts and the methods used to generate these ideas. Additionally, teachers should understand that students' prior knowledge and their schema could influence their learning. Ultimately, this principle relates students' schema to the potential misconceptions they hold regarding the content.

With regard to dispositions, the first INTASC principle requires that teachers view knowledge as complex and ever evolving. This implies that teachers must evolve with new ideas and findings within their teaching discipline. Furthermore, teachers must appreciate multiple perspectives and can explain to their students how these perspectives are developed from the point of view of the knower. The teacher will also regularly demonstrate an enthusiasm for the subject matter and must be committed to continually learn about subject matter and the most effective ways for students to learn that subject.

Finally, the first INTASC principle outlines teachers' effective performances as including multiple representations and explanations that activate and build on students' schema. Teachers must also evaluate resources and materials according to their accuracy and completeness. They have to engage students in inquiry-style activities that require students to test hypotheses according to the acceptable scientific standards.

The NSTA Core Knowledge Standards are based on a review of the professional science education literature and on the goals set forth in the National Science Education Standards. These standards outline the knowledge that teachers ought to have about specific content in four areas of scientific study: biology, chemistry, earth sciences, and physics. Within each of these domains, numerous objectives describe the most important ideas teachers ought to understand and demonstrate throughout their preservice experiences.

*A call for strong science content knowledge*

Since the science education movement began in the 1960's, the study of student misconceptions about scientific phenomena have been prolific in the literature. Students develop these misconceptions as a result of either personal experience, from other people, or through the media (Ausubel, 1968; Driver, 1985). Driver (1985) reported that different people have different misconceptions in different areas of science.

In teacher education, it is critical to evaluate the conceptions of preservice teachers. If they have misconceptions, it is likely they will pass the incorrect content on to their future students. The result of persistent wrong conceptions about scientific phenomena is an ill-informed citizenry and a reduced possibility of appropriate preventive actions by these citizens against future problems (Boyes, 1995).

This is a cascading effect that has not been widely addressed. For example, an analysis of survey data indicated that the many pre-service high school teachers possess an array of misconceptions about the causes and effects of the greenhouse effect, ozone depletion, and acid rain (Khalid, 2003). The problem grows more complex due to mismatched concept and student developmental levels. Inaccuracies in textbooks, incorrect information provided by instructors, and student memorization of prior concepts without meaningful understanding of the basic concepts compounds the problem and ultimately creates a lineage of confused science concepts (Westbrook, 1992).

In earth science education, it is not well documented as to what preservice teachers know or what they are learning to prepare them to be effective teachers. Much of the literature on earth science has focused on what K-12 students know about earth science phenomena. There are a few exceptions to this as (Barba, 1992, 1993; Schoon, 1995; Stofflett, 1993; Trend, 2000, 2001) attempted to look into preservice teacher earth science knowledge. Gruber (1999-2000) reported that 79% of earth science teachers were not earth science majors. Furthermore, the National Assessment of Educational Progress (2000) reported that 19% of grade 8 teachers were earth science majors. Grade 8 is the level where earth science has traditionally been taught until recently integrated into the high school curriculum.

*Science Teacher Development*

What teachers know and do is the most important influence on what students learn (The National Commission on Teaching and America's Future, 1996). If we are to challenge students to deeper understanding and high order thinking, teachers need to have a thorough conceptual and pedagogical understanding of content (Enfield, 2000). This has become to be known as Pedagogical Content Knowledge (PCK). Shulman (1986) defined PCK as the understanding of what makes the learning of specific topics easy or difficult. Shulman (1987) elaborated on this definition as, PCK encompasses knowledge of students' preconceptions, understanding and alternative conceptions of specific topics in the subject, knowledge of curriculum and standards, and finally instructional strategies and representations for teaching specific subject matter.

Veal (1999) suggested that PCK is a hierarchy that encompasses General PCK, Domain-specific PCK and Topic-specific PCK. General PCK refers to the different content disciplines (math, science, history, etc.). Domain-specific PCK is a branch of these disciplines. For example science domains are: chemistry, physics, biology, etc. Finally, Topic-specific PCK refers to the specific topics within each domain. For example in earth science, Topic-specific PCK would entail seismology, rocks and mineral properties, topography, etc. Teachers with knowledge in the Topic-specific PCK would most likely have an array of techniques and skills in the General and Domain-specific area.

Expert teachers are said to possess Topic-specific PCK (Reynolds, 1995; Shulman, 1987). Preservice teachers, and subsequently teachers in their early years of practice (who are not considered expert), have an expectation that there is a straightforward process for science teaching, not unlike the scientific method, and if they follow this process they will be effective science teachers (Smith, 2000). However, teaching is not straightforward, and neither is learning. Student learning ultimately results from a conglomerate of teacher traits, skills and practices, which when well developed lead to effectively teaching Topic-specific pedagogical content (Shymansky, 2000). It is at this juncture of teaching experience and PCK where teachers must be able to diagnose student misunderstandings and later prescribe strategies to combat such misunderstandings (Butler, 2003). When teachers learn to focus on student understanding, they recognize the need to modify their teaching practices. They become motivated to engage in the change process, and they begin to use student responses to assess whether they are teaching effectively (Harcombe, 2001). It is only at this point when teachers can be considered expert.

Arguably the most important component of PCK is science content knowledge. If a teacher is strong in pedagogy but lacks the science core knowledge to facilitate students beyond their misconceptions, then learning will most likely not occur. In licensing science teachers, it is critical we are preparing them to be highly qualified, helping them develop strong teaching methods and properly juxtapose their content knowledge to their pedagogy to elicit meaningful learning.

## METHODS

### *Sample*

A case study designed was used with twenty-four students enrolled in an introduction to science teaching course at a large, southeastern United States university were the sample of the study. The course design was 2-pronged: An introduction to teaching for science majors who are considering the teaching field as a profession; and an introduction to how the science students learn science content. The sample consisted of 19 undergraduates (1 freshman, 6 sophomores, 8 juniors and 4 seniors) and 5 alternative licensure students. Alternative licensure students are defined in this study as those students with a documented bachelors degree in a science domain and who have returned for teaching licensure.

*Instrument and data collection*

The students in this course were challenged on their basic content knowledge in 3 critical areas of science taught in the middle and secondary schools (physical, life and earth science). Students were assessed as to what, if any, misconceptions they thought their future students had within these broad content areas prior to the administration of the instrument. Using 15 released grade 8 items from the 1995 and 2000 National Assessment of Education Progress (NAEP) and the Trends in Mathematics and Science Study (TIMSS) test; an instrument was designed to garner the knowledge these students possess in these domains and to challenge what they thought they already knew about these domains. Five items were used to gain insight into student knowledge of life science, 6 from physical science and 4 from earth science. These items were chosen due to their alignment with the NSTA core knowledge standards (Appendix A) and because they are used as the benchmarks for domain specific knowledge of grade 8 students nationally and internationally. Table 1 illustrates a matrix of the NSTA Core competencies and how they align with the items within the instrument.

Life science items aligned with 7 of 12 core knowledge standards for biology. The physical science items aligned with 11 of 12 physics core knowledge standards and 2 of the 13 chemistry standards. Finally, the earth science items aligned with 8 of 12 core knowledge standards. Appendix A illustrates specific standards addressed by each question in the instrument.

Students were given this instrument in class and the results were used to inform future instruction. The multiple choice items were selected based on the responses students provided as to their belief of their knowledge in these areas. Anecdotal evidence prior to administering the test suggested students did not feel as confident with their knowledge of earth science as opposed to their knowledge in life and physical science. As earth science is becoming a required and tested course in middle and high schools, the results of the instrument would shed light on the areas where preservice science instruction needs to be redirected so future teachers are better prepared to teach a wide variety of science topics; most specifically earth science.

*Data analysis*

Student responses to the instrument were collapsed into life, physical and earth science based on the content description provided by the NAEP and TIMSS test. Items were collapsed by calculating the mean of individual responses to each item that aligned with 1 of the 3 domain

Table 1: Matrix of NSTA Core Competencies and their match to instrument domain items

| | Question | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **NSTA Competency** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| C.2.a. Core Competencies. All teachers of biology should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand: | | | | | | | | | | | | | | | |
| 1. Life processes in living systems including organization of matter and energy. | x | | | | | | | x | x | | | | | | |
| 2. Similarities and differences among animals, plants, fungi, microorganisms, and viruses. | x | | | | | | | | | | | | | | |
| 4. Scientific theory and principles of biological evolution. | | | | | | | | | | | | x | | | |
| 5. Ecological systems including the interrelationships and dependencies of organisms with | x | | | | | | | | x | | | | | | |
| 7. General concepts of genetics and heredity. | | | | | | | | | | | | x | | | |
| 10. Regulation of biological systems including homeostatic mechanisms. | | | | | | | | x | | | | | | | |
| 11. Fundamental processes of modeling and investigating in the biological sciences. | | | | | | | | x | x | | | | | | |
| 12. Applications of biology in environmental quality and in personal and community health. | x | | | | | | | x | x | | | x | | | |
| C.3.a. Core Competencies. All teachers of chemistry should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand: | | | | | | | | | | | | | | | |
| 11. Environmental and atmospheric chemistry. | | x | | | | | | | | | | | | | |
| 13. Applications of chemistry in personal and community health and environmental quality. | | x | | | | | | | | | | | | | |
| C.4.a. Core Competencies. All teachers of the Earth and space sciences should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand: | | | | | | | | | | | | | | | |
| 1. Characteristics of land, atmosphere, and ocean systems on Earth. | | x | x | | | | | | | | | | | | |
| 3. Changes in the Earth including land formation and erosion. | | | x | | | | | | | | | | | | |
| 5. Energy flow and transformation in Earth systems. | | | | | | | | | | | | | x | | |
| 6. Hydrological features of the Earth. | | | x | | | | | | | | | | x | | |
| 7. Patterns and changes in the atmosphere, weather, and climate. | | x | | | | | x | | | | | | x | | |
| 8. Origin, evolution, and planetary behaviors of Earth. | | | | | | x | x | | | | | | | | |
| 10. Fundamental processes of investigating in the Earth and space sciences. | | | | | | x | x | | | | | | x | | |
| 12. Applications of Earth and space sciences to environmental quality and to personal and community health and welfare. | | x | | | | | | | | | | | | | |
| C.5.a. Core Competencies. All teachers of physics should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand: | | | | | | | | | | | | | | | |
| 1. Energy, work, and power. | | | | | | | | | | x | x | | | x | |
| 2. Motion, major forces, and momentum. | | | | | | | | | | x | | | | x | |
| 3. Newtonian principles and laws including engineering applications. | | | | | | | | | | x | | | | x | |
| 4. Conservation of mass, momentum, energy, and charge. | | | | | | | | | | x | | | | x | |
| 5. Physical properties of matter. | | | | x | x | | | | | x | | | | | |
| 7. Radioactivity, nuclear reactors, fission, and fusion. | | | | | | | | | | | x | | | | |
| 8. Wave theory, sound, light, the electromagnetic spectrum and optics. | | | | x | x | | | | | | | | | | |
| 9. Electricity and magnetism | | | | | | | | | | | | | | | x |
| 10. Fundamental processes of investigating in physics. | | | | | | | | | | | | | | x | |
| 11. Applications of physics in environmental quality and to personal and community health. | | x | | x | x | | | | | | x | | | | x |

areas of life, physical and earth science. Frequency of responses based on academic year (grouped as freshman, sophomore, junior, senior, and alternative licensure) was calculated and a Kruskal-Wallis test was conducted. Differences in mean rankings were analyzed to gain insight as to which, if any, academic subgroup had more knowledge of these 3 areas of science content than another.

## RESULTS

Table 2 shows the descriptive statistics of the academic subgroups and the results of the instrumental responses. From this table it is interesting to note that the percent of questions in the physical science domain that all students answered correctly is the lowest (0.725) of the 3 content domains. However, the standard deviation in responses is considerably higher for earth science (2.395). A mean rank was calculated for each content domain based on the academic year of the respondents (see table 3).

Table 2: Descriptive statistics of sample by academic year and test results by content domain

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| LIFE | 24 | .8917 | .16659 | .40 | 1.00 |
| PHYSICAL | 24 | .7254 | .20173 | .29 | 1.00 |
| EARTH | 24 | .8613 | .23959 | .33 | 1.00 |
| YEAR | 24 | 3.2500 | 1.18872 | 1.00 | 5.00 |

Table 3: Mean ranks of content domain by academic year of sample

| | YEAR | N | Mean Rank |
|---|---|---|---|
| LIFE | freshman | 1 | 6.50 |
| | sophomore | 6 | 15.25 |
| | junior | 8 | 13.88 |
| | senior | 4 | 11.75 |
| | licensure only | 5 | 8.80 |
| | Total | 24 | |
| PHYSICAL | freshman | 1 | 2.50 |
| | sophomore | 6 | 10.08 |
| | junior | 8 | 15.00 |
| | senior | 4 | 13.25 |
| | licensure only | 5 | 12.80 |
| | Total | 24 | |
| EARTH | freshman | 1 | 2.00 |
| | sophomore | 6 | 12.50 |
| | junior | 8 | 16.00 |
| | senior | 4 | 9.88 |
| | licensure only | 5 | 11.10 |
| | Total | 24 | |

Sophomores had a higher rank on life science (15.25) and juniors had the highest rank in physical (15.0) and earth science (16.0) respectively. Although Chi square results show life (4.514), physical (3.938) and earth (7.686) sciences are considerably different in terms of responses from this sample, the Kruskal-Wallis test suggest no differences in student scores for any of the 3 domains tested (see table 4).

Table 4: Kruskal-Wallis test for significance on academic year and domain specific knowledge

| | LIFE | PHYSICAL | EARTH |
|---|---|---|---|
| Chi-Square | 4.514 | 3.938 | 7.686 |
| df | 4 | 4 | 4 |
| Asymp. Sig. | .341 | .414 | .104 |

## CONCLUSIONS

The null hypothesis of no differences in accurate knowledge of earth science phenomena between preservice science teachers and alternative licensure students is not accepted. It is important to note that only 1 freshman was a participant of the study and thus does not provide a true reading of content knowledge differences between these groups. The university in which the study took place has recently made accommodations to the science teacher licensure program to encompass more required earth science courses to better prepare the graduates with a broader knowledge base in the sciences. However, what is intriguing are the mean ranks illustrated in table 2. These students take most of the biological sciences in the freshman year and physical sciences in the sophomore and early junior years. Most of the participants take the required earth science content courses during the junior year and juniors performed better on earth science questions than the other academic levels. The basic knowledge of earth science is more than likely fresher to these students and thus it might explain why they performed better on the earth science items in the instrument.

These results suggest the potential impact of graduating teachers with lacking Domain-specific knowledge; specifically in earth science. In North Carolina for example, the majority of first year teachers with a comprehensive teaching license are generally asked to teach earth science. With recent science education reform movements advocating for a greater development of PCK for preservice teachers (Doster, 1997) it is crucial teacher educators develop an understanding of what their prospective teachers have assimilated in their science content courses.

The National Science Education Standards call for teachers to acknowledge and redirect student preconceptions about incorrect scientific phenomena (National Research Council, 1996). It can be argued that teachers who themselves have misconceptions about basic scientific phenomena will not likely be able to redirect students with naive conceptions. As Standard 1 of the National Science Teachers Association (1998, section 1.3 Recommendations of the National Science Teachers Association) stated, *The content knowledge of the prospective science teacher is developed primarily in science courses taught by science faculty. Assigning the development of the skills and knowledge required by this standard to one or even several science method courses is unlikely to produce the depth of understanding needed for effective teaching practice. All science teacher candidates should be provided with a carefully designed, balanced content curriculum leading to a demonstrated knowledge of the concepts and relationships they are preparing to teach.*

Moreover, INTASC I calls for teachers to be able to articulate the major concepts within the science domain in which they teach. Certainly, one could argue that grade 8 test items are not complex enough to be considered anything other then “Big Ideas” in that domain. These standards need to be taken seriously and teacher educators need to acquire information that assures their students are prepared to teach a wide variety of science topics. Hewson and Hewson (1983) defined conceptual change as allowing learners to examine their own experiences and confront naive conceptions. It is critical that teacher educators challenge presevice teachers to confront expert views and to reflect upon their current views and how that might impact teaching and learning; specifically in earth science (Dahl et. al., 2004). As Lynch (2003) suggested, with increased understanding of content, teachers may change their beliefs on how science should be taught. "Unless we make some effort to explore students personal theories we will continue to graduate college students with their childhood misconceptions virtually untouched" (Woods, 1994). In science education if this phenomenon is perpetuated, the NSTA Core Knowledge Standards and INTASC Standard I will likely never be met.

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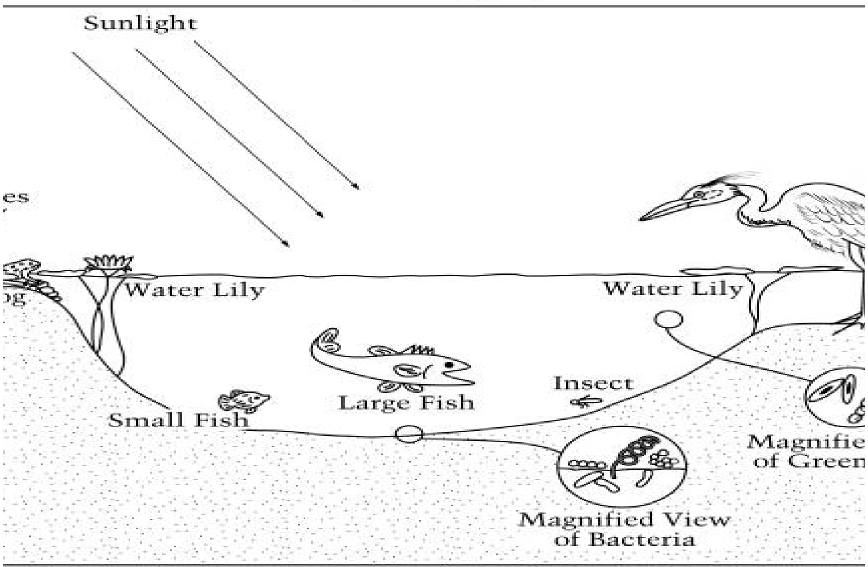
Appendix A

Figure 1

The picture below shows a pond ecosystem. Use this picture and what you know about the things in it to answer the questions in this section.




1. If air pollution causes the rain that falls on this pond to become much more acidic, after two years how will this acidity affect the living things in this pond?

A) There will be more plants and animals because the acid is a source of food.

B) There will be fewer plants and animals because the acid will dissolve many of them.

C) There will be fewer plants and animals because many of them cannot survive in water with high acidity.

D) There will be more plants and animals because the acid will kill most of the disease-causing microorganisms.

STANDARDS C.2.A. 1,2,5,12

2. Which of the following best explains why the pressure inside a high-flying airplane must be controlled?

A) At high altitudes there is greater atmospheric pressure than on the surface of the Earth.

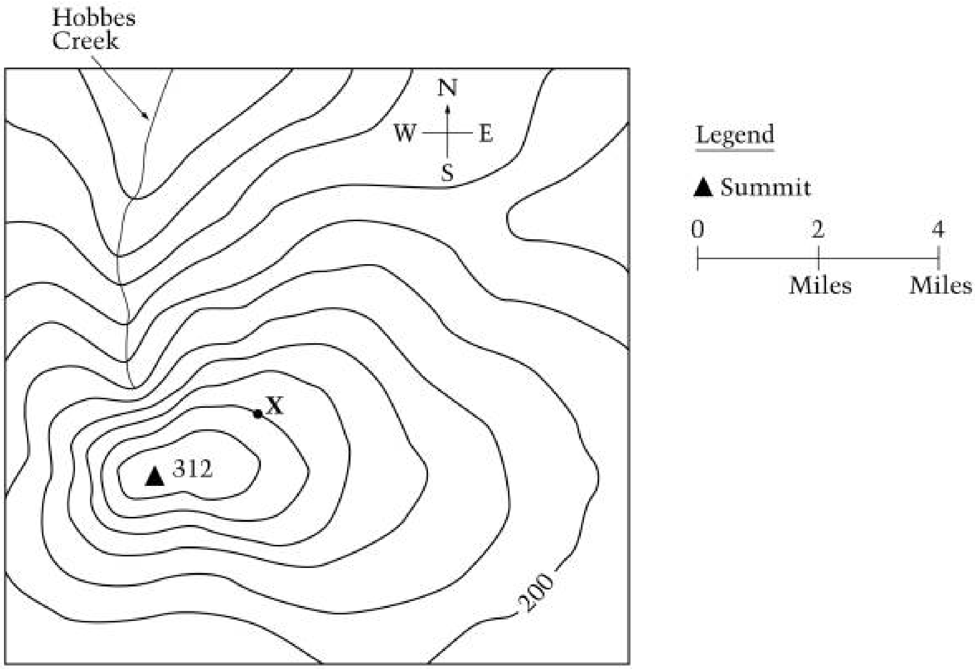
B) At high altitudes there is lower atmospheric pressure than on the surface of the Earth.

C) If the cabin is not pressurized, ozone and other upper atmospheric gases will enter the airplane.

D) If the cabin is not pressurized, carbon dioxide will escape from the airplane.

STANDARDS C.3.A. 11, 13; C4.A. 1,7,12; C.5.A. 11

The following question refers to the topographic map below, which shows Willow Hill (elevation 312 feet) and Hobbes Creek. On the map, each contour line represents 20 feet of elevation.




3. In which general direction does Hobbes Creek flow?

A) To the north

B) To the east

C) To the south

D) To the west

STANDARDS C.4.A. 1,3,6

4. If you were looking at an apple in a completely dark room (absolutely no light source present), what would you see after being in the room for more than 5 minutes?

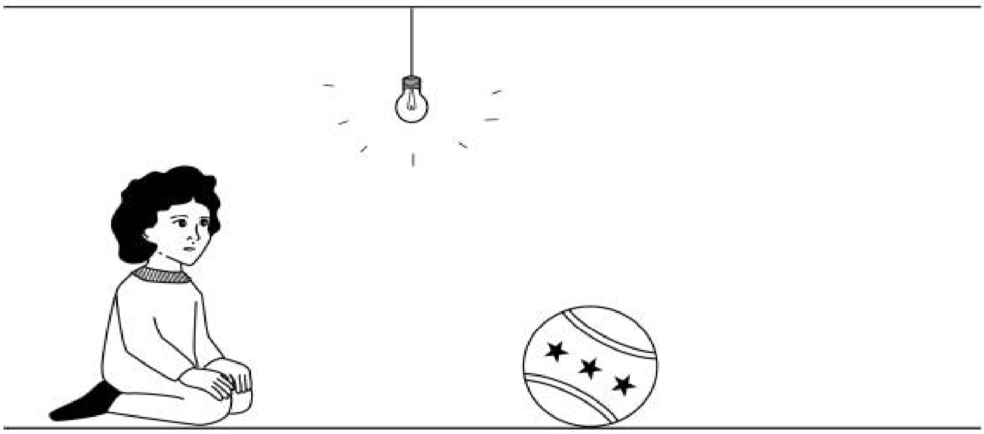
a. The shape of the apple, but not the color.

b. The color of the apple but not the shape

c. Nothing at all

d. Everything with some difficulty

STANDARDS C.5.A. 5,8,11



5. In the figure above, which of the following is the pathway of light that allows the child to see the ball?

A) Light bulb * child's eyes * ball

B) Child's eyes * light bulb * ball

C) Ball * light bulb * child's eyes

D) Light bulb * ball * child's eyes

STANDARDS C.5.A. 5,8,11

6. The Earth's Moon is

A) always much closer to the Sun than it is to the Earth

B) always much closer to the Earth than it is to the Sun

C) about the same distance from the Sun as it is from the Earth

D) sometimes closer to the Sun than it is to the Earth and sometimes closer to the Earth than it is to the Sun

STANDARDS C.4.A. 8,10

7. What causes North Carolina to experience different seasons throughout the year?

a. It is warm (summer) when earth is closer to the sun in its orbit and cold (winter) when earth is further away from the sun?

b. Earth is always equidistant to the sun

c. Earth is tilted on its axis and North Carolina is never tilted toward the sun

d. Earth is tilted on its axis and tilts toward the sun at one point and tilts away from the sun in the opposite point of its orbit.

STANDARDS C.4.A. 7,8,10

8. In the human body the digestion of proteins takes place primarily in which two organs?

A) Mouth and stomach

B) Stomach and small intestine

C) Liver and gall bladder

D) Pancreas and large intestine

STANDARDS C.2.A. 1,10,11,12

9. What property of water is most important for living organisms?

A) It is odorless.

B) It does not conduct electricity.

C) It is tasteless.

D)It is liquid at most temperatures on Earth.

STANDARDS C.2.A. 1,5,12

10. To keep a heavy box sliding across a carpeted floor at constant speed, a person must continually exert a force on the box. This force is used primarily to overcome which of the following forces?

A) Air resistance

B) The weight of the box

C) The frictional force exerted by the floor on the box

D) The gravitational force exerted by the Earth on the box

STANDARDS C.5.A 1,2,3,4,5

11. Which of the following is designed to convert energy into mechanical work?

A) Electric fan

B) Kerosene heater

C) Flashlight

D) Baking oven

STANDARDS C.5.A. 1,7,11

12. Which of the following is most consistent with the modern theory of evolution?

A) Parents pass their physical traits to their offspring; those offspring with traits that help them survive in the environment are able to reproduce.

B) Parents change their physical traits in order to survive in the environment, then those parental traits are passed to their offspring.

C) Life on this planet came from another planet far out in space.

D) Living organisms have not changed for hundreds of millions of years.

STANDARDS C.2.A. 4,7,12

13. Which of the following would be the best model to show the interactions between water and the Sun's heat energy in cycles of precipitation?

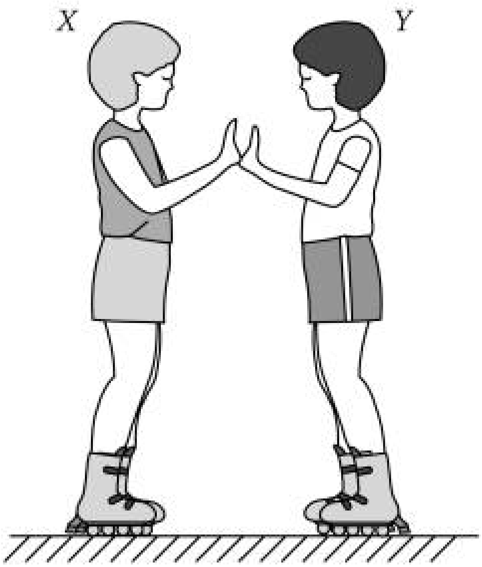
A) A light shines on an aquarium covered with glass, and water droplets form on the inside of the glass.

B) A light shines on a closed cardboard box containing a plant.

C) A light shines on a man's face. Droplets of sweat form on his face as he exercises.

D) A light shines on a glass of iced tea. Water droplets form on the outside of the glass.

STANDARDS C.4.A. 5,6,7,10




14. Two boys wearing in-line skates are standing on a smooth surface with the palms of their hands touching and their arms bent, as shown above. If Boy X pushes by straightening his arms out while Boy Y holds his arms in the original position, what is the motion of the two boys?

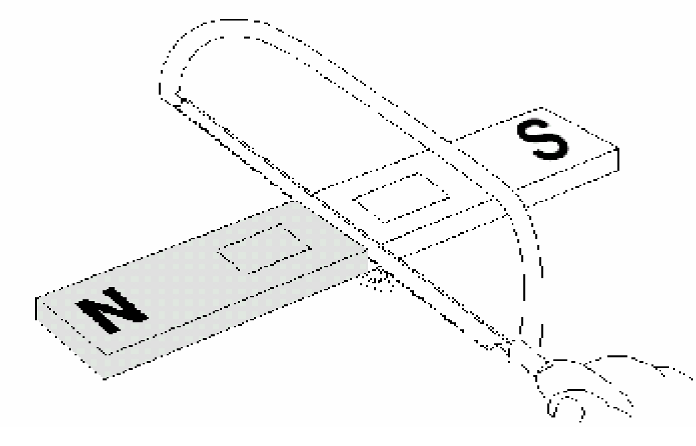
A) Boy X does not move and Boy Y moves backward.

B) Boy Y does not move and Boy X moves backward.

C) Boy X and Boy Y both move backward.

D) The motion depends on how hard Boy X pushes.

STANDARDS C.5.A. 1,2,3,4,10




15. A bar magnet is cut in two with a hacksaw. Write an “N” or an “S” in each box on the diagram to show the polarity of the cut ends.

STANDARDS C.5.A. 9,11

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# WHAT MALAYSIAN SCIENCE TEACHERS NEED TO IMPROVE THEIR SCIENCE INSTRUCTION: A COMPARISON ACROSS GENDER, SCHOOL LOCATION AND AREA OF SPECIALIZATION

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**Lilia Halim**

**Subahan Mohd Meerah**

**ABSTRACT.** This research looks specifically at the perceived needs of secondary school science teachers in Malaysia so that subsequent effective in-service programmes can be planned and implemented. The prime aim of this cross-sectional survey study is to ascertain the perceived needs of 1,690 practicing secondary school science teachers, characterized by gender, school location, and area of specialization. The main instrument used is a questionnaire. The validity and reliability of the instrument were systematically established through relevant test procedures. The questionnaire seeks feedback on the eight dimensions of science teachers' needs: generic pedagogical knowledge and skills, knowledge and skills in Science subjects, managing and delivering science instruction, diagnosing and evaluating students, planning science instruction, administering science instructional facilities and equipment, integration of multimedia technology and the use of English language in science instruction. Data were descriptively analyzed, followed by a series of chi square analysis. Results of the descriptive analysis demonstrate that the most prevalent needs of the Malaysian secondary school science teachers are the integration of multimedia and the use of English in science instruction. When measures of association were gauged between the science teachers' needs and the independent variables, it was found that significant associations exist. The associations were apparent between most of the dimensions of science teachers' needs and school location.

**KEYWORDS.** Malaysian, Science Teachers' Needs, Gender, School Location, Area of Specialəzation.

## INTRODUCTION: CONTEXT OF THE PROBLEM

Analysis of the historical panorama of Science education in Malaysia leads to the conclusion that science curriculum innovation is continuously in the state of flux. To date, continuous modification has been planned and hence implemented to suit the current national as well as global needs (Kamisah, 1999). Lee (1992) argues that such innovation is triggered by the interface between internal affairs and external global factors, which leads to the production of a



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local made science curriculum. This curriculum is not only recognized in Malaysia, but is also accepted in the international arena. Compared to the other subjects in the curriculum, changes in the science curriculum occurred at a much faster pace. This is due to significant impact created by science and technology advancement of human civilization. As a result, to keep abreast with the changes, science teachers must be well-equipped with the necessary knowledge and skills so that what is outlined in the curriculum is being realized in the classroom. In other words, science teachers must deliver their lesson effectively as envisaged in the curriculum.

As a transmitter of knowledge, skills and values to the mass population, teachers in Malaysia or in any other parts of the world, are always considered as the nation's greatest asset. As such, teachers must be able to play their roles and fulfill their responsibilities to their utmost capabilities. To be able to do so, teachers must be well prepared for the profession and at the same time maintain and improve their skills through lifelong career learning. Support for their well being and professional development should therefore be an integral and essential part of the efforts made to raise the standard of teaching and learning, and students' achievement. At the same time, teachers must also inculcate in their students dispositions towards lifelong learning and skills required in facing the upcoming national and global challenges. As a role model, teachers must first exhibit their commitment and enthusiasm towards lifelong learning.

Currently, the situation in Malaysia does not only call for the need to equip teachers with the necessary knowledge and skills per se, but includes tackling issues pertaining to the quality of teaching and learning Science. Arguably, Malaysia, like many other countries in the world (e.g. Pakistan, Australia, New Zealand, United States of America and Britain) is confronted with the problem of inadequate trained science teachers especially in the teaching of Physics, Chemistry and Mathematics. As such, teachers of various educational backgrounds teaching science subjects were common in most schools. As a result, teachers with various subject majors' background are often required to teach science subjects which they are not trained for. Though these teachers might have used various kinds of coping strategies in their teaching, they are in dire need for in-service training courses in order to teach science meaningfully and effectively whilst filling the gaps of content knowledge and pedagogical content knowledge in the subject that they are required to teach (Subahan, Lilia, Khalijah and Ruhizan, 2001). Arguably, as documented in the literature, this situation is also overwhelming in many developed countries such as in the United States of America and United Kingdom since the mid 1980s (Millar, 1987).

It has been argued elsewhere that effective in-service training programmes should include program development and orientation geared towards meeting the stated needs of the teachers' concern (Amir Salleh, 1993). Nevertheless, to date, there is only one comprehensive study conducted by Kamariah (1984) on the perceived needs of Malaysian secondary school science teachers. Based on a total of 1,330 samples, it was concluded that the most prevalent need of science teachers then was providing for students' safety in the science laboratory. It could therefore be argued that science teachers' perceived needs, as identified by this study, is in contrast to the current accepted view of priority needs which lead to effective science teaching; viz. developing students' understanding and creating meaningful learning (Harlen, 1996). Thus, it is timely that another comprehensive assessment of the perception of the professional needs of secondary school science teacher's be conducted. Craft (1996), Day (1999) and Parkinson (2004) concur by negotiating that the first step in designing a curriculum for continuous professional development is revelation and assessment of teachers' needs. In a similar vein, Baird and Rowsey (1989), based on their survey of secondary school science teachers needs conclude that without accurate data on teachers' needs, planning is not only difficult, but results generated are likely to be disappointing to both teachers and those who offer in-service courses.

Baird and Rowsey (1989) also highlight teachers' complaints that much time spent during in-service programmes and activities had been wasted where such programmes were not applicable in meeting their respective classroom needs.

Another significant point is that those who teach science at secondary school level are from diverse groups and thus require different needs. High quality in-service programmes designed to meet the perceived needs of science teachers are necessary if teachers are to respond and benefit from staff development programmes.

## NEEDS ASSESSMENT MODEL: A RETROSPECTIVE

Analytical scrutiny of needs assessment model used in educational research indicates the availability of a variety of models such as Discrepancy Model (Sweigert and Kase (1971), System Model and Organizational Needs Model (Kaufman (1972), and Marketing Model (Kotler (1982). Based on his conception of training needs as "…a discrepancy between an educational goal and trainees performance in relation to this goal", Borich (1980; p.40) proposes another needs assessment model known as the Borich Needs Assessment Model. This model primarily focuses on (i) underlining the competencies, (ii) surveying the in-service teachers, (iii) ranking competencies, and (iv) comparing high priority competencies with training programme content. Although Borich's (1980) model is widely used in determining the science teachers' needs, Witkins (1984) contends that there is no "best" or single universally accepted model of needs assessment in the educational field since its choices, procedures as well as instrument used to gauge the needs will depend on the purpose and context of the assessment study.

Reviews on empirical studies on science teachers' needs and the development of procedures for identifying and categorizing science teachers' needs have been a major educational agenda since the 1970s. The evolution of science teachers' needs instrument inaugurated with the development of Moore Assessment Profile (MAP) was further refined by Blakenship and Moore (1977) and Rubba (1981). Eleven years later, Kamariah, Rubba, Tomera and Zurub (1988) established the Science Teacher Inventory of Needs (STIN) which classify the science teachers' needs into seven categories. The STIN was widely used primarily in Jordan and in Malaysia. STIN was further used and contextually refined by Baird and Rowsey (1989) by comprehensively administering the instrument to 1,870 science teachers across Alabama. In 1993, once again STIN was used by Zurub and Rubba in identifying the needs of 1,507 rural science teachers in Arkansas, Illinois, Oklahoma, Kansas, Tennessee and Texas. Until recently, the needs of the science teachers is still a major national agenda as evidenced in Dillon, Osborne, Fairbrother and Kurina (2000) and State of Delaware study (2002).

It could be synthesized that from all the needs assessment study highlighted, its major outcome is the identification of contextualized, science teachers' needs. In Malaysia, a needs analysis study was initiated in an effort to establish empirical evidence of the science teachers' needs in meeting the challenges of science education. In 1984, Kamariah first undertook a national needs assessment study to ascertain the needs of Malaysian science teachers five years after the implementation of the New Integrated Science Curriculum for Secondary Schools. At the primary level, currently there is only one comprehensive study conducted by Mohamad (2002). These studies therefore served as a point of departure for this paper, which specifically focuses on the identification of the secondary school science teachers' needs in Malaysia.

## AIMS OF THE STUDY

The main aim of this study is to identify the most prevalent needs of Malaysian secondary school science teachers in keeping themselves abreast with the current demands in teaching and learning science. This is essential so as relative measures can be undertaken to prepare teachers in meeting with these local challenges as well as confronting issues of globalization. This study also seeks to identify existing associations if any, in the science teachers' needs across gender (male, female), geographic regions change to school location (rural, urban) and area of specialization (physics, chemistry, biology).

## RESEARCH METHODOLOGY

### *Research Design*

The research design employed in this study is a cross-sectional survey using a questionnaire as the prime instrument. The survey design is chosen so that generalizations can be made from the samples representing the population (Creswell, 2005; Kerlinger and Lee, 2002). Neuman (2000) argues that such an approach can be justified in terms of the nature of information gathered. This study garnered information on the Malaysian science teachers' needs based on gender, school location and area of specialization. The nature of such data justifies the suitability of the survey design employed.

*The Samples*

The population of this study comprised practicing science teachers in all secondary schools in Malaysia. Using the research questions developed as points of reference, a stratified random sampling of respondents was made, taking these factors into consideration; gender of the respondents (male vs. female), geographical location of the schools involved (rural vs. urban) and the respondents' area of specialization (physics, chemistry, biology, science and mathematics). As a result, 1,690 science teachers were randomly selected as respondents for this survey. Table 1 summarizes the demographic data of the science teachers who participated in this study.

Table 1: School Location by Gender and Area of Specialization

| **School Location** | | **Area of Specialization** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Physics | Chemistry | Maths | Biology | Science | Others |
| **Urban** | Male | 31 | 35 | 32 | 33 | 25 | 30 |
| | Female | 63 | 132 | 83 | 186 | 57 | 81 |
| **Rural** | Male | 38 | 39 | 39 | 29 | 43 | 57 |
| | Female | 58 | 97 | 99 | 165 | 76 | 111 |

As displayed succinctly in Table 1, almost 85.9% of the teachers in the urban areas are science majors compared to only 80.2% in the rural areas. For both locations, most of the teachers are majoring in biology (urban = 219; rural = 194) and the least number of teachers are majoring in physics (urban, n = 94; rural, n = 96). Nonetheless, there are about an equal percentage of teachers majoring in chemistry and mathematics both in the rural and urban areas. The percentages of teachers who are not majoring in science in urban and rural areas are 14% and 19.7% respectively.

Analysis across gender shows that most of the male respondents are physics (n = 69), chemistry (n = 74), mathematics (n = 71) or biology (n = 62) teachers. This is evidenced by the almost equal number of male science teachers majoring in all those four subjects. On the other hand, most female respondents are biology teachers (n = 351), followed by chemistry (n = 229), mathematics (n = 182), and physics (n = 121). On examination, it was also found that almost 20.0% of male respondents and 15.8% of female respondents are not majoring in Science. When the distribution of science teachers is examined across school location, it was found that the ratio of male to female teachers in both rural and urban schools is about 1 to 3.5. From the ratio, it could be inferred that for both urban and rural areas, there are more female compared to male teachers. It was also found that only 14.0% of science teachers in the urban schools are not Science majors. In contrast, the percentage is slightly higher in rural areas with almost 20.0% of science teachers who taught in rural schools were not majoring in Science.

## THE INSTRUMENT

Primarily, the term science teachers' needs used in this study is defined as "…a conscious drive, or desire on the part of the science teacher, which is necessary for the improvement of science teaching" (Moore, 1977; p. 145). The needs analysis instrument used in this study is developed by using the Science Teacher Inventory of Needs (STIN) developed by Zurub and Rubba (1983) as its main reference. Items were carefully and collectively crafted, which reflect the current needs of the secondary school science teachers in Malaysia. The overall process of item development involved five main stages. Firstly, the existing perceived needs sub-scales were consecutively reviewed. Secondly, a thorough review and analysis of the needs literature were conducted. Thirdly, in order to identify the needs of science teachers, structured interviews were conducted which involved eight experienced science teachers across the country. The interview data were used as background information in constructing the needs items. Fourthly, a panel of experts in the area of science teaching representative of biology, chemistry and physics were engaged to add, edit, or eliminate irrelevant items from the initial pool of items.

At the final stage of items construction, the instrument was validated by having teachers and lecturers review the items with respect to its readability, clarity and ease of response. Instructions or items that were equivocally stated were identified and improvements were made. The final version of the instrument consists of two sections. Section one seeks information on the demographic characteristics of the respondents, while section two consists of 72 items pertaining to in-service needs of the science teachers. These needs can be categorized into eight distinct dimensions: (i) management of science lessons, (ii) diagnosing and evaluating students, (iii) generic pedagogical knowledge and skills, (iv) knowledge and skills in Science subjects, (v) managing science facilities and utilities, (vi) planning science instruction, (vii) integrating multimedia technology in science instruction and (viii) using English language in science instruction. Each item constitutes a statement, which is followed by a three-point Likert scale ranging from (1) not needed to (3) greatly needed. Table 2 summarizes the distribution of items according to the dimensions identified.

Table 2: The Distribution of Items for Each Dimension of Science Teachers' Needs

| Dimension | No of Items | Item Distribution |
|---|---|---|
| Management of science instruction | 16 | B11, C16, C19, C22, C23, C24, C27, C29 C31, C32, D33, D34, D35, D37, A38, A39 |
| Diagnosing and evaluating students | 11 | A1, A2, A3, A4, A5, A6, A7, A8, B9, B10, C28 |
| Generic pedagogical knowledge and skills | 14 | F57, F58, F59, F60, F61, F62, F63, F64, F65, F67, F68, F69, F70, F71 |
| Knowledge and skills in science subjects | 7 | F50, F51, F52, F53, F54, F55, F56 |
| Administering science instructional facilities and equipment | 10 | D36, E40, E41, E42, E43, E44, E45, E46, E47, E49 |
| Planning activities in science instruction | 8 | B12, B13, C14, C15, B17, C21, C25, C26 |
| Integration of multimedia technology in science teaching | 4 | C18, C20, E48, F72 |
| Use of English language in science teaching | 2 | C30, F66 |

*Reliability and Validity of Instrument*

Reliability of the needs instrument was established by employing the internal consistency (Cronbach Alpha) approach. Based on Table 3, the alpha values range from .674 to .953. In discussing item reliability, score variability, item homogeneity and test length are three main issues commonly associated with it (Anastasi, 1982; Youngman, 1979). It was found that, the number of items for each dimension did not have any significant impact on the reliability index. For instance, the alpha value generated from planning activities in science instruction dimension (n = 8) is not much different from the alpha value generated from diagnosing and evaluating students dimension (n = 11). Based on the alpha values generated and the heterogeneous nature of the samples who participated in the study, it could be argued that the heterogeneity of scores is obtained. To summarize, a higher value of reliability index is demonstrated due to score heterogeneity caused by a balanced distribution of science teachers with respect to independent variables that characterized them (see also Table 1).

Table 3: The Reliability Coefficients of the Science Teachers' Needs Assessment Instrument

| Dimension | No of Items | Alpha Coefficient |
|---|---|---|
| Management of science instruction | 16 | 0.953 |
| Diagnosing and evaluating students | 11 | 0.909 |
| Generic pedagogical knowledge and skills | 14 | 0.861 |
| Knowledge and skills in science subjects | 7 | 0.900 |
| Administering science instructional facilities and equipment | 10 | 0.878 |
| Planning activities in science instruction | 8 | 0.902 |
| Integration of multimedia technology in science instruction | 4 | 0.830 |
| Use of English language in science instruction | 2 | 0.674 |

It is almost axiomatic that the choice of validation mechanism will primarily depend on the purpose of the test scores (Anastasi, 1982). The same test, when employed for different purposes should be validated in rather different ways. Considering the main function of the instrument developed in this study, it was reckoned that the most suitable approach for establishing the validity is construct validity. By definition, construct validity of a measure is directly concerned with the theoretical relationship of a variable with other variables. It refers to the extent in which a measure "behaves" the way the construct purports to measure with regard to established measures of other constructs. The construct validity of the needs instrument was established by employing the confirmatory factor analysis. As suggested by De Vaus (2001; p. 257), "… this inductive approach to scaling clusters item that go together" and extracting items based on the samples respond consistently in harmonious ways. In the confirmatory factor analysis, the first step involved extraction of factors via principal component analysis. By doing so, certain eigen values, represented by certain percentage of variance will be generated. The eigen value represents a measure that attaches to the factors and indicates the amount of variance in the pool of original variables that the factors explain. Each construct (factor) will be retained if its eigen value is more than 1. The second step involved additional procedure called factor rotation. Varimax rotation method is used due to its advantage in producing factors (constructs) that are free and independent of one another. By doing so, the subsequent factor interpretation is relatively easy (Blakenship and Moore, 1977; Bryman and Cramer, 1998).

By systematically and meticulously conducting all the procedures mentioned, nine factors were successfully extracted, which as a whole contribute 66.7% of the overall variance. Nevertheless, based on the corresponding Scree plot analysis, eight factors were then identified which as a whole represent 64.5% of the overall variance. Close examination of each factor generated reveals that each factor is mainly represented by at least three items. The application of all those procedures finally generated eight factors (dimensions) of Malaysian science teachers' needs. Table 4 depicts factors that were successfully extracted as well as the labels that are given to them.

Table 4: Factors Extracted by Factor Analysis Procedures

| Factor | Dimension | No of Items | Percentage of Variance |
|---|---|---|---|
| I | Management of science instruction | 16 | 0.953 |
| II | Diagnosing and evaluating students | 11 | 0.909 |
| III | Generic pedagogical knowledge and skills | 14 | 0.861 |
| IV | Knowledge and skills in Science subjects | 7 | 0.900 |
| V | Administering science facilities and equipment | 10 | 0.878 |
| VI | Planning activities in science instruction | 8 | 0.902 |
| VII | Integration of multimedia technology in science instruction | 4 | 0.830 |
| VIII | Use of English language in science instruction | 2 | 0.674 |

## RESEARCH FINDINGS

To reiterate, the definition of perceived science teachers' need as measured in this study is referred to as an area for in-service help; a situation in which science teachers indicate more than a moderate need. Hence, it was then decided that science teachers' need will be categorized as a priority when the percentage of respondents indicating a great need is 40 percent or more. This is in line with Moore and Blakenship (1978) suggestion whereby a priority science teachers' need is defined as "…an area for in-service help when science teachers indicate more than a moderate need" (page 514). Similarly, the 40 percent cut-off point was also used in previous studies (Baird and Rowsey, 1989).

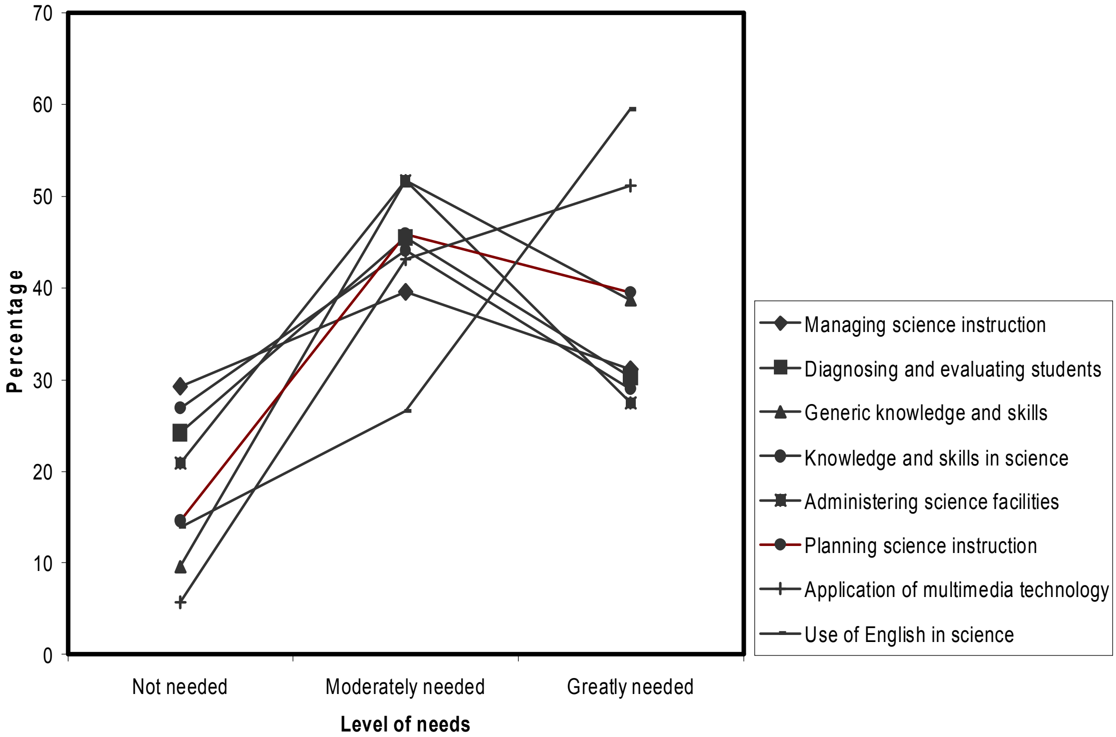
Table 5 summarizes the level of needs for each of the eight dimensions as perceived by the 1,690 Malaysian secondary school science teachers who participated in this study. Overall, it could be inferred that Malaysian secondary school science teachers have demonstrated their need to improve knowledge and skills in all eight dimensions of science teachers' needs. More than 60.0% of the science teachers echoed 'moderately and greatly needed' in all the eight dimensions.

Table 5: Level of Needs for Each Dimension

| **Dimension** | **Level of Needs N (%)** | | | | | |
|---|---|---|---|---|---|---|
| | Not needed | | Moderately Needed | | Greatly Needed | |
| 1. Managing and delivering science instruction | 496 | (29.3) | 669 | (39.6) | 525 | (31.1) |
| 2. Diagnosing and evaluating students for science instruction | 409 | (24.2) | 769 | **(45.5)** | 512 | (30.3) |
| 3. Generic pedagogical knowledge and skills | 162 | (9.6) | 874 | **(51.7)** | 654 | (38.7) |
| 4. Knowledge and skills in Science subjects | 454 | (26.9) | 745 | **(44.1)** | 489 | (29.0) |
| 5. Administering science instructional facilities and equipment | 353 | (20.9) | 873 | **(51.7)** | 464 | (27.5) |
| 6. Planning of science instruction | 247 | (14.6) | 775 | **(45.9)** | 668 | (39.5) |
| 7. Integration of multimedia technology | 96 | (5.7) | 729 | (43.1) | 865 | **(51.2)** |
| 8. Use of English language in science teaching and learning | 235 | (13.9) | 450 | (26.6) | 1005 | **(59.5)** |

With reference to Table 5, the highest percentage of the greatly needed scale is demonstrated in the use of English in science teaching and learning dimension (59.5%). This is followed by the integration of multimedia technology dimension (51.2%). The third highest percentage of moderately and greatly needed scale selected is related to planning of science instruction dimension (39.5%), which is then followed by the need for generic pedagogical knowledge and skills dimension (38.7%). It seems that the moderately needed skill is in managing and delivering science instruction (31.1%). In terms of diagnosing and evaluating students, only 30.3% of the science teachers expressed their great need for the skill while 45.5% of them expressed a moderate need. Table 5 also reveals that most of the science teachers who participated in this study perceived that their knowledge and skills in science subjects is adequate to ensure effective and meaningful science instruction. This is evidenced when only 29.0% of the respondents perceived that they greatly needed assistance in that particular skill, and about 44.0% displayed a moderate need for such skill. Finally, the least needed skill is in administering science instructional facilities and equipment, whereby only 27.5% of the science teachers felt that they should upgrade their knowledge and skills in that aspect. Figure 1 illustrates a comparative illustration of science teachers' needs based on the percentage of the likert scale (degree of needs) used. (See also Table 5).

Figure 1: Comparative Illustration of the Malaysian Science Teachers' Needs




## THE CATEGORIZATION OF SCIENCE TEACHERS' NEEDS

Further analysis of the science teachers' needs with respect to independent variables that characterized them would enhance the conclusion that will be generated from the analysis. Consequently, the proposed in-service programmes could be tailored according to the science teachers' characteristics. The following is a detailed analysis of perceived science teachers' needs of each dimension according to gender, school location and area of specialization. Based on the aims and objectives of the study and the consideration of the type of data generated from it, the analyses used are mainly cross tab procedures followed by subsequent Chi Square measure of association (Kerlinger and Lee, 2002).

Table 6:

| Dimension | Variables | | Not Needed | Moderately Needed | Greatly Needed | $x^2$ | p |
|---|---|---|---|---|---|---|---|
| Administering science instructional facilities and equipment | Gender | Male | 102 (22.8) | 236 (52.8) | 109 (24.4) | 3.325 | .190 |
| | | Female | 251 (20.2) | 637 (51.2) | 355 (28.6) | | |
| | School | Rural | 147 (16.8) | 461 (52.7) | 266 (30.4) | **20.611** | **.000*** |
| | | Urban | 206 (25.2) | 412 (50.5) | 198 (24.3) | | |
| | Area of specialization | Physics | 48 (25.3) | 100 (52.6) | 42 (22.1) | **29.208** | **.001*** |
| | | Chemistry | 75 (24.8) | 165 (54.5) | 63 (20.8) | | |
| | | Mathematics | 60 (23.7) | 120 (47.4) | 73 (28.9) | | |
| | | Biology | 86 (20.8) | 198 (47.9) | 129 (31.2) | | |
| | | Science | 29 (14.4) | 117 (58.2) | 55 (27.4) | | |
| | | Others | 42 (15.1) | 147 (52.7) | 90 (32.3) | | |
| Knowledge and skills in science subjects | Gender | Male | 130 (29.1) | 194 (43.5) | 122 (27.4) | **1.745** | **.000*** |
| | | Female | 324 (26.1) | 551 (44.4) | 367 (29.5) | | |
| | School | Rural | 204 (23.4) | 383 (43.9) | 286 (32.8) | 17.368 | .418 |
| | | Urban | 250 (30.7) | 362 (44.4) | 203 (24.9) | | |
| | Area of specialisation | Physics | 60 (31.6) | 82 (43.2) | 48 (25.3) | 13.710 | .187 |
| | | Chemistry | 89 (29.4) | 138 (45.5) | 76 (25.1) | | |
| | | Mathematics | 75 (29.6) | 102 (40.3) | 76 (30.0) | | |
| | | Biology | 101 (24.5) | 197 (47.7) | 115 (27.8) | | |
| | | Science | 45 (22.4) | 89 (44.3) | 67 (33.3) | | |
| | | Others | 70 (25.3) | 116 (41.9) | 91 (32.9) | | |
| Diagnosing and evaluating students for science instruction | Gender | Male | 106 (23.7) | 222 (49.7) | 119 (26.6) | 5.080 | .079 |
| | | Female | 303 (24.4) | 547 (44.0) | 393 (31.6) | | |
| | School | Rural | 171 (19.6) | 416 (47.6) | 287 (32.8) | **21.680** | **.000*** |
| | | Urban | 238 (29.2) | 353 (43.3) | 225 (27.6) | | |
| | Area of specialization | Physics | 50 (26.3) | 89 (46.8) | 51 (26.8) | **22.616** | **.012*** |
| | | Chemistry | 87 (28.7) | 141 (46.5) | 75 (24.8) | | |
| | | Mathematics | 63 (24.9) | 109 (43.1) | 81 (32.0) | | |
| | | Biology | 106 (25.7) | 175 (42.4) | 132 (32.0) | | |
| | | Science | 40 (19.9) | 94 (46.8) | 67 (33.3) | | |
| | | Others | 44 (15.8) | 146 (52.3) | 89 (31.9) | | |
| Managing and delivering science instruction | Gender | Male | 135 (30.2) | 189 (42.3) | 123 (27.5) | 3.730 | .155 |
| | | Female | 361(29.0) | 480 (38.6) | 402 (32.3) | | |
| | School | Rural | 216 (24.7) | 360 (41.2) | 298 (34.1) | **19.781** | **.000*** |
| | | Urban | 280 (34.3) | 309 (37.9) | 227 (27.8) | | |
| | Area of specialization | Physics | 68 (35.8) | 68 (35.8) | 54 (28.4) | 14.800 | .140 |
| | | Chemistry | 100 (33.0) | 119 (39.3) | 84 (27.7) | | |
| | | Mathematics | 73 (28.9) | 97 (38.3) | 83 (32.8) | | |
| | | Biology | 114 (27.6) | 169 (40.9) | 130 (31.5) | | |
| | | Science | 59 (29.4) | 80 (39.8) | 62 (30.8) | | |
| | | Others | 61 (21.9) | 122 (43.7) | 96 (34.4) | | |

* significant at .05

Table 6:

| Dimension | Variables | | Not Needed | Moderately Needed | Greatly Needed | $x^2$ | p |
|---|---|---|---|---|---|---|---|
| Generic pedagogical knowledge and skills | Gender | Male | 62 (13.9) | 231 (51.7) | 154 (34.5) | **14.470** | **.001*** |
| | | Female | 100 (8.0) | 643 (51.7) | 500 (40.2) | | |
| | School | Rural | 60 (6.9) | 449 (51.4) | 365 (41.8) | **18.411** | **.000*** |
| | | Urban | 102 (12.5) | 425 (52.1) | 289 (35.4) | | |
| | Area of specialization | Physics | 31 (16.3) | 90 (47.4) | 69 (36.3) | **28.727** | **.001*** |
| | | Chemistry | 32 (10.6) | 176 (58.1) | 95 (31.4) | | |
| | | Mathematics | 26 (10.3) | 130 (51.4) | 97 (38.3) | | |
| | | Biology | 33 (8.0) | 217 (52.5) | 163 (39.5) | | |
| | | Science | 14 (7.0) | 106 (52.7) | 81 (40.3) | | |
| | | Others | 19 (6.8) | 129 (46.2) | 131 (47.0) | | |
| Planning science instruction | Gender | Male | 92 (20.6) | 208 (46.5) | 147 (32.9) | **21.643** | **.000*** |
| | | Female | 155 (12.5) | 567 (45.6) | 521 (41.9) | | |
| | School | Rural | 98 (11.2) | 402 (46.0) | 374 (42.8) | **19.228** | **.000*** |
| | | Urban | 149 (18.3) | 373 (45.7) | 294 (36.0) | | |
| | Area of specialization | Physics | 38 (20.0) | 78 (41.1) | 74 (38.9) | **20.832** | **.022*** |
| | | Chemistry | 43 (14.2) | 155 (51.2) | 105 (34.7) | | |
| | | Mathematics | 41 (16.2) | 115 (45.5) | 97 (38.3) | | |
| | | Biology | 60 (14.5) | 180 (43.6) | 173 (41.9) | | |
| | | Science | 28 (13.9) | 98 (48.8) | 75 (37.3) | | |
| | | Others | 23 (8.2) | 130 (46.6) | 126 (45.2) | | |
| Integration of multimedia technology in science teaching | Gender | Male | 37 (8.3) | 199 (44.5) | 211 (47.2) | **9.366** | **.009*** |
| | | Female | 59 (4.7) | 530 (42.6) | 654 (52.6) | | |
| | School | Rural | 36 (41) | 363 (41.5) | 475 (54.3) | **12.389** | **.002*** |
| | | Urban | 60 (7.4) | 366 (44.9) | 390 (47.8) | | |
| | Area of specialization | Physics | 11 (5.8) | 85 (44.7) | 94 (49.5) | 10.083 | .433 |
| | | Chemistry | 21 (6.9) | 140 (46.2) | 142 (46.9) | | |
| | | Mathematics | 19 (7.5) | 105 (41.5) | 129 (51.0) | | |
| | | Biology | 16 (3.9) | 180 (43.6) | 217 (52.5) | | |
| | | Science | (8 (4.0) | 86 (42.8) | 107 (53.2) | | |
| | | Others | 15 (5.4) | 110 (39.4) | 154 (55.2) | | |
| Use of English language in science teaching and learning | Gender | Male | 74 (16.6) | 134 (30.0) | 239 (53.5) | **9.309** | **.010*** |
| | | Female | 161 (13.0) | 316 (25.4) | 766 (61.6) | | |
| | School | Rural | 64 (7.3) | 230 (26.3) | 580 (66.4) | **70.940** | **.000*** |
| | | Urban | 171 (21.0) | 220 (27.0) | 425 (52.1) | | |
| | Area of specialization | Physics | 36 (18.9) | 53 (27.9) | 101 (53.2) | **26.890** | **.003*** |
| | | Chemistry | 54 (17.8) | 71 (23.4) | 178 (58.7) | | |
| | | Mathematics | 36 (14.2) | 68 (26.9) | 149 (58.9) | | |
| | | Biology | 52 (12.6) | 126 (30.5) | 235 (56.9) | | |
| | | Science | 21 10.4) | 56 (27.9) | 124 (61.7) | | |
| | | Others | 23 (8.2) | 64 (22.9) | 192 (68.8) | | |

* significant at .05

With reference to the administering science instructional facilities and equipment dimension, there is no significant association between gender and science teachers' perceived needs ($\chi^2 = 3.325$; p>.005). This is evidenced when results show that the perceived needs of female teachers are similar to the perceived needs of their male counterparts. However, the school location and area of specialization factors established significant association with the science teachers' needs. A comparison in school location reveals that 30.4% of teachers in the rural areas expressed a great need for the skill as opposed to 24.3% of teachers in the urban areas. More teachers from the rural areas felt that they moderately need such assistance in this aspect (rural = 52.7%; urban = 50.5%). In contrast, 25.2% of teachers in urban areas felt that they had already acquired such skills. With respect to the teachers' area of specialization, it was found that the highest percentage of respondents opting for the 'greatly needed' scale is shown by non-Science option teachers (32.3%). More than half of the science option teachers (52.7%) felt that they moderately need refresher courses in this aspect, whereas 25.0% perceived that they had already acquired the necessary skills in administering science instructional facilities and equipment.

The results displayed in Table 6 show that overall, science teachers portrayed that they moderately need support in upgrading their mastery of knowledge and skills in science subjects. Further Chi Square analysis reveals that significant association only exist between gender ($\chi^2 = 1.745$; p<.005). Specifically, female teachers demonstrated a higher percentage (29.5%) compared to their male colleagues (27.4%) in expressing their great need for such support. Concomitantly, a higher percentage is displayed by male teachers (29.1%) who perceived that such support is not needed. Female teachers on the other hand demonstrated a lower percentage of 26.1%.

Discussion on teaching and learning processes is not confined to teaching and learning per se, but should ideally include measurement issues. In general, there are significant associations between school location ($\chi^2 = 21.68$; p<.005) with perceived science teachers' needs with reference to diagnosing and evaluating students. As shown in Table 6, most teachers felt that they moderately need assistance in this aspect. Detailed analysis of the association between school location and perceived science teachers' needs shows that 47.6% of science teachers in the rural areas moderately need assistance in assessing their students. Nonetheless, 32.8% of the teachers in rural areas expressed a great need for skills in the said dimension.

The managing and delivering science instruction dimension reveals a significant association between teachers' perceived needs and school location ($\chi^2 = 19.781$; p< .005). Generally, most science teachers in the rural areas require assistance in terms of managing and delivering science instruction. This is evident where 34.1% of the science teachers from this geographical region expressed their great need in this dimension as opposed to only 27.8% of science teachers from urban areas. However, there is no association between gender and perceived science teachers' needs ($\chi^2$ = 3.730; p>.005). For both genders, most of them perceived a moderate need for assistance in this dimension. In contrast, 32.3% of female teachers compared to 27.5% of their male counterparts expressed a great need. When the perceived science teachers' need in this dimension is associated with their area of specialization, there is no significant association detected ($\chi^2$ = 14.8; p>.005). The science teachers, regardless of their specific area of specialization, felt that they moderately need assistance in managing and delivering Science lessons. Interestingly, it was also found that the highest percentage identified is in the 'greatly needed' scale which was expressed by 34.4% of non-Science option teachers; viz. the percentage of greatly needed as expressed by this cohort of science teachers. On the average, respondents majoring in physics, chemistry and mathematics, only moderately need assistance in this dimension.

There is no significant association identified in managing and delivering science instruction dimension and the independent variables, except for gender and the teachers' perceived needs. However, in the acquisition of generic pedagogical knowledge and skills dimension, associations exist in all the three teacher variables. It seems that most of the teachers felt the urgency to upgrade their generic pedagogical knowledge and skills. A comparison between male and female respondents shows that female teachers (40.2%) demonstrated a great need. Nevertheless, for both genders, the percentage of responses received on a 'moderate need' is similar (51.7%). Data on school location reveals that teachers in the rural areas (41.8%) require great assistance in this aspect as opposed to teachers in urban areas (35.4%). In the case of area of specialization variable, 47.0% of non-Science option teachers greatly need the respective knowledge and skills. The science option teachers (physics, chemistry, biology and mathematics) on the other hand, only moderately need such generic pedagogical knowledge and skills.

In the planning science instruction dimension, association exists between all three independent variables. The strongest association is established between gender and science teachers' needs ($\chi^2$ = 21.643; p<.005). It was found that 41.9% of female teachers compared to 32.9% of male teachers, greatly need assistance with regard to planning science instruction. Interestingly, 46.5% of male teachers moderately need such assistance. Further analysis of the findings reveals that only 12.5% of female teachers felt that such competencies is not needed as opposed to male teachers who displayed a significantly higher percentage of 20.6%. It was also found that school location is significantly associated with the perceived needs expressed by science teachers ($\chi^2$ = 19.228; p<.005). Forty-two point eight percent (42.8%) of teachers in rural areas perceived that they greatly need and 46.0% of them moderately need such skills. Teachers in the urban areas expressed similar views with 45.7% of them moderately need such skills and 36.0% of them felt that such skills are crucially important. The teachers' area of specialization also seems to be associated with their perceived needs ($\chi^2$ = 20.83; p<.005). The highest percentage of a great need for planning science instruction competencies is demonstrated by non-science option teachers (45.2%), followed by teachers majoring in biology (41.9%), and those majoring in physics (38.9%).

In the integrating multimedia in science instruction dimension, a significant association exists between gender ($\chi^2$ = 9.366; p<.005) and school location ($\chi^2$ = 12.39; p<.005) with perceived science teachers' needs. For gender, both male and female teachers felt that they either greatly need or moderately need such skills. For both genders, only a low percentage felt that such skill is irrelevant and hence unimportant. For school location, mostly teachers from least advantaged areas expressed their concern for this skill. More than 50.0% of them felt that such skill is greatly needed. For urban teachers, the percentage of those who expressed a great need for such skills (47.8%) and the percentage of those who demonstrated a moderate need (44.9%) show little difference. However, no significant association is found between respondents' area of specialization and perceived needs of the science teachers. Therefore it could be inferred that science teachers, regardless of their options, have similar needs in terms of integrating ICT in their science instruction.

With the implementation of teaching science in English language, naturally teachers must be competent in imparting their lessons using the prescribed medium of instruction. As expected, when association is gauged between this dimension of science teachers' need and teacher variables, significant associations exist. More than 50.0% of the respondents indicated that they greatly needed assistance in all three dimensions of teacher variables: gender, school location, and area of specialization. Sixty-six percent (66.0%) of those teaching in rural schools indicate a great need for help in mastering the English language compared to those in urban schools (52.1%). At the same time, 61.6% of female teachers echoed similar cries compared to 53.5% of male teachers. Similarly, non-science option teachers (68.8%) also indicated a great need.

Table 7: Summary of Association between Teachers' Needs Dimensions and Demographic Variables

| **Dimension** | **Teachers' Variable** | | |
|---|---|---|---|
| | Gender | School Location | Area of Specialization |
| Administering science instruction facilities and equipment | 3.325 | 20.611** | 29.208** |
| Knowledge and skills in science subjects | 1.745** | 17.368 | 13.710 |
| Diagnosing and evaluating students for science instruction | 5.080 | 21.680** | 22.616** |
| Managing and delivering science instruction | 3.730 | 19.781** | 14.800 |
| Generic pedagogical knowledge and skills | 14.470** | 18.411** | 28.727** |
| Planning science instruction | 21.643** | 19.228** | 20.832** |
| Integration of multimedia technology in science teaching | 9.366** | 12.389** | 10.083 |
| Use of English language in science teaching and learning | 9.309** | 70.940** | 26.890** |

** Association is significant at ? .05

Based on data interpreted from Table 6, it could be synthesized that school location seems to be a detrimental factor in determining Malaysian secondary school science teachers' needs. As shown in Table 7, significant associations exist between school location and science teachers' needs in all dimensions except one: knowledge and skills in Science subjects. Most rural teachers demonstrated a great need for all the other seven dimensions highlighted. Nonetheless, the existence of significant association between science teachers' needs and gender is similar as in respondents' area of specialization.

Analysis of data also reveals that teachers' gender seems to be associated with their perception towards upgrading their knowledge and skills in science subjects, as well as generic pedagogical knowledge and skills required for effective science instruction. Such needs affect the respondents' perception of the importance of planning effective science instruction. As a consequence, they also need assistance in command of the English language so as to be able to deliver effectively. The integration of ICT in science instruction also appears to be a skill which needs to be developed greatly. Analysis across gender reveals that female teachers require more attention in equipping themselves with the skills in all the dimensions identified. Meanwhile teachers' area of specialization seems to be associated with teachers' perceptions of the importance of specific skills pertaining to science teaching and learning such as administering science instructional facilities and equipment, diagnosing and evaluating students, generic pedagogical knowledge and skills, planning science instruction and the use of English language in science teaching. It was also detected that for almost all dimensions, non-option science teachers appear to be those who require more attention in all the dimensions of science teachers' needs as measured in this study. When all the analysis is integrated together, it could be synthesized that specifically, the cohort of science teachers who require more training in all dimensions of science teachers' needs are non-science option female teachers in rural areas.

## DISCUSSION

It should be reiterated that in this study, a particular need is considered a priority science teachers' need when the percentage of greatly needed scale selection is more than 40 percent. Based on Table 5, it could be inferred that the topmost priority needs which entail are the use of English language as the medium of instruction and the integration of multimedia technology in science teaching and learning. Additionally, science teachers also need support in planning and designing their science instruction as well as equipping themselves with generic pedagogical knowledge and skills. On the other hand, teachers only require a moderate need of assistance in managing their science instruction and in measuring students' performance. It is also apparent from the findings that science teachers do not have problems with updating their content knowledge as well as technical skills in administering science instructional facilities and equipment. When such classification of science teachers' need is compared with previous local studies conducted by Kamariah (1984), Kamariah, Rubba, Tomera and Zurub (1988), and Mohamad (2002), it could be argued that science teachers' needs evolve with time as well as social and political scenarios that navigate the policy implementation of the country. Twenty years ago, during the wake of the New Integrated Malaysian Science Curriculum implementation, the prominent needs of the Malaysian science teachers then, mainly involved delivering and managing science instruction, and administering science instructional facilities and equipment, which as a whole contributed towards improving one's self competence as a science teacher in meeting new challenges in science teaching.

Currently, in Malaysia, we are witnessing the use of English language as the medium of instruction for teaching Science. In addition a great emphasis is put on integrating ICT in science lessons. Undoubtedly, the implementation of such new approaches, generate anxiety on the part of teachers, especially in imparting scientific knowledge using English language as the medium of instruction. It must be pointed out that education in Malaysia, can be argued to be justifiably intertwined with political interest as it is increasingly the case in the west, particularly in the United Kingdom. Thus, in furnishing science teachers with the necessary knowledge and skills required as a result of new policy implementation, many short courses have been inaugurated. Nevertheless, most of the programmes were implemented in an *ad hoc* or "bolt on" fashion, and hence failed to equip science teachers with the necessary knowledge and skills. The need for integrating ICT in science instruction as publicized in the media (written as well as electronic), has successfully instilled in the teachers cognizance of the importance of ICT in every niche of human activities. In this context, the teachers' main concern is how they could upgrade their knowledge of integrating ICT towards a more interesting yet meaningful science lesson. Literature evinces that the teachers' concern on how to fully utilize ICT facilities effectively in science lessons, is also a major problem in the United States and United Kingdom (Banilower, 2000; Dillion, Osborne, Fairbrothre and Kurina, 2000; Smith, 2000). Although many support systems were granted by the government, such as providing every science teacher with a laptop computer and an LCD, a wide dissemination of stand alone science teaching software, and organizing short courses on integrating ICT in their lessons, nonetheless, many science teachers still felt incompetent and hence need much support in this aspect.

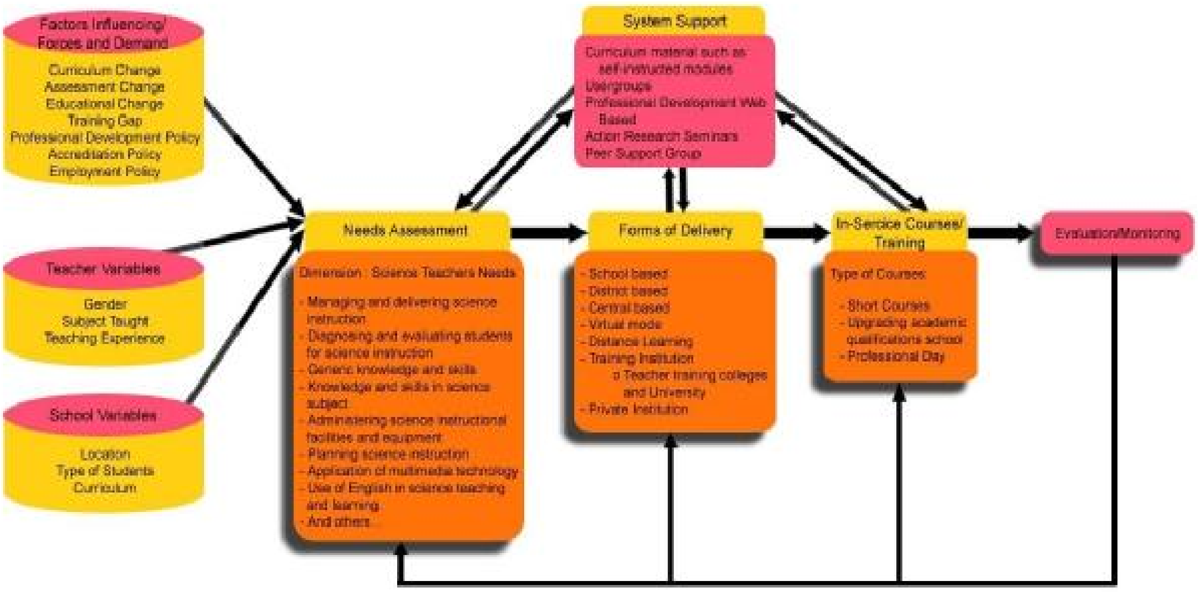
The third main concern of the Malaysian secondary school science teachers is proper planning of science instruction. The main concern about planning is entrenched in the teachers' inclination to motivate their students to learn science. Such situation is triggered due to the current practice of teaching science in English, beginning in Year One of primary education. The existence of a wide spectrum of children's abilities thus creates a need for teachers to make their lessons interesting and attractive especially for children with low ability levels. The science teachers' awareness of the importance of varying their pedagogical approaches and how to constructively maneuver their lessons with the support of ICT and other teaching aids also contribute to such pattern of feedback. Another plausible reason for the concern in planning instruction is associated with the government policy of achieving a 60 to 40 ratio of science to art students. This is a new phenomenon which science teachers are currently facing, especially in dealing with students who do not really want to take up science subjects but were forced to do so. The students' lack of interest and the lack of motivation mould their attitudes towards the science subject, which ultimately shape their negative behaviors during science lessons.

Several interesting issues emerged when association is gauged between gender, school location, areas of specialization and science teachers' needs. As earlier mentioned, the cohort of science teachers who require more training in all dimensions of science teachers' needs as measured in this study are non-science option female teachers teaching in rural schools. Arguably, schools in urban areas offer a more conducive environment for the teaching of science particularly in the usage of English language as well as the integration of ICT in teaching and learning Science. This is not surprising as many support systems and infrastructure are made available in urban areas. In addition, these schools are located near Teacher Activity Centres as well as the District Education Office, which provide avenues for exchange of ideas as well as keeping them well informed of the latest policy implementation in science teaching and learning. The needs of non-science option teachers on the other hand, revolve around updating knowledge and skills for effective science instruction. Consequently, the issue of using English language as the medium of instruction also takes priority in their self improvement agenda.

Based on the findings, several suggestions can be forwarded to meet the current needs of science teachers. Undoubtedly, in-service courses which offer continuous development of science teachers appear to be the best platform in upgrading science teachers' needs as identified in this study (Craft, 1996; Parkinson, 2004). Figure 2 displays in graphical manner a proposed framework for the Malaysian secondary school science teachers' in-service training (INSET) model. As shown in Figure 2, the INSET established can take many forms; school-based, central-based, institutionalized training either via public or private institutions, conducted by means of a virtual or a distance learning mode. Compatriot institutions such as the District Education Department and Teacher Education Division can offer support in ensuring effective implementation of the programmes. Figure 2 also highlights three main modus operandi which can be undertaken: short courses, professional day, or long term courses such as pursuing a masters or doctoral degree programme.

It is recommended that multimedia technology is used as the main teaching tool, in addition to face to face interaction. Loucks-Horsley, et al. (1998) argues that the key feature of technology is not only as a tool for presenting ample opportunities for diverse learning experiences, but it can become the best support for professional learning. To ensure that the programmes implemented meet its objectives, continuous monitoring and evaluation by governing bodies should be systematically planned and followed. Appleton and Kindt (1999) suggest that the most helpful support is through mentoring programmes. The roles of mentors, however, should not merely be confined to tackling problems about science content and generating innovative ideas about pedagogical issues, but more importantly, mentors should provide continuous support especially for the teachers involved (Anderson and Mitchener, 1994). Besides coaching and mentoring, there are many other strategies such as provision of curriculum materials, self-instructed modules, action research network, peer and study group support, and establishing a partnership with scientists (see also Brown and Smith, 1977; Loucks-Housley, et.al. 1998).

Figure 2: A Framework of In-service Training Model for Malaysian Science Teachers




## CONCLUSION

Being descriptive in nature, this study provides meaningful empirical evidences of effective in-service programmes in the process of upgrading science teachers' professionalism in Malaysia. Data garnered in this study provide vital information especially for those involved in designing and implementing INSET, so that all the programmes implemented will be tailored specifically to the immediate needs of the science teachers. From this study, the science teachers' needs identified revolve around upgrading oneself in meeting the current challenges of teaching and learning Science, which as indicated, is determined mostly by socio-political scenario of the country. Another important feature which emerged from this study is the teachers' personal concern and awareness of the importance of self improvement, especially in making their lessons meaningful and attractive, which would subsequently lead to improvement in the students' achievement. In conclusion, it is thus apt to mention that Malaysian secondary school science teachers, as empirically indicated in this study, indulge in keeping the best interest of their students and they maintain that lifelong learning is at the heart of teacher development.

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# SECONDARY STUDENT PERCEPTIONS OF FACTORS EFFECTING FAILURE IN SCIENCE IN PORTUGAL

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**ABSTRACT.** High rates of failure in secondary level science classes are a problem worldwide. Effective teaching and efficient management of schools requires information as to the causes of failure. One approach to acquiring this information is to improve our understanding of what the students themselves perceive as the causes and antecedents of school failure. In this article, we analyze the perceptions of the factors of academic failure among grade-ten, science-tracked students. Students from eight schools in southern Portugal (N=346) participated in the study. The major factors of failure in 10th grade science courses, according to students, are quality of teaching and previous student preparation. One third of the students did not think that secondary science education prepared them for life in a scientific-technological society. A culture of high expectancy on the part of teachers, parents and administrators may be key to influencing rates of success.

**KEYWORDS.** Failure, Management Practices, Secondary Science, Student Perceptions, Teaching.

## INTRODUCTION

Failure rates are high and deficient learning in science is commonplace at both the middle and the secondary school levels in Portugal (Fonseca, 2003; GAVE, 2000, 2001; OECD, 2004). Among the 40 countries involved in the 2000 and 2003 PISA studies, Portuguese students rank among the lowest in science performance (GAVE, 2001; OECD, 2004). These shortcomings in science achievement are evident in spite of successive reforms in science education-a frequent phenomenon consistent with what has been observed in other international studies (Davies, 2003; Kozoll & Osborne, 2004; National Center for Educational Statistics, 2003).

The poor results in science achievement reflect a general panorama of poor academic performance. Portugal has the highest school abandonment rate among 26 countries studied by the European Union (European Commission, 2000). In 2001, among those 18 to 24 years of age, 45% had abandoned school without completing the 12th grade. In the same age range, one fourth had abandoned school without completing the 9th grade (Ministério da Educação, 2002). By 2003, about one third of the students in the 6th through 9th grades had experienced some form



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of school failure. The percentage is even higher in the secondary grades. As a result, only 20% of the active population in Portugal had a high school diploma in 2005 ("Insucesso escolar," 2004; Dâmaso, 2005). In southern Portugal, science performance of 15-year-olds is among the lowest in the country (GAVE, 2001) and the failure rate for all secondary students in the region is most prominent at the tenth grade level (Carreira & André, 2000).

The Portuguese educational system includes area-specific tracking after the ninth grade. Upon entering tenth grade, students must choose which major subject area they will pursue—for instance sciences, humanities, social sciences, or technology. Students who select the science track are required to enroll in eight disciplines, five of which are in the sciences: Physics/Chemistry, Biology/Geology, Mathematics, and two disciplines in Laboratory Techniques (in Physics/Chemistry and Biology/Geology). However, even among the science-tracked students in the 10th, 11th and 12th grades, failure rates continue to be high, particularly in Physics/Chemistry and Mathematics.

Because of the high levels of school abandonment, the students who enter tenth grade are already a select group. Within this select group, the students who choose the science track represent an elite in terms of academic performance and motivation. Even so, many do not enjoy success in secondary education, particularly in the 10th grade. This leads to a series of important questions for science educators and other educational leaders and policy makers: We ask first, why should this be the case? What are the factors students identify for the high failure rate? Are there relations between the factors identified by the students and other variables? And what implications for teaching, curriculum, and school organization can we infer?

The literature provides some possible answers to these questions. A number of psychosocial, organizational, teacher and student variables seem important in influencing success or failure: Parenting practices and parental involvement with the school explain much of the variation in school performance according to Desimone (1999). Student perceptions of meaningfulness, challenge, choice and appeal of class activities have been associated with motivation and learning (Raineri & Gerber, 2004; Gentry & Springer, 2002). And the science teacher has been found to be the most important factor in improving student achievement in schools (Ballone-Duran, Czerniak & Haney, 2005).

Anthony (2000) reported a study of perceptions of factors influencing success in mathematics and emphasized the role of motivation. Students and lecturers agreed on the importance of motivation, however their opinions diverged in relation to factors such as importance of active learning, help-seeking and student effort. Lecturers emphasized controllable student characteristics, while students were more prone to blame failure on course design and teaching quality.

Easton (2002) interviewed students from an alternative residential high school in the USA in order to determine perceptions of learning needs. Students identified the need for selfesteem, personal accountability, and personalized learning. They talked about the need for teachers who care and also about active learning. They further mentioned the need to feel emotionally safe, the need for high expectancy on the part of the school and the need for self-directed learning/learning by choice.

In analyzing student-generated solutions to enhance the academic success of African-American youth, Tucker, Herman, Pedersen, Vogel and Reinke (2000) found that both academic preparation of students and positive peer influences would enhance academic success and that praise and encouragement by teachers and parents is needed to facilitate student school work and achievement. They further affirm that student achievement seems to be associated with occupational aspirations. Similarly, Wong, Wiest and Cusick (2002) state that student perceptions of teacher behaviors that promote the development of student autonomy, parent involvement, competence and self-worth were predictors of motivation and achievement. Factors such as age and gender may also be related to attitudes concerning factors of achievement. So concluded Whitelaw, Milosevic and Daniels (2000) while cautioning that the relations are complex and require further study.

In Portugal, studies conducted in schools that had confronted and reduced failure rates highlight the importance of variables such as (a) school organization, including a collaborative environment with parental involvement; (b) relevant curriculum and classroom activities; and (c) the quality of science teaching, including teacher support and expectancies (Fonseca, 2003).

While many strategies may be put forward to reduce high failure rates, at a primary level it is important for science educators and other educational leaders and policy makers to recognize what the students themselves perceive as the causes and antecedents of school failure in order to better comprehend students' academic needs. A better understanding of student perceptions of the factors that lead to failure can provide one way of informing the science education community about what should be done if we want to increase academic success and reduce the risk of school abandonment. The purpose of this study, therefore, was to analyze student perceptions of the factors involved in academic failure in science disciplines (including Physics/Chemistry, Biology/Geology and Mathematics). The tenth grade was chosen due to its high incidence of failure.

## METHOD

### *Participants*

The study included 346 tenth-grade, science-tracked students, from eight state sponsored schools in the Algarve region of southern Portugal. In each school, two class groups were selected to participate.

*Materials*

Based on the relevant literature, a data collection instrument was developed that included variables related to achievement, teacher expectancies, support mechanisms and parent involvement. The questionnaire also asked about student views on the importance of school (for instance, if the students felt that secondary school prepared them for life); if they felt it was important to finish grade 12 and why; and if science disciplines are useful for their future. Three summative scales included in the questionnaire (parent involvement--six items; importance of the sciences for the future--seven items; and student aspirations--six items) displayed moderate reliability ($\alpha$ = .734, .775 and .742, respectively).

Six variables (school organization, school physical conditions, quality of teaching, previous student preparation, outside interests and the difficulty of the subject matter) were proposed to students as possible failure factors in the 10th grade. Each was presented as a possible cause of (a) failure in general, (b) failure in mathematics and (c) failure in science.

These individual items were combined in summative scales measuring the tendency to attribute failure to the six specific causes. Each scale was composed of three items measuring the combined attributional tendency for failure in science, mathematics and academic failure in general. We observed good reliabilities for these scales (school organization, $\alpha$ = .90; previous preparation, $\alpha$ =. 80; physical conditions of the school, $\alpha$ = .83; teaching quality, $\alpha$ = .80; outside interests, $\alpha$ = .91; difficulty of the material, $\alpha$ = .80).

*Procedure*

Student participants completed the responded to the data collection instrument individually,Data were collected in group settings at the end of the school year. Prior to the field phase of the study, the data collection instrument and procedures were piloted in two other secondary schools in the same region.

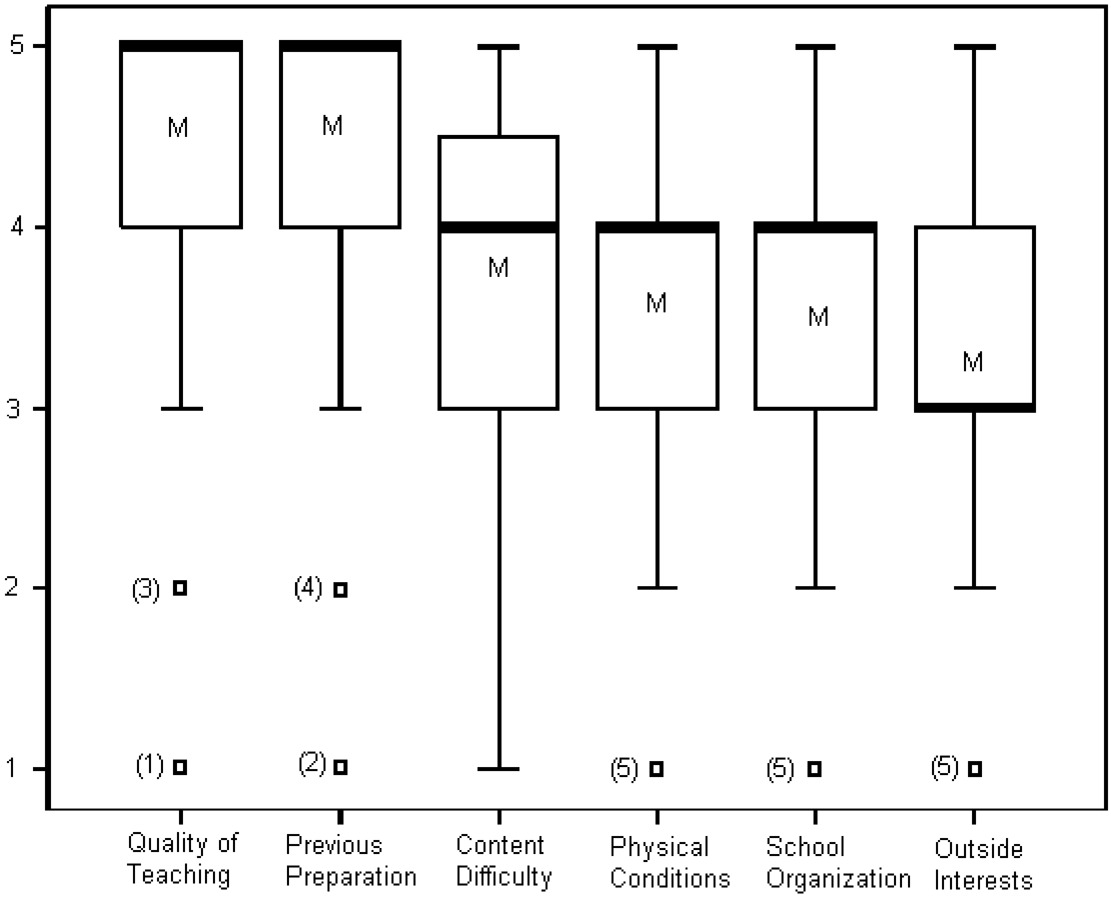
## RESULTS

*Sample characteristics*

The study included 214 girls and 132 boys with a median age of 16. Of the students, 13% reported nationalities other than Portuguese (in the Algarve state school system there are students from many different countries, particularly Eastern Europe and Africa). Of all the students, 11.3% had previously failed the tenth grade at least once. Mean tenth-grade science and mathematics classifications for the sample were typical for the Algarve. On a scale that varies from 0 to 20, with 10 representing a passing grade, mean scores were 12.5 in Physics and Chemistry (PC), 11.5 in Mathematics (Math), and 13.4 in Biology and Geology (BG). About

25% of students reported failing grades in PC; about 34% in Math and 9% in BG. The great majority of students lived with at least one parent (331, of whom 255 lived with both parents). Almost all of the students (98%) affirmed that it was important to finish secondary school. When asked why it was important to finish high school, 90% of these indicated, “in order to continue studies” and 92% specified, “to get a good job”.

Figure 1: Boxplots for six student-rated failure factors




Note: Each Boxplot shows the Median (heavy horizontal line), Interquartile range, Mean (M), theoretical minimum and maximum scores as well as the number of outliers.

*Failure factors*

Students were asked to rate the importance, as causes of academic failure in science, of six factors identified in the literature. Each factor was rated on a five-point scale, anchored at the extremes as Very Important (5) and Not at all Important (1). Figure 1 shows expanded box-plots of the central tendency and dispersion of the responses. The Quality of Science Teaching (M= 4.55; *sd* = .68) and Previous Student Preparation (*M*= 4.53; *sd* = .71) were rated the most important causes of failure followed by Difficulty of Academic Content (*M*= 3.83; *sd* = .97), Physical Conditions of the School (*M*= 3.62; *sd* = .97), School Organization (*M*= 3.56; *sd* = .95), and conflicting Outside Interests (*M*= 3.31; *sd* = 1.07).

Table 1: Pearson Correlations among Principal Variables

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1. Parent Involvement | *r* | -- | | | | | |
| | *N* | 346 | | | | | |
| 2. Teacher expectancy | *r* | **.204**** | -- | | | | |
| | *N* | 321 | 321 | | | | |
| 3. Perceived Support | *r* | **.165**** | .103 | -- | | | |
| | *N* | 342 | 319 | 342 | | | |
| 4. Science Achievement | *r* | **.150*** | **.239**** | .023 | -- | | |
| | *N* | 287 | 267 | 285 | 287 | | |
| 5. Attribution to Difficulty | *r* | -.029 | -.053 | -.007 | **-.265**** | -- | |
| | *N* | 340 | 315 | 336 | 282 | 340 | |
| 6. Science Related Vocation | *r* | **.195**** | .114 | .093 | **.170**** | -.055 | -- |
| | *N* | 308 | 287 | 306 | 262 | 303 | 308 |

* *p* (2-tailed) < .05.
** *p* (2-tailed) < .01.

*Intercorrelations of the Principal Variables*

Table 1 presents Pearson correlations among the principal variables in the study.

Parent involvement and teacher expectancies. Small but significant correlations support the following conclusions: Students reporting higher parental involvement also may tend to believe (a) that their teachers expect them to work hard and learn a great deal (r= .204; $p$<.01); and (b) that support mechanisms exist in school ($r$= .165; $p$<.01). Higher parental involvement and teacher expectancies were also associated with higher grades in science ($r$= .150; $p$<.05 and $r$=.239; $p$<.01, respectively).

Science achievement. In addition to the associations with parent involvement and teacher expectancies, science grades were negatively correlated with the tendency to attribute failure to the difficultly of the academic material ($r$ = -.265; $p$<.01). A small but significant association was observed between grades and a vocational goal that was science related (r = .170; $p$<.01). Science achievement was also positively correlated with the perceived future importance of science disciplines to the students' lives (physics-chemistry, $r$ = .327; biology-geology, $r$ = .188; mathematics, $r$ = .155; all $p$<.01).

The participants in the study also indicated reasons for completing secondary education. Science achievement was positively associated with the choice "because I like to learn" ($r$ = .216; $p$<.01) and negatively associated with the choices "to please parents" ($r$ = -.251; $p$<.01) and "so I don't have to get a job" ($r$ = -.174; $p$<.01).

Table 2 shows the results of a multiple regression analysis of three simultaneously entered factors predicting science achievement. Perception of Teacher Expectancy, Failure Attributions to Difficulty of Material and Science Related Vocation were included as predictors, first because of their observed correlations with science achievement, and second since these factors are uncorrelated among themselves. Simultaneous entry of the factors was employed rather than stepwise entry, first since there are no theoretical constraints on the exploratory model, and second in order to avoid the problem of uncontrolled error rates (Onwuegbuzie & Daniel, 2003). The case/independent variable ratio in the analysis exceeded the requirements suggested by Green (1991). Analysis of residual plots verified the linearity of the relation. This three-factor model explained about 16% of the variance in science achievement.

Table 2: Summary of Simultaneous Regression for Variables Predicting Science Achievement

| Variable | *B* | *SEB* | $\beta$ | *t* | *p*< |
|---|---|---|---|---|---|
| Perceived Teacher Expectancy | 1.52 | .432 | .213 | 5.53 | .010 |
| Difficulty Attribution | -.349 | .076 | -.273 | -4.57 | .001 |
| Science Related Vocation | 1.15 | .488 | .142 | 2.35 | .030 |

Note. $R^2 = .16$

*Analysis by gender*

There were no differences in science achievement on the basis of gender. As verified in a series of Mann-Whitney tests, the girls in the study tended to attribute more importance than the boys to the failure factor Quality of Teaching in tenth grade in general, and also specifically in Mathematics and Physics/Chemistry (all tests $p<.05$). Girls also rated Previous Preparation for the tenth grade in general, and specifically for failure in Physics/Chemistry, as more important as a failure factor than did the boys in the study (both tests $p<.01$).

Additional analyses of contingency tables revealed other small but significant relations. We report here measures of effect size using coefficient $\phi$. Girls were more likely than boys to choose the option “to pursue further studies” as a reason to finish grade 12 ($\phi=.13$; $p=.014$). The option “because I like to learn” was more frequently indicated by girls than by boys as a reason to finish grade 12 ($\phi=.13$; $p=.016$). Girls had a tendency to affirm, more frequently than boys, the existence of support mechanisms (“Is there someone in school you can ask for help if you need it?”) ($\phi=.13$; $p=.014$).

*Secondary Science as Life Preparation*

When asked if secondary education prepares students to function effectively in today’s scientific-technological society, fully one third of the participants (35.1%) said “no”. Students who thought that secondary science was good preparation also tended to believe that academic support mechanisms exist in the school ($\phi$=.185; $p$=.001). No relation was observed between the perceived preparation that secondary science provides for life and "parent involvement", nor with achievement as measured by science grades.

## DISCUSSION

Effective science education implies the creation of environments for maximizing learning success, which in turn requires information as to the causes of failure. The findings and conclusion of this study provide some useful insights for science educators and other educational leaders regarding the teaching and learning of secondary level science.

The students in this study perceive the lack of quality teaching and a lack of previous student preparation as the major failure factors in the tenth grade. About one-third of the students (regardless of their level of academic success) do not believe that secondary school prepares them for our scientific-technological society. The findings in this study replicate results of previous studies that show an association between achievement and student perceptions of teacher expectancies, parent involvement, quality of science teaching, a supportive learning environment, and previous preparation. It extends those findings to science learning in southwest Europe.

Some results of this study can be interpreted in terms of motivation and attribution theory: As Covington (2000) found, although the academic and social goals that students bring to class are important as a factor for achievement, another factor is equally important-- the motivating properties of these goals. An individual student can have goals, can express those goals and even justify the goals without constructively acting upon them. This helps explain the case of those students who want to achieve good grades (the goal) but do not really work for them (lack of motivating property of the goal). The emotional and motivational component of goals interacts with the cognitive components to influence learning and the will to continue learning. This may explain in part why failure is so frequent among science-tracked students in Portugal, a group that should be an academic elite.

The data reveal that student affects and emotions provide motivational impulse to the goal of achievement. For instance, the importance attributed to individual science disciplines for a student's future, and enjoying learning as a reason for wanting to finish high school were both associated with greater achievement. On the other hand, perceiving subject matter as difficult, choosing "To please parents" and "To not have to get a job" as reasons to finish high school, were both associated with lower achievement, which can be inferred as lack of motivation in spite of the existence of the academic goal (to finish high school).

Our data collection instrument was based on a review of relevant literature. It is interesting to note, however, that all the failure factors so identified could be considered, within the scope of attribution theory (Weiner, 1980, 1986), as external, stable and uncontrollable. For instance, there is little basis for a student to believe that her/his own actions might influence school organization, physical conditions, the quality of teaching, difficulty of material or previous preparation. If these are indeed the predominant attributions for failure, as the literature suggests, students have no cognitive basis for altering their own behavior in an attempt to improve achievement outcomes. By encouraging attributions to internal, unstable and controllable factors, such as effort, teachers and parents can sow the cognitive seeds for behavioral change leading to greater academic success.

The associations encountered in this study are suggestive, but are not strong individually. They paint a picture of a multifaceted system that reflects the complexity of the problem of academic success or failure in secondary schools. These results are in general conformity with previous studies (Buxton, 2005, 2003; Yore, Anderson, & Shymansky, 2005): There is no single factor identified through which educational professionals can expect to effect change. To the contrary, a constellation of factors must be addressed in any program designed to create environments for maximizing learning success.

Despite the general agreement of our data with previous studies, our results differ from the position of Whitelaw et al. (2000) in that no achievement differences were found between the young men and women in the study. A number of attitudinal differences were observed however, with the girls tending, in general, to display a more positive outlook than the boys in the study. We also differ from authors (e. g. Desimone, 1999) who affirm that a large portion of the variance in science achievement can be explained by a linear relation with parental involvement.

Our data suggest that, in the Portuguese context, and with science-tracked secondary students, the association between parental involvement and achievement, though real, is small: Perhaps 3% of the variance in achievement can be so explained. Due to its correlation with Teacher Expectancy, Parental Involvement was not included in the three-factor regression model presented. Once Teacher Expectancy is included, Parental Involvement fails to enhance the predictive value of the model. These discrepancies in our results may have their origin in cultural differences of the populations studied. However, a more parsimonious explanation may be based on a statistical artifact. Only a reduced number of students experience the success necessary to complete the ninth grade. Fewer still are sufficiently motivated to attempt the challenging science track in secondary school. Therefore, the group studied may be considered a fairly homogeneous elite. The small correlation observed between parent involvement and achievement may simply be due to reduced variability in parental involvement. That is, in this restricted group, the parents may all be substantially involved in their children's learning, attenuating correlations observed between this variable and others. Further research in Portugal, with more heterogeneous student groups, will help resolve the question.

The results of this study, as well as previous research, indicate some of the elements to be considered in attempts to understand and exploit, pedagogically, student perceptions of failure: (a) teacher expectancies, (b) a supportive learning environment, (c) parent involvement, (d) previous academic preparation, and (e) quality of science teaching.

Science educators and school leaders need to implement measures that encourage the development of teacher expectancies for high academic performance. The ultimate goal should be the development of a culture of high expectancies within a supportive environment. While it may seem contradictory, this implies both the availability of generous support mechanisms and, at the same time, a low tolerance for failure. Too often, the existence of support mechanisms, especially in the presence of students deemed "at risk", is tied to a *laissez faire* attitude of the passive acceptance of failure. Science education leaders must guard against such self-defeating attitudes and provide institutional support for teachers' high expectancies. Teachers must feel they are supported in holding all students to high academic standards and in presuming that students possess ample abilities. Fonseca and Conboy (1999) report a case study of an intervention with introductory physics students fraught with negative attitudes and repeated failure. The experience showed that continuous engagement of the students within meaningful contexts and in a supportive environment (characterized by personal commitment on the part of the teacher, high teacher expectancies and clear objectives and policies), can improve student performance. The study offers insights and suggestions on strategies to improve students' knowledge, competence and expectancies.

Parental involvement is not a panacea for the problem of academic failure. Even so, leaders of the education community must also encourage parental involvement in the learning process and promote the perception among students that parents are involved. The involved parent is not necessarily the parent who attends school meetings. Involved parents know their child's strengths and weaknesses; inform themselves of the date of their child's next evaluation; are aware of what homework there is and when it is due. Once again, the general culture of high expectancies will encourage parents in this role.

Previous academic preparation may be well beyond the reach of the science educator and school leader. We cannot be expected to alter the past or influence what is carried out in, sometimes distant, schools. However, the findings in this study describe an association between achievement and the *perception* of previous preparation. This perception can be influenced in at least two ways: first, through the actual knowledge of how good or poor the previous preparation was, and second, through the social-cognitive evaluation of the previous preparation. We submit that the most probable source of the perception, on the part of students, of the quality of previous academic preparation is to be found in teachers who complain openly about their students' lack of previous preparation—a common practice and probably as old as the profession of teaching. The students may internalize these comments and employ them as convenient, ego-protecting excuses for failure. Science educators and school leaders, then, should encourage science teachers to refrain from such musings. Once again, the general environment of high expectancies will be strengthened by not providing the students with easy excuses.

Perhaps the most important factor, and one of the most difficult to influence directly, is the quality of teaching. Students readily recognize if their teachers are effective or ineffective. Educational leaders may not be privy to the same level of knowledge of the competence of their teaching staff. How can they know— how can they control— the quality of their teachers? The principal mechanisms for dealing with teaching quality are hiring practices and evaluations. Unfortunately, both processes may be subject to extraneous influences that weaken their efficacy. Teachers may be hired for the wrong reasons, and may be retained, or even promoted, for motives unrelated to teaching proficiency. Given the inherent weaknesses in systems of assessment of teacher effectiveness—a concept quite difficult to operationalize—the promotion of professional development activities is paramount for the improvement of teaching quality. Current science reform documents (National Research Council, 1996, 2002) emphasize the importance of quality of teaching and of quality of professional development, and talk about teacher development as a channel for influencing student learning and academic success

While not identified as a major factor associated with failure in this study, other studies have pointed to the physical conditions and organization of schools as facilitators or inhibitors of the construction of a culture of success. Reasonable lab conditions, good school organization, and even details such as classroom decoration can be an important element in improving student interest and achievement in science. For example, schools can portray positive images (through posters, news stories, video presentations, student projects and awards) that present science careers as attainable, and scientific knowledge as pertinent and contributing to a better life (Buxton, 2005; Hammond, 2001; Zacharia & Barton, 2004).

In this paper we looked at student perceptions of failure and associated them with a series of relevant variables. The collection of small associations encountered in this study is suggestive of a complex and multifaceted system that constitutes the problem of academic failure in secondary schools. The results are in general conformity with previous studies and point to the need for higher teacher expectancies in a supportive learning environment. While we must be attentive to the factors identified by students as causes of failure (quality of science teaching, previous student preparation), educators and administrators should also recognize the opportunity for influencing student behavior through strategies that promote effort.

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# FOSTERING CONCEPTUAL CHANGE BY COGNITIVE CONFLICT BASED INSTRUCTION ON STUDENTS' UNDERSTANDING OF HEAT AND TEMPERATURE CONCEPTS

**Mustafa Başer**

**ABSTRACT.** The purpose of this study was to investigate the effectiveness of cognitive conflict based physics instruction over traditionally designed physics instruction on preservice primary school teachers at grade 2. The subjects were 82 (27 boys, 55 girls) second grade pre-service teachers in two classes. One of the classes (42 students) was randomly assigned as experimental and the other class (40 students) assigned as control group. Both groups were taught by the same instructor. While the experimental group received cognitive conflict based physics instruction, control group were taught by traditionally designed physics instruction. The data were obtained through Thermal Concept Evaluation test (TCE). Prior to instruction, students in both groups were pre-tested by TCE in order to determine their initial understanding of heat and temperature at the beginning of instruction. The same tests were applied as posttest after the instruction. Independent samples t-test on pre-test scores showed that there was no statistical significant difference between experimental and control group at the beginning of the instruction in terms of understanding of heat and temperature concepts. ANCOVA results showed that mean scores on the post-TCE of students in experimental group were significantly higher than those of the control group. While interaction between gender difference and treatment made a significant contribution to the variation in achievement, gender difference did not.

**KEYWORDS.** Misconception, Conceptual Change, Cognitive Conflict, Heat, Temperature.

## INTRODUCTION

As a human being, students have natural tendency to understand the physical world. Students construct their own naive concepts as a result of their observation and investigation of the physical world (Driver, 1989; Osborne & Freyberg, 1985). When they confronted a problem in everyday live, they try to solve it by their naive conceptions (Petersson, 2002). Research education over the past 30 years showed that these naive conceptions, in this paper called alternative conceptions, are common to many students independent of their age and culture (Yeo & Zadnik, 2001). Students' alternative conceptions in physics are well documented in the literature (i.e., Ma-Naim, Bar, and Zinn 2002; Maloney et al., 2001; Athee 1993; Heller & Finley, 1992; Feher and Rice 1992).



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From a constructivist viewpoint of learning, knew knowledge is constructed upon the existing one. Therefore, one of the factors in learning is learners' pre-existing knowledge, usually alternative conceptions, about the topic. Since the alternative conceptions are usually not consistent or partially consistent with currently accepted scientific knowledge (Wiser & Amin, 2001; Solomon, 1992), they can distort new learning (Novak, 2002). It is reported by the physics education researches that traditional instruction is mostly ineffective in changing these alternative conceptions as they are resistant to change and persistent (Eryilmaz, 2002).

Since many concepts in physics are abstract and can not be directly observable, it is natural that students come to physics class with many alternative conceptions. Heat and temperature concepts are very abstract (Harrison, Grayson, & Treagust, 1999) and difficult subjects not only for students but also for scientists and adults (Lewiss and Linn, 2003). This paper describes one model and investigate it's effectiveness for changing students' alternative conceptions in heat and temperature concepts.

## ALTERNATIVE CONCEPTIONS IN HEAT AND TEMPERATURE

Concepts related to heat and temperature are directly related to physical environment of living organism. Hence, heat and temperature are not directly observable quantities, concepts developed by students originated from the interpretation of ideas gained from everyday experiences (Leura, Otto, & Zitzewit, 2005). In addition, culture and language are the effectual factors for developing concepts related to heat and temperature (Lubben, Nethisaulu, & Campell, 1999; Lewsis & Linn 1994). On the other hand, textbooks may contribute and/or strengthen students' alternative conceptions in heat and temperature (Leite, 1999). So, it is likely that students come into thermodynamics course with common alternative conceptions related to heat and temperature concepts.

Alternative conceptions in thermodynamics usually arise from substance-based conceptions (Harrison, Grayson, and Treagust, 1999; Ericson, 1979,). For example students thought that heat is a substance, something like air or stream which could be added or removed from an object, very similar to the caloric theory of heat held by scientist in 8th century (Brush, 1976). Most students, as well as adolescents, could not differentiate the terms "heat" and "temperature" and they use these terms interchangeably (Harrison, 1996; Jara-Guerro, 1993; Kesidou & Duit, 1993; Ericson & Tiberghien, 1985). Usually, this mutual substitution imitate not only to everyday conversation but to TV programs and technical reports. For example, it is common to hear that "the heat of the day rises and reaches a peak in the afternoon" while watching weather report on TV. Most students tend to reason that different sensations mean different temperatures. Students encountered difficulty in accepting that different objects are at the same temperature when left in same environment for a long time (Thomaz et al., 1995). The temperature of an object is seen as a characteristic of the material from which the object is made. Many students taught that heating a body always increases temperature of an object (Yeo & Zadnik, 2001). An extensive list of alternative conceptions related to thermodynamics was provided by Yeo & Zadnik (2001).

Students may answer questions in a test correctly in formal settings but these students usually fall back to their alternative conceptions while applying to everyday situations (Kolari & Savander-Ranne, 2000; White, 1992). Not only students but also scientists also have difficulties applying their scientific knowledge related to heat and temperature to everyday situations. For example, scientists gave different answers to a question of relative insulating properties of aluminum foil and wool.

## COGNITIVE CONFLICT AS A BASE FOR CONCEPTUAL CHANGE

Student alternative conceptions that are grounded in everyday experiences are resistant to change (Harrison, Grayson, and Treagust, 1999; Driver, 1989; Hameed, Haekling, & Garnet, 1993; Osborne & Freyberg, 1985). High school students have difficulties with energy concepts, the particle model, and the distinction between heat and temperature (Kesidou & Duit, 1993). Furthermore, some students complete thermodynamic courses with many of their alternative conceptions unchanged (Carlton, 2000; Thomaz et al., 1995). It can be concluded that the instruction they receive unaffected their alternative conceptions. Moreover, scientists also have difficulties with heat and temperature concepts (Lewis & Linn, 1994). Although they may make more accurate predictions than students, they have difficulty in explaining everyday phenomena (Lewis and Linn, 2003; Tarsitani & Vicentini, 1996).

Use of a conceptual change learning models is one way of closing the gap between children's science and scientists' science (e.g., Posner e al., 1982; Hewson, 1981). Most of the conceptual change models are grounded on Piaget's ideas and notions of constructivism (Gega, 1994; Hynd et al., 1994; Stofflett, 1994; Hewson & Hewson, 1983; Posner et al., 1982). These methods suggests creating dissatisfaction in student's mind with his alternative conception, in this paper called cognitive conflict, followed by strengthening the status of the preferred scientific conception.

On the other hand, peer/social interaction and group discussion are important factors leading conceptual change as social constructivism insists (e.g., Uzuntiryaki, 2003; Brophy, 1986; Vygotsky, 1978). According to conctsructivist learning approaches knowledge is socially constructed (Duit, 2002) and intrinsic motivation that can be generated via group discussion, play an important role on knowledge construction (Pintrich, Marx, & Boyle, 1993). The learning method used in this study considered the importance of both cognitive conflict and peer interaction.

Since 1990's, cognitive conflict based instructions have been extensively used in science education. Several studies concluded that that cognitive conflict has an important/positive effect on conceptual change (e.g., Lee et al., 2003; Kim, Choi, & Kwon, 2002; Stern, 2002; Kwon, 1997; Druyan, 1997; Niaz, 1995; Thorley & Treagust, 1989; Hashweh, 1986; Stavy & Berkovitz, 1980). Lee et al. (2003) & Kwon (1997) are insisting the need for cognitive conflict in order to conceptual change takes place. Kwon & Lee (1999) demonstrated that students who had higher level of conflict showed very high rate of conceptual change from unscientific to scientific conceptions, while the low level conflict group showed very little improvement. Ting and Chong (2003) concluded that cognitive conflict fosters conceptual change. Zohar and Aharon-Kravetsky (2005) found that students with high academic achievements benefited from the cognitive conflict teaching method. On the contrary, there are some researchers who dispute the effectiveness of cognitive conflict on conceptual change (Limon, 2001; Hewson, Beeth, & Thorley, 1998). Some researchers (Dekkers & Thijs, 1998; Elizabeth & Galloway, 1996; Dreyfus, Jungwirth & Eliovitch, 1990) argued that instruction based on cognitive conflict do not necessarily promote conceptual change. Students often refuse to accept ideas in direct conflict with their alternative concepts (Bergquist & Heikkinen, 1990).

## CHANGING STUDENTS ALTERNATIVE CONCEPTS IN HEAT AND TEMPERATURE

Some empirical studies conducted to change students alternative conceptions related to heat and temperature. These studies basically use constructivist and/or conceptual change teaching strategies to promote conceptual understanding. Most of them used cognitive/conceptual conflict as a key concept (e.g., Leura, Otto and Zewitz, 2005; Thomaz, 1995; Satvy and Berkovits, 1980)

Satvy and Berkovits (1980) used cognitive conflict in developing a teaching strategy which is aimed at advancing children's understanding of the concept of temperature. Their findings indicated that training by conflict did improve children's understanding of the concept of temperature both in individual and in classroom training situations. Thomaz et al. (1995) used a constructivist teaching approach to teach heat and temperature concepts at introductory level. His findings suggest that the model has potentialities for promoting a better understanding of the phenomena concerning heat and temperature. Harrison, Grayson, and Treagust (1999) used inquiry based teaching model coupled with concept substitution strategies to restructure student's alternative conceptions related to heat and temperature concepts. They found that students progressively accepted greater responsibilities for his learning related to heat and temperature concepts, was willing to take cognitive risks, and become more critical and rigorous in both written and verbal problem solving. Ma-Naim, Bar, & Zinn (2002) used conceptual change oriented approach to improve teachers' understanding of thermodynamics concepts.

Their results implied that teachers in the conceptual change approach teaching model has grater gains than their control group counterparts. Another inquiry based teaching method was used by Jabot and Kautz (2003) who showed the impacts of teaching and preparation of physics teacher in the case of thermodynamics. Their results suggested that guided inquiry group had greater learning gains. Clark and Jorde (2004) analyzed the effect of an integrated sensory model within thermal equilibrium visualizations. They found that students in the experimental tactile group significantly outperformed their control group counterparts on posttests and delayed posttests. Leura, Otto and Zewitz (2005) developed pedagogy, called misconception-guided instruction, based on conceptual change theory. Their results suggest that misconception-guided instruction promotes students understanding of heat and temperature concepts.

Consequently, it can be said that instruction aimed to change students' alternative conceptions in heat and temperature is somewhat effective. This paper discussed the effectiveness of instruction based on cognitive conflict to promote students conceptual understanding of heat and temperature concepts.

## METHOD

*Purpose*

The purpose of this study was to examine the effectiveness of cognitive conflict based instruction (CCI) over traditional physics instruction (TPI) on pre-service primary school teachers in terms of understanding heat and temperature concepts. The specific questions that were answered by this study were:

1. Is there a significant difference between effects of CCI and TPI on students' understanding of heat and temperature concepts?

2. What is the effect of interaction between treatment and gender difference on students' understanding of heat and temperature concepts?

3. Do previous understanding, treatments, gender, and the interaction between treatment and gender explain a significant portion of the variation in improving students' understanding of heat and temperature?

*Design and Subjects of the Study*

The subjects of the present study consisted of 82 (27 male, 55 female) second grade pre-service teachers in two classes of the same instructor. Students' native language and language of instruction was Turkish. Each of two instructional methods was randomly assigned to one class after individuals were already in each class. The data were obtained from 42 students in the experimental group and 40 students in the control group.

*Instruments*

Thermal Concepts Evaluation Test (TCE). To asses students' conceptual understanding of heat and temperature concepts Turkish version of Thermal Concept Evaluation (TCE) developed by Yeo and Zadnik (2001) was used. The TCE targeted students' alternative concepts that were derived from misconception research, and posed questions in the context of everyday situations. The TCE consisted of 28 multiple-choice questions. Since TCE does not include question related to thermal insulation, two questions were added to the original test (see Appendix A). There are five categories in TCE: (1) heat, (2) temperature, (3) heat transfer and temperature change, (4) thermal properties of materials, and (5) thermal insulation. Each question consisted of a situation followed by statements that included common alternative conceptions related to thermodynamics. The TCE asks students for the 'best' rather than 'right' answer.

The test was translated and adapted to Turkish by the author. The pilot study of this test was applied to 430 second year students at Department of Elementary Education of Izzet Baysal University, Turkey. The reliability of the test was found to be 0.71 which is an acceptable value for a cognitive test (Maloney et al., 2001).

In order to investigate the effect of treatment on students' understanding of heat and temperature concepts, TCE was applied as a pre and post test to all subjects of this study.

*Treatment*

The study took approximately 3 weeks. A total of 82 students were enrolled in two classes of the same instructor at Department of Elementary Education of Izzet Baysal University, Turkey. There were two modes of treatments in this study. The control group received Traditional Physics Instruction (TPI). The experimental group taught with Cognitive Conflict based Instruction (CCI).

Throughout this paper Traditional Physics Instruction refers to the following teaching strategy. The teacher followed lecture and discussion method to teach concepts in thermodynamics. The students studied physics textbook on their own before the class hour. The instructor structured the entire class as a unit, wrote notes on the black board about the definition of concepts, and solved enough number of quantitative problems. The main principle was that knowledge resides with the instructor and that it is instructor's responsibility to transfer knowledge to students. When the instructor finished his explanation, some concepts were discussed through instructor directed questions. The instructor solved some chapter end problems in their textbook on the black board. The classroom typically consisted of the instructor presenting the "right way" to solve problems. The instructor assigned some of the chapter end problems to students as homework. In the lab hours of TPI students did the experiments in their laboratory manual. Before coming to lab hours, students read the manual on their own and made some preliminary work, e.g., write some theoretical framework of the experiment, answered questions about the theoretical base of the experiment. In the laboratory, they followed the manual to make the experiment, take data, analyze data, come up to results and accordingly write the report of the experiment.

The experimental group received Cognitive Conflict based Instruction (CCI). Students were set to two or three peers. In this group, whenever possible, the instructor demonstrated an anomalous situation to activate students' alternative conceptions. If an experiment possible, students did the experiment and come up the result that contradict with their pervious conceptions and set students in cognitive conflict. The students were asked to discuss the result of the experiment and their previous ideas with their peers. This enabled them to interact with their peer to exchange their ideas and their observations from the experiment. If an experiment is not possible, the instructor asked students to discuss the situation with their peer. Then the instructor collected different ideas about the situation on the board and discussed them with the class. Finally, correct ideas were determined and explained in detail. If possible, the instructor used analogies to explain the phenomena.

An example for cognitive conflict situation was as follows: Students were asked what they think about the temperature of metal and vynlex (artificial leather) part of their seat. Most of the students were thought that metal part of the seat was colder than vynlex part. The students allowed to measure temperature of each part and took notes. The temperature of metal and vynlex part was measured with a multimeter that is capable of measuring temperature by touching through a thermocouple. This type of devices can be obtained easily from electronic shops. In Figure-1 a student measures metal and vynlex part of his seat.

Figure-1: Student measures metal and vynlex part of his seat. He see that both parts were at the same temperature ($19^oC$).

Students see that both parts were at 19 ºC. This set them in a cognitive conflict with their previous idea. Students discussed possible reasons of this result with their peer. Then, students were asked to do another experiment. In this experiment students were provided three bowls containing water at different temperatures: 0 ºC (yellow bowl), 20 ºC (green bowl), and 40 ºC (brown bowl). Students were asked to place one hand in the yellow bowl and other hand in the brown bowl. They were asked which one is "hot" and "cold". After a minute they were asked to place the cold hand in the green bowl and described the temperature as being hot. Next the hot hand is placed in the green bowl and this time the temperature is described as being cool. After the experiment students were asked questions about the result. For example,

*Although the water in the green bowl was the same, once you decided it as hot, and once you decided as cold. So do you think it is possible to determine temperature of objects with our sensation?*

The students discussed and decided that:

*It is not always possible to determine temperatures of objects by touching*

Then they were asked to think about their feelings about temperatures of metal and vynlex part of their seat. Students come up to the following conclusion

*Since we could not correctly determine temperatures of objects by touching, feeling metal part as being cool does not necessarily mean that it is actually colder than vynlex part.*

The key question asked by the students:

*Our sensation tells us something, we know that it may not be temperature. So what is the thing we sense?*

This question is not directly answered. Students will answer this question by themselves with doing another experiment. Students were given brass and silver rods about 25 cm long. They were asked to put the one end of the rods to the radiator and measure temperatures of other hand in 10 seconds interval. They were directed the questions:

*Which temperature increases rapidly?*

*Why silver first becomes hotter than brass?*

*Could the answer is the difference of rate of heat conducted through the rods?*

Students were left to think and discuss the answer of these questions with their peer. It was seen that, they taught:

*Since the rate of heat conducted through silver is more than brass, silver becomes first hot.*

Then they were asked to think about the rate of heat transfer when they touch to metal and vynlex part of their seat. They concluded that the rate of heat conducted through metal part is much more than vynlex part. They were asked

*So, do you think that we could sense the rate of heat transfer rather than the temperature?*

Students decided that what we sense is the rate of heat transfer rather than temperature of the object when we touch it. Students were asked more questions about sensation, heat transfer and temperature. For example, *When our clothes become wet in the rain, we become cool. So do you think the clothes become cold? Or the rate of heat transfer increased?*

This type of questions will make students that the newly constructed concept is fruitful (agree with the last stage of Postner's et al.(1982) conceptual change model). The same quantitative problems that were solved in control group also solved for students in experimental group.

## RESULTS

To investigate the effect of treatment difference on the dependent variable and control the students' previous learning with respect to heat and temperature concepts, all of the subjects were administered TCE at the beginning of instruction. Data related to pre- and post-test is presented in Table-1. It was found that there was no significant difference between CCI group and TPI group in terms of understanding related to heat and temperature concepts ($t=0.89$, $df=80$; $p>0.05$) before the treatment.

Table 1: Means (M) and Standard Deviations (SD) of pre- and post- test results of Thermal Concepts Evaluation test (TCE) of experimental (CCI) and control (TPI) group.

| | | **PRE TCE** | | **POST TCE** | |
|---|---|---|---|---|---|
| Group | N | M | SD | M | SD |
| Experimentanl (CCI) | 42 | 9.02 | 2.82 | 17.26 | 2.70 |
| Control (TPI) | 40 | 8.48 | 2.78 | 11.45 | 2.48 |

After treatment, the effects of two modes of instructions on students' understanding of heat and temperature concepts was determined with analyses of covariances (ANCOVA) by controlling the effect of pre TCE scores as a covariate. The summary of analysis was given in Table-2. The analysis showed that the post-test mean scores of CCI group and TPI group with respect to understanding heat and temperature concepts were significantly different. Mean scores of CCI group (17.26) were significantly higher than that of TCI group (11.45).

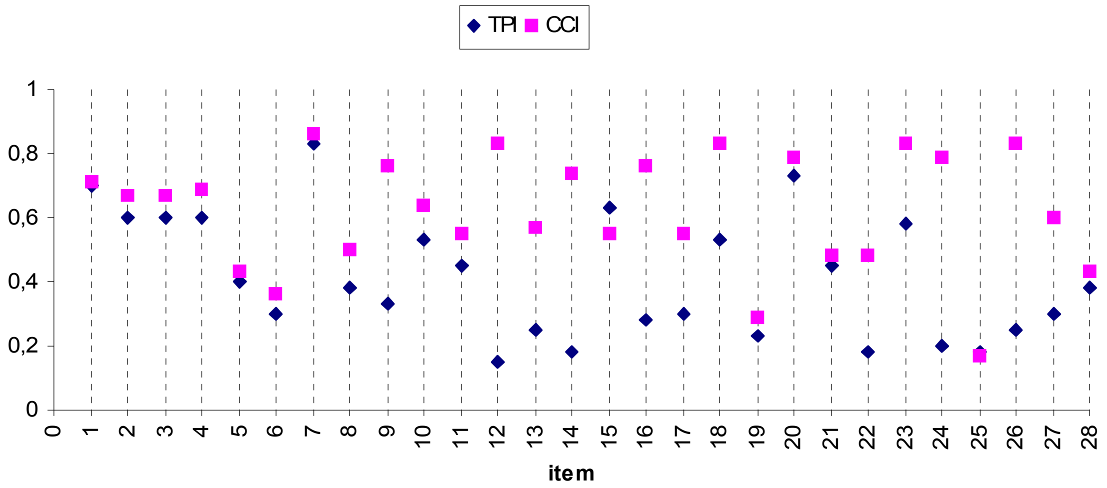
Table-2: ANCOVA Summary (Group vs. Achievement)

| **Source** | **Sum of squares** | **df** | **Mean square** | **F** | **p** |
|---|---|---|---|---|---|
| Covariate (Pre TCE) | 117.79 | 1 | 117.79 | 24.11 | 0.00* |
| Treatment | 472.62 | 1 | 472.62 | 96.72 | 0.00* |
| Gender | 6.77 | 1 | 6.77 | 1.39 | 0.243 |
| Treatment * Gender | 30.61 | 1 | 30.61 | 6.26 | 0.014* |
| Error | 376.27 | 77 | 4.89 | | |

* $p < 0.05$

Figure 2 displays the proportions of correct responses to questions in the post-test. As it can be seen from the figure, responses of the two groups were different on some items at the post TCE.

Figure 2 Proportions of Correct Responses in the TCE Post-test of TPI group and CCI group.




The two group responses approximately same on some items. Especially, proportions of correct responses for the first seven questions were about same and considerably high in five questions for the two groups. When these questions were investigated, they were numerical questions. For example, in the first question the temperature of ice cubes stored in a refrigerator's freezer compartment were asked. The highest correct proportion was question numbered 7. This question is a classical mix problem, e.g., the question asked temperature of the mixture when two cups of water at different temperature were mixed. These types of problems were solved in both groups while teaching heat and temperature unit. On the other hand, correct proportions of this question were more than 0.72 in the pre test.

Correct proportion for question 19 was very low for both groups. The question asked why pressure cooker cooks faster than a normal saucepan. It was not known that if a student did not know (a) pressurized water boils above 100 $^{o}$C or (b) soup at high temperature cooks faster. Another question (numbered 25) asked whether there was a limit for lowest temperature. Although it was mentioned that -273 $^{o}$C was the lowest minimum temperature during the lecture, neither students remind this nor students understand what is asked with this question. Since the question does not directly ask the lowest possible temperature, students may fail to answer correctly this question.

About half of the students in the control group did not know the scientific reason for wearing wool cloth on winter. More than 30% of the students in control group relay that wool generates heat. The same difficulty was previously stated by Duit ve Treagust (1998).

Figure 2 showed that there was striking differences between experimental and control groups in favour of the experimental group on several items. When investigated it was ween that, these items probed those alternative conceptions which attempted to change by cognitive conflict with experiments. For example, the concept of "objects that are at the same environment have the same temperature" was probed by 14, 16, and 24. More students in experimental group gave correct answer to these questions than students in control group. In question 12, the content of the bubbles in the boiling water were asked. 83% of the students in experimental group correctly answered this question, while only 15% of the students in the control group gave correct answer. The reason may be that, in experimental group, while doing an experiment where water was boiled, students were asked what the bubbles were. Likewise, Luera, Otto, & Zitzewitz (2005) found that most of the students failed to give correct answer for this question in conceptual change teaching medium.

Students did not recognize that objects must be wrapped by wool material for keeping as cold as possible in relatively warm environment. More than half of the students both in experimental and control group still thought that objects should be wrapped by aluminium foil to remain cool for a time. Lewis and Linn (2003) reported that scientist also had difficulties about the insulation properties of wool and aluminium foil.

As it can be seen from Table 2, the gender difference was not a significant effect on achievement. On the other hand, the interaction between treatment and gender difference significantly contributed to students' understanding of heat and temperature concepts.

Multiple regression analyses was used to analyse the contribution of previous understanding, treatments, gender difference of students, and the interaction between treatment and gender to the variation in improving students' understanding of heat and temperature. Table 3 represents the summary table for the regression of achievement related to heat and temperature concepts on gender, treatment, and interaction between gender and treatment.

Table 3. Summary Table of Regression of Achievement Related to Heat and Temperature Concepts on Pre-TCE, Gender, Treatment and Interaction between Gender and Treatment

| **Dependent Variable** | **Predictor Variables** | **B** | **Std. Error** | **t** | **p** |
|---|---|---|---|---|---|
| Achievement $R^2$=0.69 | Pre-TCE | 0.44 | 0.09 | 4.91 | 0.00* |
| | Treatment | 3.87 | 0.87 | 4.47 | 0.00* |
| | Gender | -0.69 | 0.79 | -0.89 | 0.38 |
| | Interaction | 2.63 | 1.05 | 2.5 | 0.01* |
| | Constant | 8.26 | 1.04 | 7.94 | 0.00 |

* $p < 0.05$

The F value for the full regression model was significant ($F$=43.37, $p < 0.00$). The four predictor variables (pre-TCE, treatment, gender, and interaction) together accounted for 69.3%

of the variance in achievement related to heat and temperature concepts. In addition, pre-TCE, treatment and interaction between treatment and gender each made a significant contribution to the variation in achievement. But, gender did not make a significant contribution to the variation. Similar result was found by Başer (1996).

## DISCUSSION AND IMPLICATIONS

This study explored the effect of instruction based on cognitive conflict to facilitate conceptual change in heat and temperature concepts. Physics education studies on thermodynamics showed that students had many alternative conceptions and difficulties related to heat and temperature concepts (e.g, Leura, Otto & Zewitz, 2005; Güneş & Gülçiçek, 2003; Yeo & Zadnik, 2001). Adults and scientist as well has alternative conceptions related to heat and temperature concepts (e.g., Leura, Otto and Zewitz, 2005; Lewis ve Linn, 2003; Cailot ve Xuan, 1993). Preliminary studies of this paper also showed that preservice teachers had similar alternative conceptions and difficulties.

Cognitive conflict based physics instruction improved students understanding of heat and temperature concepts more than traditional physics instruction. Although both type of instruction provided gain in achievement related to heat and temperature, the gain in experimental group was statistically higher than in control group. The big difference in normalized gain obtained by cognitive conflict based physics instruction (<g>exp=42.7%) relative to traditional physics instruction (<g>cont=14.7%) can be attributed to the following properties: (1) activation of students' alternative conceptions, (2) presentation a situation that could not be explained with existing concepts, (3) creation of cognitive conflict with this anomalous situation, (4) the need for other conception(s) to explain this anomalous situation, (5) active construction of students' own knowledge, (6) students interaction with each other to share their ideas about the anomalous situation and it's possible solution, and (7) the knew conception is helpful to solve similar problems that may be encountered in the future. These are in agreement with themes of both constructivism and conceptual change theory posed by Posner et al. (1982). As shown from this study, conceptual change based on cognitive conflict is still a powerful instruction to teach physics concept (Duit, 2002). Additionally, taking account students' difficulties in designing the lecture fosters conceptual change (Jones et al., 2000). The students were avoided to think what they liked, during the discussion sessions in experimental group (Harrison, Grayson, & Treagust, 1999). The difference between their alternative conceptions and scientist' were explained.

In one question students were asked why pressure cooker cooks faster than a normal saucepan. To answer this question, students should know (a) pressurized water boils above $100^{o}C$ and (b) soup at high temperature cooks faster. The second conception was not in the objectives of the course given to the both experimental and control group students. It was not known that why students gave incorrect answer for this question. Another explanation for the bad achievement in this question was given by Leura, Otto, & Zewitz (2005). They concluded that a student who never cooked with pressurized cooker may not be give correct answer for this question. Therefore, this question needs to be modified to fit one of the objectives for thermodynamics coursed.

Some of the alternative conceptions were still retained by students in experimental group. For example, although many students in experimental group understood that objects needed to be wrapped with wool to keep them as hot as hot possible, they failed to understand that objects needed to be wrapped with wool to keep them as cold as possible. This sowed that accomplishing conceptual change is not an easy task if the difficulty arises from the interpretation of daily life events (Campanario, 2002). When asked to students in an informal context, most of them said that everyone uses aluminium foil to keep hot cake, toast, hamburger, etc. In such cases, students relayed their daily life observations rather than what they learned within the course.

Although, gender did not account for a significant portion of the variation in achievement of heat and temperature concepts, the interaction between gender and treatment did. Similar findings were obtained by Başer (1996). This interaction could come from the gender difference in the group who utilized the cognitive conflict based instruction. When ANOVA statistics were run on normalized gain <g> female students were significantly gained more than male students in experimental group. Hake (1988) argues that the normalized gain is a meaningful measure of how well a course teaches physics to students. So it is more reliable to investigate the gain score to discuss what have learned from a physics course rather than post-test itself. It can be concluded that cognitive conflict based physics instruction was superior for females. In the directions of ECT it was stated that "think of a group of friends in a kitchen." These may be increased girls' attention to the thermodynamics course. This conclusion requires validation with a future research.

The final remark is that, as supposed by the result of this study, it is required to make radical changes in the design of physics instruction if we want to increase students' conceptual understanding (Meltzer, 2004).

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## APPENDIX A: QUESTIONS APPENDED TO TCE

1. Ali wants to keep the cola can taken from the refrigerator as cold as possible when going to picnic. Which one of the following material will you suggest to Ali for wrapping the cola can?

A) Aluminium foil

b) Plastic film

c) Cotton material

d) Wool material

2. Ayşe will bring the newly toasted hamburger to his sun in the school. Which of the following material will you suggest to wrap the hamburger, if she wants it be as hot as possible?

A) Aluminium foil

b) Plastic film

c) Cotton material

d) Wool material

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# SEARCH, CHOICE AND PERSISTENCE FOR HIGHER EDUCATION: A CASE STUDY IN TURKEY

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**Münir Oktay**

**ABSTRACT.** The purpose of this study was to investigate students' behaviors in search and choice during university placement, and also to examine how students' choice process affects on their persistence decisions. Participants in the study were 51 second year students studying in the Department of Chemistry Education of Kazim Karabekir Education Faculty, in Ataturk University, in Turkey. The survey instrument used in this study employed a scale to identify sources of information benefited, types of information obtained and factors which students took into consideration in choice process. In addition to this, a semi-structured interview was used to take profound information about this process. The study indicates that most of the students choose their program by an inadequate search process. Findings also indicate that the students show negative behaviors in their decision making process. Finally, a persistence phase is suggested for college or university choice process.

**KEYWORDS.** Higher Education, Chemistry Teacher, Choice Process, Persistence Decision, Turkey, University.

## INTRODUCTION

As in some other countries, such as China, Japan, Greece and Iran, entrance to higher education in Turkey is determined through a nationwide examination. Universities in Turkey recruit students according to their scores of an examination that is named Student Selection Examination (SSE). The SSE is held in all city centers of the country at the same time after students complete secondary education. This exam gives students the right to be placed in colleges, faculties and different departments of the Open University.

In recent years, there has been an increasing demand for higher education in Turkey. Student Selection and Placement Center (SSPC) reported that almost one-and-a-half-million students have taken SSE in every year of the last decade. However, some of these students had already been placed into a higher education institution. In 2004, 14,2% of the students taken SSE were already enrolled in a higher education program (SSPC 2004). Also, 11 (22%) of the second year students studying in the Department of Chemistry Education of Kazim Karabekir Education



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Faculty, in Ataturk University, in Turkey took SSE again in this year. This may be due to a change in students' decision that they might want to change the university, the program or both. In addition, 4 (8%) of the students who are in this class passed to another university by lateral transfer when they are at the end of the first year in 2003.

There are three different ways to change the institution for undergraduates in the Turkish higher education system. First, students may seek reentry to a higher education program by taking SSE again. This generally occurs when students are at the end of the second year, because, the SSE scores of the students are reduced if he or she takes SSE at the end of the first year. However this is not done at the end of the second year and the following years. Second, students may use the right of lateral transfer providing that student will pass to another university but to the same program if she/he gets adequate grades from the courses taken. Students who make lateral transfers may continue to study at the level they left. Third, students may use the right of vertical transfer which means: the student can enter any university and the same or a similar program by taking SSE again. The students who make vertical transfer may continue to study at the level they left.

Tatar (2003) states that choosing a higher education program is almost the same as choosing a job in Turkey. The most important factor which affects program selection is the job opportunities in the future. On the other hand, in 2003, 27,9% of the population unemployed consisted of graduates from secondary and tertiary level in Turkey (TIS 2004).

## THEORETICAL FRAMEWORK

Making college choice decision is a critical stage for all high school graduates who plan to attain higher education in future. However, the college students may make decisions which will affect persistence which is a critical stage in their education. They may make decisions to leave, reenroll or transfer to another higher education institution or continue their studies in their current college.

How does student's choice affect their persistence? Which college choice behaviors lead to leave from an institution of higher education? To answer these questions needs to examine both college choice and persistence decisions.

The literature on student college choice suggests a three-stage process for decisions to go to college (Jackson 1982; Litten 1982; Chapman 1984; Hossler and Gallagher 1987; Hossler et al. 1989). Hossler and Gallagher (1987) proposed the stages of college choice process as follows:

- The first stage is the predisposition phase in which students determine whether they would like to continue their education beyond the secondary level or not. This phase is affected by student ability, achievement, socioeconomic status, parent, peer, educational activities and school characteristics (Tillery 1973; Litten 1982; Stage and Hossler 1989; Nora and Cabrera 1992; Somers et al. 1999).

- The second stage is the search phase during which they gather information about institutions of higher education and formulate a choice set that is the group of institutions to which students will actually apply. The search phase is affected by students' preliminary college values, their search activities and college or university search activities for students (Hossler and Gallagher 1987; Chapman 1981).

- The third stage is that of choice, that is, deciding which college or university a student will actually attend. Educational and occupational aspirations, costs and financial aids and college or university courtship activities influenced the choice phase (Hossler and Gallagher 1987; John 1990; Nora and Cabrera 1992).

On the other hand, student persistence is defined as behavior of whether an enrolled student chooses to reenroll or continue his or her studies during the next semester or year (Astin 1975; Pascarella and Terenzini 1980; Tinto 1987).

In the literature, there are many studies examining college choice behaviors and persistence. Also, it is known that students' background characteristics, personal characteristics, costs and financial aids and academic and social variables influence both choice and persistence (Bean 1990; Hossler et al. 1989; Paulsen 1990; Cabrera et al. 1992). But it wasn't examined adequately how college choice process affects persistence.

The purpose of this study is to investigate students' behaviors in search and choice phases during the university choice process, and also to examine how the students' choice process affects their persistence.

## METHOD

A survey instrument based on studies concerned with the process of placement into higher education programs was developed (Brenan 2001; Frisbee et al. 2000; Osoro et al. 2000; Price et al. 2001; Belcher et al. 2003). The instrument consisted of four sections. The first section concerned demographic information about the students. In the second section, there were questions concerned with the sources of information that student used in decision making for the program and the university. The third section aimed to determine types of information that students collected. Finally, the fourth section aimed to determine factors which students took into consideration in the university entry process. The instrument was piloted with a group of 115 freshmen who studying in the Department of Mathematics and Computer Education. These students and also three faculty members in the Department of Chemistry Education were asked to establish content and face validity for the instrument. They were asked to make changes or offer suggestions for the addition or deletion of items, and to evaluate the overall format and appearance of the instrument.

As a result, the items concerned with faculty magazines, student clubs, and recruitment office of faculty were deleted from the instrument because these did not exist at the time students made their decisions. However, the item relating to brochures and handbooks was added to the instrument. The revised instrument finally included 10 items of types of information actually used (see Table 1), 11 items of sources of information students used (see Table 2) and 17 items of factors that students may take into consideration during choice process (see Table 3). Finally, this survey was administered to 51second year students studying in the Department of Chemistry Education.

In addition to the survey, 11 students who had retaken SSE were interviewed. Semi-structured interviews were held. The interviews were recorded on audiotapes after taking the interviewees' consent.

In analyzing the survey results, descriptive analysis techniques were used and results were tabulated in terms of frequencies and percentages. To identify a relationship between types of information source used and amount of information obtained, the Chi-Square analysis technique was used. Interview data were analyzed by using content analysis technique. Initially, all the responses were read, patterns were identified and first categorization was done. Then the responses were tallied and finally similar categories were combined and final categorization was made. Results are presented under three main headings: search, choice and persistence.

## RESULTS

*Survey Analysis*

The results of the survey data analyses are tabulated and given in Table 1, 2 and 3. As shown in Table 1, information of admission criteria was the most used type of information. It has been gathered by all the students. This finding shows similarity with the previous studies. Hughes (1994) states that students who are not as capable may seek an institution where access is more readily available, however they may maximize their choices within their self perceived capability. Availability of majors is one of the primary considerations shaping actual matriculation (Choy and Ottinger 1998; Hossler et al. 1999). Also, Brennan (2001) states that admission criteria as a proxy for quality is potentially more important than the program offering.

Table 1: The frequencies and the percentages of the types of the information students gathered

| Type of information | Frequency | % |
|---|---|---|
| Admission criteria | 51 | 100 |
| Quality of degree and diploma offered | 25 | 49 |
| Scholarship opportunities | 25 | 49 |
| Maps of faculty grounds or pictures of faculty | 24 | 47 |
| Atmosphere of students socializing and studying | 23 | 45 |
| Sports activities and facilities available | 20 | 39 |
| Academic studies and reputation | 18 | 35 |
| Artistic, social programs and facilities available | 16 | 31 |
| Curriculum and courses | 14 | 27 |
| Students clubs | 14 | 27 |

Surprisingly, Table 1 shows that less than 50% of the students gathered the other types of information, whereas, the literature suggests that information about social life and social activities of the institution, campus life, location financial aids, courses and quality or reputation of the program or university are key criteria in the decision to attend an institution of higher education (Ihlanfeldt 1980; Litten 1982; Straumanis 1987; John 1990; Bruwer 1996; Cullen and Edgett 1998; Choy and Ottinger 1998; Hossler et al. 1999; Kern 2000; Brennan 2001).

Table 2: Comparison of the types of sources of information student applied and percentage of the students who applied these by the number of information gathered

| Types of source of information | Usage (%) | Rank of usage | Percentage of student by the number of collected information (%) | | Rank of usefulness |
|---|---|---|---|---|---|
| | | | - | + | |
| Guidebook to place for higher education | 98 | 1 | 73 | 27 | 10 |
| Family and relatives | 74 | 2 | 66 | 34 | 9 |
| Teachers and counselors in secondary school | 36 | 3 | 64 | 36 | 8 |
| Friends and neighbors | 27 | 4 | 48 | 52 | 6 |
| Faculty students | 26 | 5 | 58 | 42 | 7 |
| Brochures and handbook | 26 | 6 | 58 | 42 | 7 |
| The Internet (related webs and web pages of the university) | 17 | 7 | 47 | 53 | 5 |
| National or local newspaper and magazines | 14 | 8 | 21 | 79 | 3 |
| Lecturers | 11 | 9 | 22 | 78 | 4 |
| Faculty staff | 10 | 10 | 20 | 80 | 2 |
| Faculty visits which organized by secondary school or personal visits | 8 | 11 | 11 | 89 | 1 |

Table 2 indicates percentages of students who used the sources of information. Guidebook to place for higher education was the most used (98%) information source. 74% of the students turned to their families and relatives for information. Moreover, in previous studies, it is stated that parents and relatives have an important affect on student's attending an institution of higher education (Hossler et al. 1990; Frisbee et al. 2000). Hossler and Gallagher (1987) stated that parents and peers influence the enrollment decision. Brennan (2001) stated that family and friends are perceived as having the greatest degree of source credibility and their advice is much more believable. But, in this study, it was found that only 27% of the students turned to their friends and neighbors. Formal sources of interpersonal information such as agents, experts, university staff and counselors are less easily accessed than informal sources such as friends, family, neighbors and relatives. However, formal sources may be more believable if the product is perceived to be highly technical (Moorthy et al. 1997). It is indicated in Table 2 that teachers and counselors in secondary school (36%), lecturers (11%) and faculty staff (10%) had not been heavily consulted. However, teachers and counselors in secondary school have been more used a source of advice by the students than friends and neighbors.

Table 2 also indicates that sources of non-personal information (Brochures and handbooks, internet and National or local newspaper and magazines) had been used less. Whereas, the internet can provide all the information currently available in books, college catalogues, class bulletins, financial aid brochures, and so forth (Hossler 1999). Paulsen (1990) states that college publications are one of the six most preferred information sources for both parents and students. It is also reported in Table 2 that information from faculty students was sought by only 26% of the students. However, it was pointed out in past studies that alumni are an important means of recruitment and promotion (Devier 1982; Isbell and Lovedahl 1989; Hossler et al. 1990).

Campus visits are the most effective source of information in helping students about their choice decision (Craft 1980; Hossler et al. 1990; Wanat and Bowles 1992; Yost and Tucker 1995). But, this study indicates that campus visits were the least used source of information with 8 percent. Consequently, these findings indicate that easily available information sources were used more extensively than not easily available information sources.

Table 2 also shows percentages of the students according to the number of information that they have collected. In Table 2, whereas the negative mark means inadequate, the positive mark means adequate. These are defined as followed;

- ; shows the percentage of the students who collected five or less types of information within students using related source.

+ ; shows the percentage of the students who collected six or more types of information within students using related source.

To identify a relationship between types of source used and amount of information obtained, the Chi-Square analysis was carried out. It was found that there was a significant relationship ($X2= 34,443$, $df=10$, $p<.001$) between these two factors. This result is indicated as the rank of usefulness of the information sources in this table. Consequently, the results of this analysis indicate that the more used sources gave less information, while the less used sources gave more information.

Table 3: The frequency and the percentage of factors the students took into consideration

| Factors | Frequency | % |
|---|---|---|
| To be adequate for my SSE score | 30 | 59 |
| To led to a job when I graduate | 22 | 43 |
| Fees and costs associate with study | 19 | 37 |
| Proximity to home | 17 | 33 |
| To be appropriate to my aptitudes | 11 | 22 |
| Size of campus and faculty | 10 | 20 |
| Job prestige | 9 | 18 |
| Image and reputation of faculty | 5 | 10 |
| Shelter facilities | 3 | 6 |
| Scholarship facilities | 2 | 4 |
| Prestige of chemistry | 2 | 4 |
| Relevance of course to my chosen career | 2 | 4 |
| Educational facilities such as library, classrooms and lab | 1 | 2 |
| Prestige of lecturer | 1 | 2 |
| Activities such as sports, arts and societies | 0 | 0 |
| Campus facilities such as faculty buildings, gardens and sports fields | 0 | 0 |
| Other factors | 6 | 12 |

As shown in Table 3, the SSE score is the most important factor that influenced students' choice, and the next two factors are related to the students' economic state. Proximity to home is the fourth factor students took into consideration during decision making. Table 3 shows that the other factors were taken into consideration by less than 25% of the students.

*Qualitative Data Analysis*

In the interviews, the following questions with their probes in parenthesis were asked: What kind of difficulties did meet during the search process for entry to higher education? (Give me an example). What was the role of information from sources close to you? (e.g. family, relatives, friends and neighbors etc). What was the role of information from sources which are near to your faculty in this process? (e.g. lecturers, staff and students etc). What was the role of your school in this process? (e.g. teachers, counselors and school organizations etc). Did you use non-personal information sources? (e.g. guidebook to place for higher education, brochures, handbooks, media, internet, and web pages etc). Did you make faculty and campus visits individually? What do you think about whether you find the expectations or you not find for your program? (Give an example). Why did you take SSE again?

Results are presented under three main headings, namely the search phase, the choice phase and the persistence phase, and these headings were showed with their codes in Figure 1. Predisposition phase was not needed in this analysis because interviewees intended to reenroll.

## SEARCH

The overwhelming response of the interviewees indicates that they feel that they have used the information sources inadequately. This suggests that there is a lack of search motivation among the students. For example, one of the interviewees said that "I have not consulted enough….I mean I did not do much research" and "I have never talked to lecturers and staff…….I mean it was already defined what I have in mind" and "Although there is internet in my school, I have never used it……I made a superficial search."

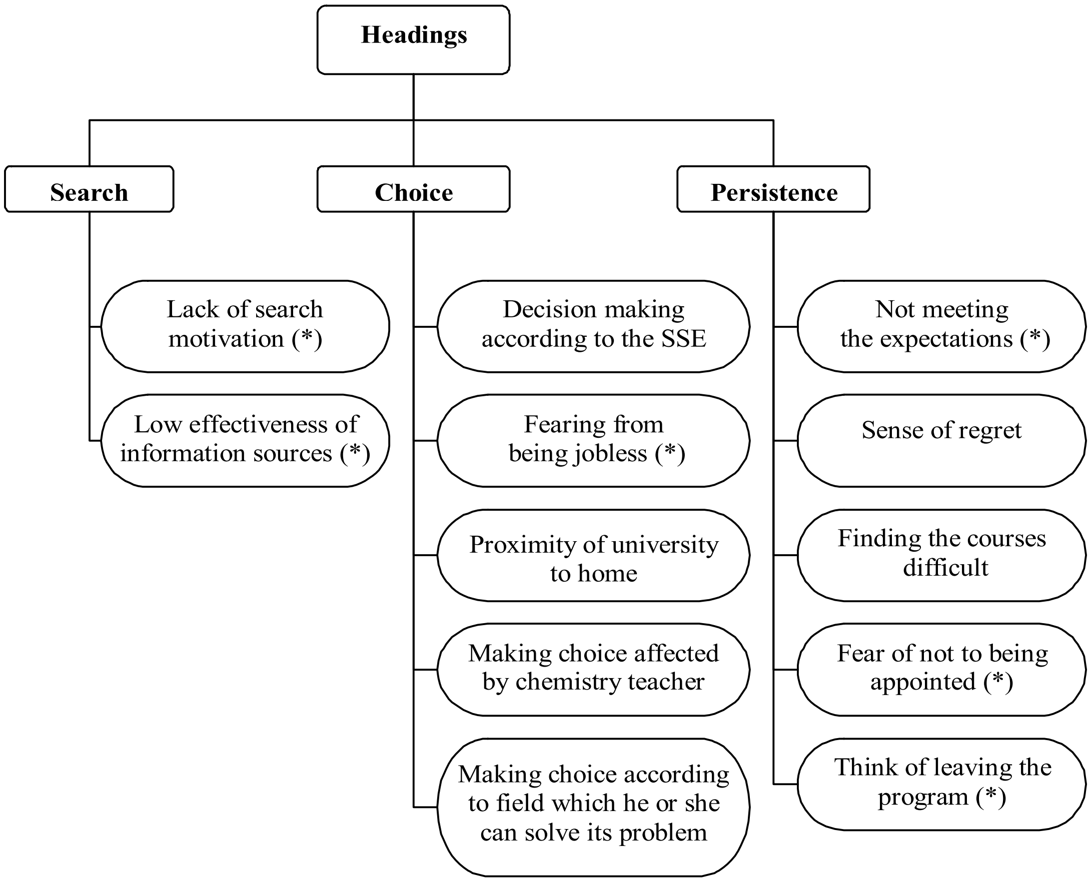
With respect to the role of information sources in the search process, interviewees are in agreement about the low effectiveness of information sources. A typical response was, "….assistance from my counselor and other teachers was inadequate…..and my school has never organized a campus visit" and "…there was only information about program quotas and extra points in the guidebook for higher education place…..I mean it was not indicated which universities had what kind of facilities."

## CHOICE

In general, interviewees complained about being forced to decide according to the SSE score. For example, "…..SSE score was the only point that we took into consideration. So, I directly thought whether I can be placed or not into a program according to my SSE score…..my choice changed completely when my SSE score was explained."

All the interviewees stated explicitly that one of the most significant factors in the choice phase was job opportunities. The fear of being jobless at the end of education affected their choice. A typical response was "to study in a higher education institution that has the possibility of finding a job was important for me".

Figure 1. Results of interview data.




(*) indicates that all interviewees were agree.

As some interviewees stated they took into consideration the proximity of university to their home during choice phase, some interviewees stated that their choice was affected by their chemistry teacher. Few interviewees explained that they made choice according to types of question which he or she can solve in the SSE. For example, such a student will choose the Department of Chemistry Education instead of the Department of Biology Education so that he or she can more solve the questions of chemistry rates than those of biology.

## PERSISTENCE

In response to the question, "were your expectations fulfilled?", it was noted that all interviewees did not fined their expectations fulfilled. For example, "….I expected several things from the Chemistry Teacher Training Program but the program did not meet my expectations…. I found it was very different after I began study in here…..I mean I'm disappointed when I came here."

The overwhelming response to the question, “why did you take SSE again?”, suggested that they were worried about whether they will be placed or not, and a typical response to this question was, “…..I want to be a good chemistry teacher but I don’t know whether I will get such an opportunity or won’t…”

Views of some interviewees indicate that they had a sense of regret, and also it is understood that few interviewees experienced difficulty in following the courses. The overall view is that all interviewees think about leaving the program. They think about changing the program, the university or both. For example, “I will try to attend a university which meets my actual ideals……I mean I will choose a program in which I will not regret studying it.”

## DISCUSSION AND CONCLUSIONS

In this study, we aimed to investigate students’ behaviors in relation to search and choice during university placement, and also to examine how students’ choice processes affect their persistence. The extent of searching may be determined by the time spent, the amount of active search (campus visits), options considered and variety of sources of information used by the matriculates (Newman and Staelin 1972).

Both survey and interview data indicate that information search activities of the students were inadequate and they lacked search motivation during the search phase. Differently from previous studies this study shows that in general the students took into consideration the SSE scores as the most important factor which influenced their choice process. Therefore, they might have thought as “I want to attend any program for which my SSE score is adequate, that is, other factors are not very important for me” or “A program is good if its score is high.” Another significant factor for most of the students is the economic status of the job which they will have in future. Therefore, they might have thought that "the kind of the program is not important for me, if it gives me a job when I graduate”. Such thoughts impede their consideration about the institution of higher education. In addition, the results indicate that most of the information sources have low effectiveness. Quality of information sources may affect the students’ search phase negatively. Cabrera and Nasa (2000) stated that the importance of securing accurate information about college extends well beyond the decision to enroll in college. The findings suggest that there were negative feelings in the students’ search and choice phases. For solving this problem, a recruitment office should have been established for faculty and recruitment tools should have been activated. High schools should make their counseling activities more effectively, and finally, it is necessary that policymakers enterprise to expand the amount of financial aid.

Table 4: A four phase model of college or university choice process

| **Model Dimensions** | **Influential Factors** | | **Student Outcomes** |
|---|---|---|---|
| | **Individual Factors** | **Organizational Factors** | |
| Predisposition (Phase one) | Student characteristics<br>Significant others<br>Educational activities | School characteristics | Search for:<br>a. College options<br>b. Non-educational options |
| Search (Phase two) | Student preliminary college values<br>Student search activities | College and university search activities (Search for students) | a. Choice set<br>b. Non-educational options |
| Choice (Phase three) | Choice set | College and university courtship activities | Choice |
| Persistence (Phase four) | Quality of student's search activities<br>The level of fulfillment of student expectations<br>Student's college or university experiences | Quality of college and university recruitment activities<br>Quality of school counseling activities | a. Continue decision<br>b. Return to the search phase<br>c. Leave decision (non-educational options) |

In addition, the results of the study suggest another phase for the students in college choice process: the persistence phase (Table 4). Hossler and Gallagher (1987) proposed a three phase model of college choice. At each phase of this model, individual and organizational factors interact to produce outcomes which influence the student college choice process. Table 4 was modified from this model. Our study indicates that college choice process will restart for students who think to change their programs, university or both. Table 4 suggests a four phase model of college choice covering a persistence phase in which students may return to search phase or may continue life their actual study.

The results of this study also indicate that quality of students' search activities, level of fulfillment of their expectations and their college or university experiences affect their persistence. Also, qualities of university recruitment activities and school counseling activities have an influence on the students' persistence. Finally, students may leave or continue according to quality of the persistence phase.

## IMPLICATION FOR SCIENCE EDUCATION

It is clear that such a chemistry classroom students have difficulties in science learning. To prevent this problem, science learning environment of probable departments should be advertised well in high school counseling activities. Science classrooms, laboratories, library and other facilities are needed to be presented visually during the activities. Also science educators should design diagnostic studies for characteristics of a science teacher. That the counselor know the interests and abilities which are needed to be a science teacher is necessary for an effective counseling for the students in the choice of a science education department.

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# DYNAMIC EQUILIBRIUM EXPLAINED USING THE COMPUTER

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**Musa Şahin**

**Musa Üce**

**ABSTRACT.** Since their introduction into schools, educators have tried to utilize computers in classes in order to make difficult topics more comprehensible. Chemistry educators, when faced with the task of teaching a topic that cannot be taught through experiments in a laboratory, resort to computers to help students visualize difficult concepts and processes. Computers offer viable means to teach dynamic equilibrium, a topic that has no laboratory manuals. Recently, chemistry educators have started to focus on how to use computer animations and simulations in the teaching of equilibrium.

**KEYWORDS.** Chemistry Education, Dynamic Equilibrium, Computer Animations.

## INTRODUCTION

Most students fail to conceive the dynamic nature of chemical equilibrium. They think nothing more happens when the system reaches equilibrium. Many articles have documented learning difficulties, specific student misconceptions, and strategies for teaching chemical equilibrium. Some authors have offered ways of addressing these misconceptions (Wheeller and Kass 1978; Hackling and Garnett, 1985); others have written articles concerning student misconceptions about equilibrium and their diagnosis (Banerjee, 1991; Bergquist and Heikinen, 1990). The reasons for this failure are apparent. First, as it reported by Finely at al. (1990) chemical equilibrium is an abstract concept demanding the mastery of a large number of subordinate concepts. Even teachers don't fully understand the topic themselves (Linn, 1987; Tobin and Espinet, 1989). When they are asked to explain that equilibrium is dynamic, they are not able to do so. Thus, the teaching of dynamic equilibrium lends itself to the use of analogies to be explained and comprehended (Thiele and Tregust, 1994). Second, it is difficult to carry out an experiment to help students comprehend it. There is no laboratory manual for dynamic equilibrium in high school or university level.



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The teaching methods proposed to teach chemical equilibrium better (Treagust at all, 1999) include experiments, simulations (Huddle at all, 2000), and computer animations. For instance, Harrison and Buckly (2000) made a transparent simulation to explain dynamic equilibrium. They divided the students into two groups and gave them 24 small coins. The reaction scheme for a first order reversible reaction was shown to the class on an overhead projector transparency.

$$A\ (g) \underset{\frac{1}{4}\ min^{-1}}{\overset{\frac{1}{2}\ min^{-1}}{\rightleftharpoons}} B(g)$$

They put 24 students under A, and none under B. The students under A represented reactants, B represented products. Every minute half of the reactants were converted to products and ¼ of the products was converted back to reactants. A table of the kinetic data was also shown on the board. In this analogy, in the third minute, this simple simulation illustrates the concept of dynamic equilibrium.

Wilson (1998) did a similar simulation with 40 matches. He performed three activities. In the first activity, he explained dynamic equilibrium using the same mechanism as Harrison and we did. In the second activity, he again explained the dynamic equilibrium starting with a different number of matches but the same reaction rate. In the last activity, he used different reaction rates and temperatures to explain K changes with temperatures.

It was indicated that students had difficulty in understanding concepts at the particulate level and that it is the source of many student misconceptions (Williamson and Abraham, 1995). With the experiments and simulations performed in these two studies, it was not possible to reach the particulate level. Since the topic could not be grasped conceptually, we have designed this animation with the help of a computer program to make the dynamic equilibrium understood in the particulate level.

In this animation, we give a first order reversible reaction as Harrison and Buckley (2000) did. The students are told that constants (identified as rate constant) shown above and below the arrows are used to calculate the number of reactants going to products and vice versa at the end of each minute. A computer animation is accomplished to illustrate the actual reaction.

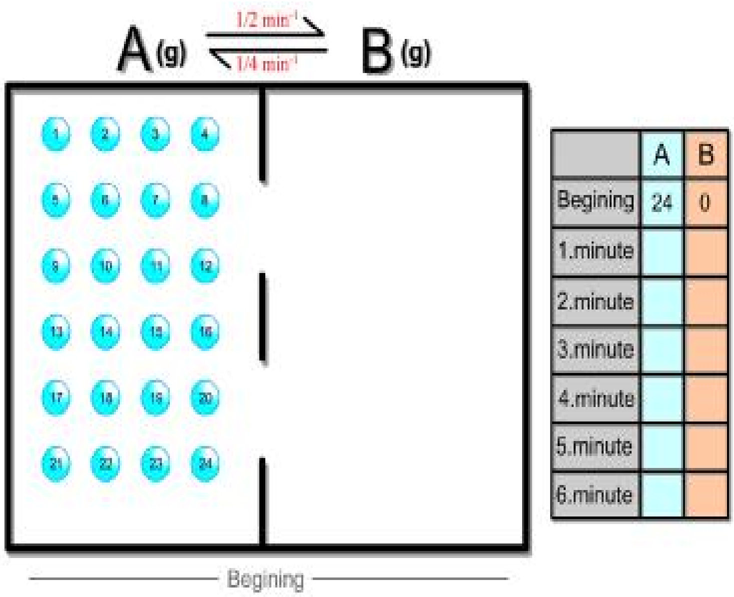
$$A\ (g) \underset{\frac{1}{4}\ min^{-1}}{\overset{\frac{1}{2}\ min^{-1}}{\rightleftharpoons}} B(g)$$

Table 1: The atom number–time table of first order reversible A(g) ⇄ B(g) reaction for six minutes

| Time /min | A(g) | B(g) |
|---|---|---|
| 0 | 24 | 0 |
| 1 | 12 | 12 |
| 2 | 9 | 15 |
| 3 | 8 | 16 |
| 4 | 8 | 16 |
| 5 | 8 | 16 |
| 6 | 8 | 16 |

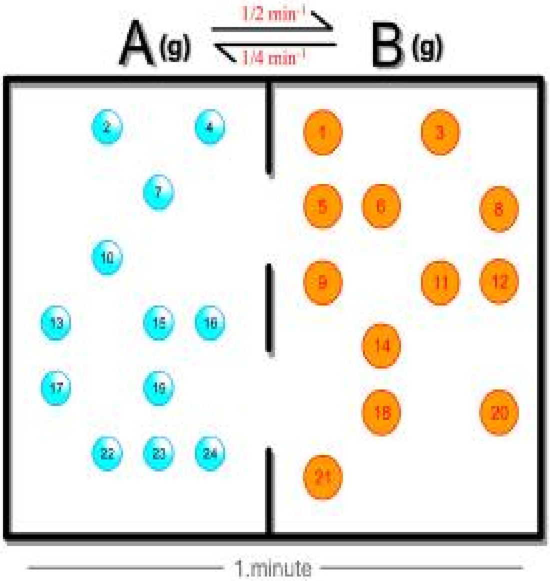
On the computer screen there are two-sided boxes named A and B. In column A there are 24 atoms. Each atom is marked from 1 to 24 (Numbers are written on each atom from 1 to 24). On the right side of the box there are no atoms because the reaction has not started yet (Figure 1).

Figure 1: The states of the atoms before reaction




When the students press the first minute button, half of the atoms in the reactant side are produced to B (24/2=12). During the first minute of chemical reactions occurring the color and size of the B atoms are changed in order to attract students' attention to these reactions. At the end of the first minute there are 12 atoms on either side (Figure 2).

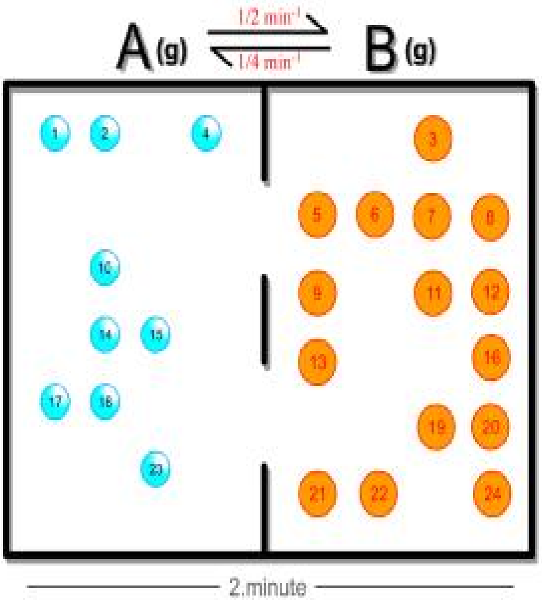
Figure 2: The states of the atoms in the first minute




| | A | B |
|---|---|---|
| Begining | 24 | 0 |
| 1.minute | 12 | 12 |
| 2.minute | | |
| 3.minute | | |
| 4.minute | | |
| 5.minute | | |
| 6.minute | | |

In the second minute, while half of the reactants produce B, ¼ of the products decompose to A. At the end of the second minute there are 9 atoms on the reactant side, 15 atoms on product side (Figure 3).

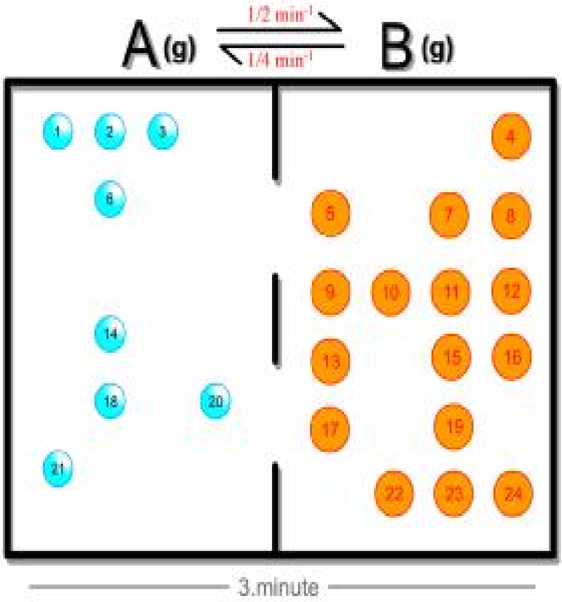
Figure 3: The states of the atoms in the second minute




| | A | B |
|---|---|---|
| Begining | 24 | 0 |
| 1.minute | 12 | 12 |
| 2.minute | 9 | 15 |
| 3.minute | | |
| 4.minute | | |
| 5.minute | | |
| 6.minute | | |

In the third minute, half of the reactants (9/2=4,5) produce B. While A produces B, ¼ of the B decomposes back to A. At the end of the third minute 4,5+3,75= 8,2 A atoms and 15,8 B atoms are formed. We tell the students to round off 8,2 and 15,8 to 8 and 16 (Figure 4).

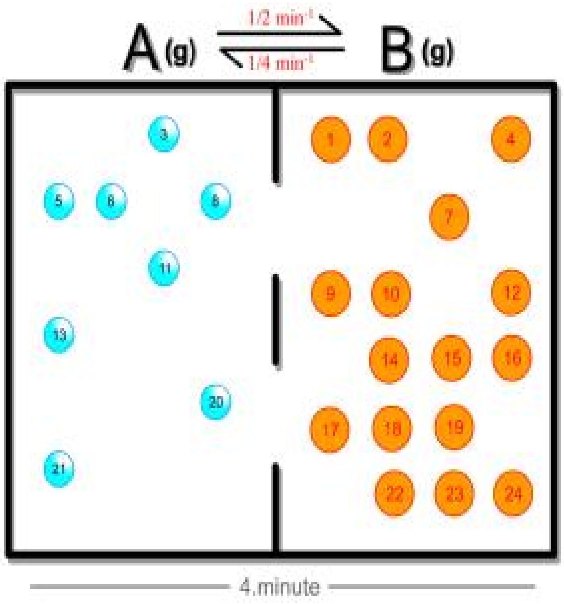
Figure 4: The states of the atoms in the third minute




| | A | B |
|---|---|---|
| Begining | 24 | 0 |
| 1.minute | 12 | 12 |
| 2.minute | 9 | 15 |
| 3.minute | 8 | 16 |
| 4.minute | | |
| 5.minute | | |
| 6.minute | | |

What happens during the fourth minute? Students see that the total numbers of the atoms on both the reactant and the product sides are constant (Figure 5).

Figure 5: The states of the atoms in the fourth minute

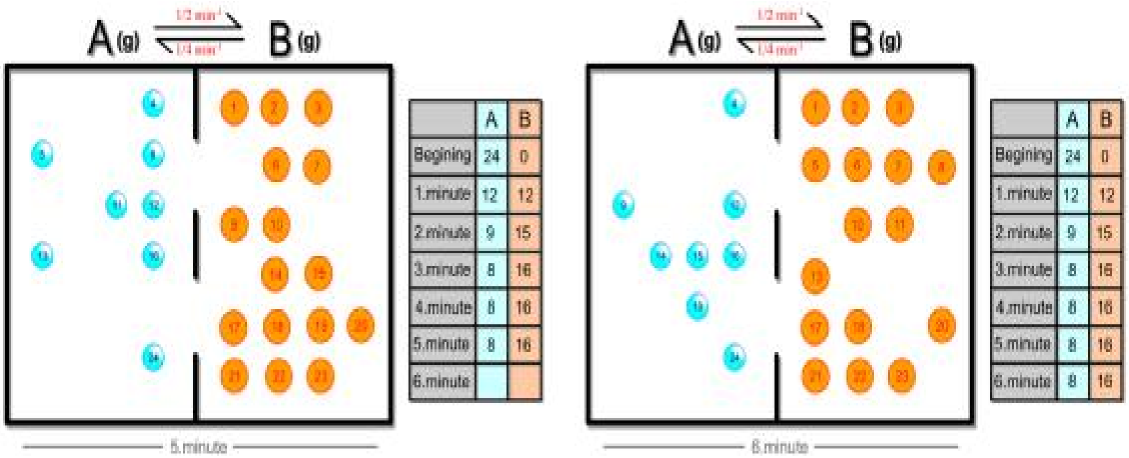



| | A | B |
|---|---|---|
| Begining | 24 | 0 |
| 1.minute | 12 | 12 |
| 2.minute | 9 | 15 |
| 3.minute | 8 | 16 |
| 4.minute | 8 | 16 |
| 5.minute | | |
| 6.minute | | |

*"We emphasize that when a system reaches equilibrium, concentrations of product and the reactant don't change but microscopic events still go on (because numbers are still changing but the total number of atoms doesn't change)"*

During the fifth and sixth minutes students are able to see this phenomenon clearly in this animation (Figure 6).

Figure 6: The states of the atoms in the fifth and sixth minutes




## CONCLUSION

The study shows that computer animations might prove to be an invaluable means in the teaching of dynamic equilibrium. The animations used in this study, unlike those in similar ones, employ the presentation of dynamic equilibrium at molecular level, thus helping increase students' awareness of the subject and hinder formation of misconceptions.

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