Using A Force Concept Inventory Test With Visually Impaired And Blind Students

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Abstract

This paper reports on a study to determine whether blind students' conceptualizations of force and motion differ from sighted students. This is particularly concerned with the question of whether the students' visual experiences have any relation to their conceptualizations or misconceptualization about force and motion. The research was designed as a case study and the data was collected from 6 blind high school students based on conceptual physics problems related to force and motion. The analysis of the data revealed that although the blind students' conceptions about force and motion are not radically different from those of sighted students, however, there were several conceptual problems that seem to be particular to the blind students because of their lack of visual experiences. The results revealed that visual experiences do not seem to have a significant role on the conceptualizations about force and motion.

Keywords: FCI, Visually impaired and blind students, Misconception.

Introduction

Compared to sighted students blind students start their formal physics education lack of visual experiences and representations related to physical phenomena. This tends to hinder the acquisition of scientific knowledge in particular concerning visually accessible phenomena (e.g., motion, light, and colors) the gap between sighted and blind students seems to be tremendous. In order to close this gap it is vital that blind students receive appropriate support. Although research shows that most science teachers believe it is unrealistic to expect blind students to become successful in science, several studies (Bulbul, 2009; Parry, Brazier & Fischbach, 1997; Thier, 1970) have shown that blind students can learn even the most challenging topics such as the structure of light and image formation on curved mirrors without memorization when given sufficient support.

Physics is a difficult subject for most students but for blind students the lack of visual ability makes the process of learning more difficult (Sevilla, Ortega et al. 1991). The most fruitful way of helping blind students learn scientific concepts is to utilize perceptual modalities other than the visual in order to make sense of the concepts. Several researchers have addressed this issue and proposed different materials (Windelborn, 1999) for topics such as mechanics (Baughman & Zollman, 1977) and modern physics (Camargo & Nardi, 2006) to make use of students' kinesthetic modalities. For example, Kandaz (2004) exemplifies the use of some hands-on activities in physics for example, using knife and nail's two sides to explain the pressure concept. Similarly, Dion, Hoffman and Matter (2000) prepared a guide for blind students containing various experiments ranging from heat to conductivity. That study also gave physics teachers' advice concerning how to redesign their physics laboratories for example, using an audible stopwatch when making pendulum measurements.

It is important to develop instructional materials to support blind students' learning of physics however; these materials should be created on the basis of a general theoretical perspective of learning. The most fundamental theory of learning shaping the current literature of physics education as well as other fields of education is constructivism. Within this theory, learning is defined as a product of cognitive acts which rest on two premises; (a) knowledge is not passively received from the environment, but it is actively constructed by cognizing subjects; and (b) knowledge acquisition is an adaptive process that organizes one's experiential world, not the discovery of an independent world outside the mind of the knower (von Glasersfeld, 1995). The major implication of these premises in physics education is that the learner's interpretations of their observations and experiences might be very different from those of scientists. An immense body of research conducted during the 1960s through to the 1990s, identified students' pre-instructional knowledge in various domains such as force, electricity, optics, and energy (Fredette & Lochhead, 1980; Halloun & Hestenes, 1985; La Rosa, Mayer, Patrizi, & Vicentini-Missoni, 1984; McCloskey, 1983; McDermott, 1984; Osborne, 1980; Viennot, 1979; Wittmann, Steinberg, & Redish). The results of these studies revealed that students' pre-instructional ideas do not always match scientifically accepted conceptions and also that they influence further learning (Driver, 1989). The main result of these studies, that pre-instructional knowledge influence further learning, encouraged many researchers to develop new learning models to effectively deal with students' pre-instructional knowledge. Among others, the Conceptual Change Model (CCM) received special interest from the educational community. The basic idea behind CCM is that learning is a rational activity and when students' central concepts are inadequate to successfully explain new phenomena, students must replace or reorganize their existing central concepts (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992).

Returning to the learning of blind students, one legitimate question emerging from the premises of constructivism and conceptual change literature is whether blind students' pre-instructional knowledge differs from sighted students with visual experiences. The significance of this problem is twofold. Firstly, to generate theoretically sound instructional practices for blind students it is important to determine their pre-instructional knowledge structures because pre-instructional knowledge is indispensable part of the knowledge construction process. A substantial part of human experience is visual; therefore, a lack of this experience might create a difference for blind students in terms of their pre-instructional knowledge and the projected learning process. Secondly, investigating the conceptual differences between blind and sighted students will provide information about the role of visual experiences in the construction of pre-instructional knowledge.

Studies related to blind students and physics education

In the literature, of 66 reports involving science education for disabled students, only 14 are relevant to visually impaired and totally blind students (Mastropieri & Scruggs, 1992). All these 14 reports have positive findings about the use of instructional strategies and techniques on blind students' learning. Most of the science materials (12 of 14) mentioned in Mastropieri and Scruggs' (1992) meta-analysis were related with physics. According to their review, studies about visually impaired students for facilitating science learning can be classified in in two ways those creating materials and those that use adapted materials. The tactile ruler (Franks, 1970) designed with raised lines to measure small distances correctly is an example of science materials that. . For adapted materials they example Linn's (1972) SCIS (adaptations of science materials for the blind) project which allowed blind students do same experiments as sighted students in their class. Small motors were designed to assist students distinguish the phases of matter in mixtures, solutions and non-solutions in properties of matter unit. However, none of these studies was designed in a way that was sufficient to determine blind students' pre-instructional knowledge.

Although many years have passed since Mastropieri and Scruggs's study, their material oriented classification seems not to have changed or be superseded. Researchers sustain material-oriented studies due to the increasing number of technological innovations. However, in a study concerning the views about physics of blind students in high school, 17 of 24 students considered that physics is a difficult course and materials are not adequate (Ünlü, Pehlivan & Tarhan, 2010).

In life sciences, generally, blind students build their pre-instructional knowledge from their experiences (e.g. lab experiments) and other sources including Braille books, recorded tapes, friends, educators, Internet with screen readers, experts, radio and television (Fraser & Maguvhe, 2008). However, these sources are still not adequate to explain how their pre-instructional knowledge differentiates.

Other studies related with blind students and science may be gathered under the umbrella of the inclusive learning environment issue. Although science instructors at all levels of education believe in inclusive science education which is associated with participation of children with disabilities and/or special needs in regular schools these instructors do not believe (Savolainen, Kokkala & Alasuutari, 2000) that it is possible for visually impaired students, since their educational background and experience are not sufficient (Norman, Caseau & Stefanich, 1998). On the other hand, in the science education literature for students with visual disability inclusive science classrooms are recommended (Zembylas & Isenbarger, 2002) and science educators are advised to regularly engage in collaborative learning (Sahin & Yorek, 2009). This kind of learning environment can have a positive effect on blind students' pre-instructional knowledge; However, students that attend schools specifically for the blind or partially sighted are generally designed for their physical needs not for their cognitive needs. In the inclusive education system the interaction between blind and sighted students can facilitate the former increasing their science knowledge with the help of their peers.

From the interaction of blind students with their friends, some may be able to partially to construct physical concepts. When referring to a person being blind this generally means that they cannot detect light in any way (totally blind), however, there are limited vision (visual impaired) students who may see if the object is enlarged (Hallahan & Kauffman, 2006). Sica (1982) indicated that there are more visually impaired students attending physics and mathematics courses in high schools and universities than totally blind students. These visually impaired students' pre-instructional knowledge may be based on their personal experiences with everyday life.

The possible problem is how to compare the students' achievement in inclusive learning environment. Parry, Brazier and Fischbach (1997) support the idea that the academic success of blind students is comparable with the achievement of sighted students' if we give them more time and use an appropriate teaching method. Cooper, Baum and Neu (2004) suggested an alternative approach, which does not limit the amount of time that students spend on the task and they successfully implemented their method, which appropriates real scientific procedure. In this research the concept of force was selected to investigate blind students' pre-instructional knowledge. These students are familiar with the concepts of force and motion and they have experience of acceleration from slides or swings, however, the theoretical aspects of acceleration and its relation to force may not be known (Pehlivan &

Unlü, 2008). In Pehlivan and Unlu's study (2008), blind students were encouraged to understand the concept by comparing the type of motion from the tactile points on the strips paper and their pulling force. However, the results showed that the blind students struggled to explain and connect the concept of acceleration to force.

Misconceptions about Force

The concept of force concept was chosen since it is related to daily life based. The investigation of how blind students comprehend this concept, the Force Concept Inventory (FCI) was used. FCI is one of the most common (Redish & Steinberg, 1998) and reliable (Huffman & Heller, 1995) measurement tools, which indicates students' conceptions about force from daily life in physics education.

When students' make repeated mistakes they are defined as misconceptions because they are sure what they support otherwise their mistake can be change whether they have ever thought about that subject. These misconceptions can be detected not only in average students but also in honor students furthermore, even physics teachers have misconceptions in mechanics (Eryılmaz, 1992).

The first version of FCI (Hestenes, Well & Swackhamer, 1992) was revised several times (Halloun & Hestenes, 1985) misconceptions are categorized in six main dimensions; Kinematics, Impetus, Active Force, Action-Reaction Pairs, Concatenation of Influences and Other Influences of Motion. For the research we used the Turkish version of FCI adapted by Temizkan (2003). Temizkan restructured the categories of FCI, added 5 new misconceptions creating an inventory consisting of eight categories including Gravity and Resistance, and involves 30 misconceptions. Among the eight dimensions of misconceptions, impetus includes the effect of keeping things moving and has an unexplainable structure. Students sometimes use power or force instead of impetus.

Methodology

To discover the most frequent dimensions of misconceptions that apply to blind students, we used case study approach using a qualitative research methodology. The sample consisted of six students who had been blind from birth we have chosen a case which reflects a natural setting (Gall, Gall & Borg, 2007) of six blind inborn students from Halide Edip High School in Ankara. We gathered data through interviews in a natural setting, which was in the dormitory where the students lived. The interviewer also lived with the students so they were able to respond to the inventory and interview questions in a comfortable and relaxed atmosphere.

A semi-structured interview approach was used (Fraenkel & Wallen, 2006) to administer the FCI verbally. After presenting each question the interviewer asked if the question was clear and if not the question could be repeated. After each question the student was requested to give their reason for their response.

Participants

For this single case design (Gay, Mills & Airasian, 2009) we focused on blind students' understanding without considering gender or school difference. Since FCI can be used with a student population across the grades it was appropriate for our research because finding blind students willing to volunteer and attending high school in the same grade is very difficult. Table 1 shows the distribution of the grades from which our participants were drawn together with their degree of blindness. To preserve confidentiality the students were given different names.

Table 1. Blind students' name, grade and blindness degree

	9th grade	10th grade	11th grade	12th grade
Stephanie				100%
Victoria				100%
Kate	100%			
Jane			100%	
Tanya				100%
Helga		95%		

Data Collection

The choice of the date and time of the individual interview was strongly related with participants' leisure time and extent of their willingness participate in the study. The students were told that the test results would only be used for research and they could choose to leave the study at any time..

Observation and interview are most common and effective data collection methods for inquiry, however, blind students have informed us that observation of the interviews using a video recorder tends to have a negative effect on them. Therefore, only voice recording and interviewer's observations were used for the analysis.

We have analyzed records according to the test answers and their categorized reasoning according to the eight FCI categories adapted by Temizkan (2003). Categorization was prepared from the literature or from new explanations that reflect the participants' experiences and understanding.

Results

Visually impaired students' responses to the FCI questions and their reasoning were used to detect students' misconceptions about force and motion. Figure 1 shows the distribution of the misconceptions held by the five blind and one visually impaired student according to 30 misconceptions of Misconception Taxonomy adapted by Temizkan (2003). It can be seen in the Figure 1, some of the misconceptions are more prevalent among students. For example, all of the participants have the misconceptions I_1, I_3 and I_4 which are about impetus.

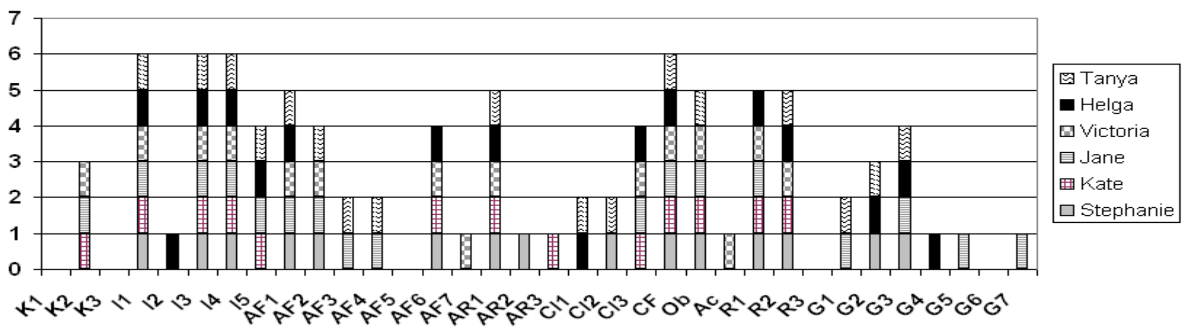

Figure 1. Distribution of six students' misconceptions

The distribution of students' misconceptions for each misconception category is shown in Figure 2. It is seen in the figure that most of the visually impaired students' misconceptions belong to "impetus" category; "followed by "active force", "gravity" and "other influences" on motion categories.

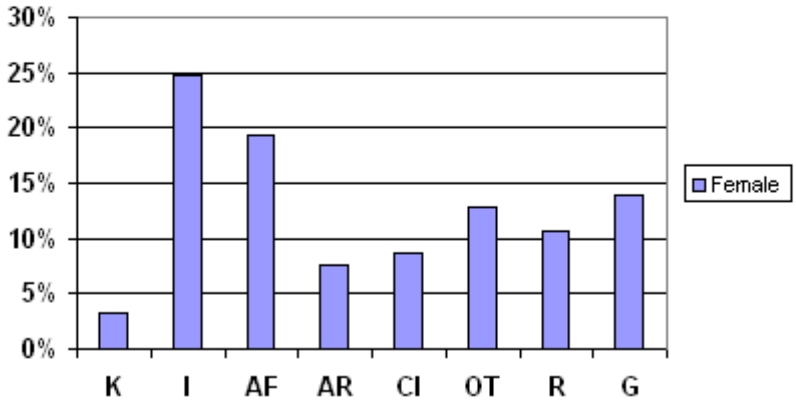

Figure 2. Distribution of main misconception categories

These four categories of student misconceptions are investigated in depth in the following sections and their reasoning will be indicated.

Impetus

The impetus view of motion is commonly held and it contradicts with Newtonian physics. Not only novices, but also experts possess impetus misconceptions when thinking intuitively (Kozhevnikov & Hegarty, 2001). Students with an impetus view believe that there should be an inanimate "motive power" or "intrinsic force" to keep things moving. Students use the terms such as "force", "energy" and "power" when explaining the effect of impetus (Hestenes et al., 1992). Participants in the study that chose the distracters related to impetus supported their choice with the following reasoning:

[1] *Interviewer:* (Reads the 24th question)
Jane: It will be constant for a few seconds and then it decreases. Due to the effect of force, it will be constant for a few seconds and then it decreases. It decreases step by step.
Interviewer: Do you have any other explanation about this question?
Jane: No.

[2] *Interviewer:* (Reads the 22nd question).
Kate: The last alternative, because everything finishes at the end. It should increase first but then it should decrease.
Interviewer: Are you sure?
Kate: Yes, of course; everything finishes after a time.

[3] *Interviewer:* (Reads the 6th question).
Helga: It will go inwards.
Interviewer: Why do you think like that?
Helga: I think from playgrounds, there are tube slides, when I slide from it I was going inwards. If I don't stop myself I will go inwards.

[4] *Interviewer:* (Reads the 10th question).
Stephanie: It will increase at first and then decrease.
Interviewer: Why do you say that?

Stephanie: I imagine myself hitting a ball, when I hit the ball it will go fast at first that it stops slowly.

In dialog [1] the student explained that velocity will be constant for a second due to the effect of force and then she expects it to decrease. In dialog [2] the student has the same idea but her reasoning is related to the philosophical principle "everything finishes at the end". In dialog [3] and [4] both students use their experiences while giving their reasonings. Helga explains her sliding experience to answer the question. Similarly, Stephanie uses her ball experience to respond to the question.

Active Force

The common belief is that only "active agents", usually living things are conceived as active agents, are able to exert force and cause motion. Due to the reasoning that every effect has a cause since motion is an effect therefore, it has a cause. Thus, it is believed that motion implies active force (Hestenes et al., 1992). The responses of students that had misconceptions about active force are as follows:

[5] *Interviewer:* (Reads the 7th question).
Kate: How fast does it turn?
Interviewer: Is it important?
Kate: Yes, there is an effect depending on whether it turns faster.
Interviewer: Constant velocity, we may say.
Interviewer:… In what direction does the ball go?
Kate: Absolutely straight. The path of the motion does not change if it goes fast. There should not be any interaction if it goes fast. The last alternative is the correct one.
Interviewer: Are you sure?
Kate: Yes, I am.

[6] *Interviewer:* (Reads the 29th question)
Jane: Now, if it stays without any motion, gravity is the reason. What was the alternative?
Interviewer: (Reads the alternatives again).
Jane: I think this choice, because if there is no motion there should not be any force. The correct alternative is E.
Interview: Any other comments?
Jane: No, that is enough.

[7] *Interviewer:* (Reads the 5th question).
Victoria: If there is a motion there should be only one force parallel to the direction of motion, so there should be only the third force.
Interviewer: There is no choice like that.
*Victoria:…*well, I cannot answer, let me pass this question.
Interviewer: Ok.

[8] *Interviewer:* (Reads the 22nd question)
Jane: I said before…It increases because the ball has been hit. This fits this question. In my opinion, it increases due to being hit but after some seconds it decreases. I think it slows down.
Interviewer: Why do you think that?
Jane: Because when we hit the ball, it goes faster for a few seconds then it slows down. Well, due to the effect of hit, it goes faster, later it slows down.

Interviewer: Is that it?
Jane: Yes.

[9] *Interviewer:* (Reads the 15th question).
Stephanie: The car is small and the track is very big, how can a car move a huge track? So the track can push the car.
Interviewer: So which answer would you choose?
(Reads the alternatives again)
Stephanie: I think D is the correct choice, because the small car is working but the track is not working so it cannot apply force.

In dialogs [5] [6] and [7] students do not distinguish between force and motion. They that if there is a force there should be motion or that motion requires force. In dialog [8] Jane uses her personal experience in answering the question. On the other hand, Stephanie uses social experiences. She did not experience the situation but has an idea developed from her understanding of the meaning of the words "small and big. Similarly while reasoning she uses meaning of "working" and expects a working car to apply force since it is an active agent.

Gravity

Students usually believe that heavier objects will fall faster than lighter objects and that there is a significant increase in gravity over a few seconds (Hestenes et al., 1992). Similar beliefs were detected in the participants of the study as shown in the following examples of their reasoning:

[10] *Interviewer:* (Reads the 13th question)
Jane: Now, after the ball is thrown it falls ball is thrown at the same time it falls…
Interviewer: Are there forces that affect the ball when thrown and until it falls to the ground?
Jane: Absolutely, there is gravity while falling. I am thinking about whether there is an upward force …Let me think, about throwing a ball. It falls when we throw…Can you read again?
Interviewer: (Reads the alternatives)
Jane: It should be "d".
Interviewer: Why?
Jane: Because of the reason I gave before.
Interviewer: OK.

[11] *Interviewer:* (Reads the 14th question)
Jane: In my opinion it falls down very straight. But how do I explain that?
Interviewer: Let me give you the alternatives again…(Reads alternatives)
Jane: I think "b" is the correct one.
Interviewer: Why?
Jane: I cannot explain…It's shape is not appropriate to get rolling, it is box… you know boxes have edges and to tumble or get rolling seems impossible for a box. I thought that a body couldn't change the motion direction while it is falling down.
Interviewer: Is that it?
Jane: Yes, I am finished.

[12] *Interviewer:* (Reads the 1st question)

Kate: The lighter ball reaches the floor, not absolutely but about half the time that the heavier one takes. The lighter one does not weigh as much, so it falls easily without interaction. The heavy ball will have some difficulties while falling. Lighter one falls before the heavy one.
Interviewer: Are you sure the answer to this question?
Kate: Yes, I am. I think it is logical…Actually, to be certain we should do this experiment. We can throw two balls from the roof.

[13] *Interviewer:* (Reads the 13th question).
Stephanie: It will accelerate as it [the ball] as it goes up and then it will fall down slowly. If it also accelerated as it fell down it would hurt my hand when I caught it.

[14] *Interviewer:* (Reads the 18th question).
(…)
Helga: There is gravity, when I lift my legs I get tired, gravity pulls the swing but it won't fall since there is a rope. And there is force from A to O since rope pulls the swing.

In dialog [10], student tries to imagine the ball throwing ball activity. In dialogs [11] and [12] the students use their common sense reasoning to answer the question. Jane gives the shape of the box as an evidence for it not moving in different directions. Kate added that she wanted to undertake an experiment to give a firm answer. In dialog [13] and [14] the students make use of their experiences when explaining the answer.

Other Influences of Motion: Centrifugal Force

FCI does not contain items designed to assess students' misconceptions about centrifugal force, therefore, verification is necessary for these misconceptions (Hestenes et al., 1992). The students' explanations for items related to centrifugal force are as follows:

[15] *Interviewer:* (Reads the 5st question)
Kate: I think…What was the last choice? I think a force from "O" to "r".
Interviewer: (Reads both alternatives again)
Kate: I do not know how to explain it.
Interviewer: What kind of force?
Kate: It should be friction force.
Interviewer: In the question, there is an explanation that there is no friction.
Kate: I cannot explain it…The distance between "O" and "r" was the reason but…
Interviewer: Don't worry. Relax…explain in your own words.
Kate: Please read other alternatives.
Interviewer: (Reads the alternatives).
Kate: Second and the last forces should exist. There should be the effect of the pipe [through which the ball passes].
Interviewer: Is that OK?
Kate: Yes, OK.

In dialog [15] Kate uses her uses common sense reasoning, she has difficulty verbalizing her ideas but she offers an opinion on the context.

Discussion and Conclusion

The results of the study show that although they are unable to make visual observations, visually impaired students have the same perception of the concept of force as their sighted peers. Visually impaired students and their sighted peers use different senses while observing the world, but both groups give similar explanations to support their responses to the questions involving the concept of force. The limitations of this study may be working with only 6 participants since more reliable results can be achieved by further studies being conducted a larger sample. Furthermore, all the participants were female and working with both male and female students could produce results that indicate a gender difference. However, six female students are enough to conclude that both sighted and blind students may have same misconceptions, although they experience from different kind of sources.
This study with other studies related with sighted students' misconceptions with FCI results indicate that both blind students and sighted students are at the same conceptualization level without formal instruction. Therefore, it can be concluded that the detailed structure of the instruction facilitates blind students being able to reach the same conceptualization level as their peers. This result supports the development of inclusive curricula for physics courses. With these types of curricula course materials appropriate for blind students need to be created including graphs, visuals and various experimental tools (Bülbül & Eryılmaz, 2012). Pablico (2010) states that when familiarity with physics increases, the number of misconceptions students has decreases. Watching may be a source to experience an event but blind students use social interactions instead of visual senses. In other words, their friends' explanations contribute their conceptualization instead of their personal visual experiences. This type of indirect experiences is not a privative factor for their conceptualization.

We think that the purpose of this research is to provide a case for blind and visually impaired students to be included in an inclusive curriculum. For these students to benefit from this approach, first their pre-instruction knowledge has to be assessed. Then within the formal physics teaching instructors need to create materials and tools to support learning. In addition peer support and collaborative learning need to be incorporated into all lessons.

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