TITLE: INTERACTIVE ENGAGEMENT MODELS IN PRE-SERVICE SCIENCE TEACHER UNDERSTANDING OF MECHANICS

Authors:

M. N KHWANDA. **University of Johannesburg. email: mkhwanda@uj.ac.za**

J. KRIEK. **University of South Africa**

I. BASSON. **University of South Africa**

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Abstract

The study was conducted to first year pre-service physics teachers at the Central University of Technology, Free State. The pilot Force Concept Inventory tests results conducted in 2007 indicated that students did not master Newtonian mechanics from high school. The Physics Education Research community internationally, suggested the use of interactive engagement models to bridge the students' conceptual gap in Newtonian mechanics. It is against this background that this study was conducted to explore the impact of interactive engagement models, Whole Class Discussions and Computer simulations on the students' conceptual understanding of Newtonian mechanics. The findings of this study suggest that the interactive engagement models used had a positive impact on students' conceptual understanding of Newtonian mechanics. The findings imply that using more than one interactive engagement models of instruction can have a greater chance of enhancing students' conceptual understanding of Newtonian mechanics.

Key words:

Interactive-engagement, Whole Class Discussion, Computer Simulation, epistemological beliefs, physics education, teacher training, conceptual understanding

1. INTRODUCTION AND BACKGROUND

The teaching of Newtonian mechanics is regarded as the most extreme example of the failure of the teaching of physics at high schools and the beginning college/university level (Hake, 1987). The failure is accredited to traditional models of instruction which are reported to fail in enhancing and building students' understanding of Newtonian Mechanics (Hake, 1998, 2002). For example, traditional teaching approaches were used in baseline study conducted in 2007 with 41 first year students who entered the B.Ed (FET) Natural Science at Central University of Technology. The analysis of the different items of the Force concept inventory instrument (FCI) (Hestenes, Wells, & Swachamer, 1992) indicated that the student-teachers had misunderstandings regarding certain concepts in Newtonian mechanics even after traditional instruction. Interactive engagement models as opposed to traditional instruction are reported to be effective because students are actively involved during the teaching and learning process. In this study, it was assumed that the involvement of student-teachers in the use of the new integrated-interactive teaching approaches could lead to ownership and the application of the new approaches in their own classes (Guskey as cited by Gunstone, McKittrick and Mulhall, 1999, p. 524) which might result in measurable conceptual gain. This exploratory study was done to determine if student teachers can improve their conceptual understanding if they are confronted with interactive engagement models in their physics training.

Two integrated-interactive teaching approaches Whole Class Discussion (WCD) and Computer Simulations (CS) were introduced the following year in 2008 to a new cohort of first year students (76). These models are reported to be superior in promoting students' conceptual understanding of physics, (Savander-Ranne & Kolari, 2003; Cahyadi, 2004) and on reducing misconceptions students have (Cahyadi, 2004). WCD were structured from the cognitive discussions which demand intellectual engagement and the recognition of existing ideas from all students in the class (Gunstone, McKittrick and Mulhall, 1999). CS was introduced because the use of tools in physics is reported to have helped students in the transition from mindless memorization to understanding and appreciation of concepts (Wieman & Perkins, 2005).

2. INTERACTIVE- ENGAGEMENT MODELS

2.1 WHOLE CLASS DISCUSSION

Whole class discussion is defined as ideas generated by individuals or during small groups to assist students to link and apply these ideas to other relevant contexts and then share their solutions with the whole class (Ybarra, n.d., Wood, Cobb & Yackel, 1993). However, the quality of whole class discussions depends on the opportunities created for reflection and the degree of students' ownership (Jones & Tanner, n.d). WCD is a complex activity that needs dynamic teachers/lecturers to encourage students to participate, while discouraging few individuals from dominating the discussions. A key issue is to create an environment where students need to feel comfortable asking genuine questions and free challenge teachers when they disagree.

WCD can be used for sharing and explaining a variety of solutions by which individual students have solved problems. As students address challenges to their methods, they strengthen their understanding of concepts and procedures as well as identifying misconceptions they have (Grouws & Cebulla, 2002). All students are involved all the time because they are obligated to wait to be nominated to speak, to respond when questioned and to have their talk evaluated by others (Snow, 2003). In addition, WCD provides good opportunities for students to actively engage themselves and construct their own knowledge (Hatano & Inagaki, 1991). Salient students can learn through peers' utterances (Hatano & Inagaki, 1991; McGraw, 2002).

Disadvantages surface when WCD is used for large groups of students because many students remain silent and may lose interest in the discourse and fail to learn (Inagaki, Hatano, & Morita, 1998). Furthermore, if the view of science teaching and learning by students is different from that of the teacher, a barrier to teaching and learning can be created (Scott, Asoko & Driver, 1992). The challenges were solved by first discussing the motive for using WCD and why sharing of ideas would be crucial.

2.2 Computer Simulation

Computer Simulations (CS) are programmes used in physics to model the behaviour of a physical system and allow students to explore and visualize graphic representations (Concari, Giorgi, & Giacosa, 2006). They also generate a high level of engagement, exploration and understanding among students of diverse backgrounds (Perkins & Wienman, 2006). Before the introduction of simulations in the teaching and learning of physics, computer applications were only used to facilitate various tasks like data acquisition, provision of real-time data display and in analysis of data (Finkelstein, Adams, Keller, Podolefsky, & LeMaster, 2005).

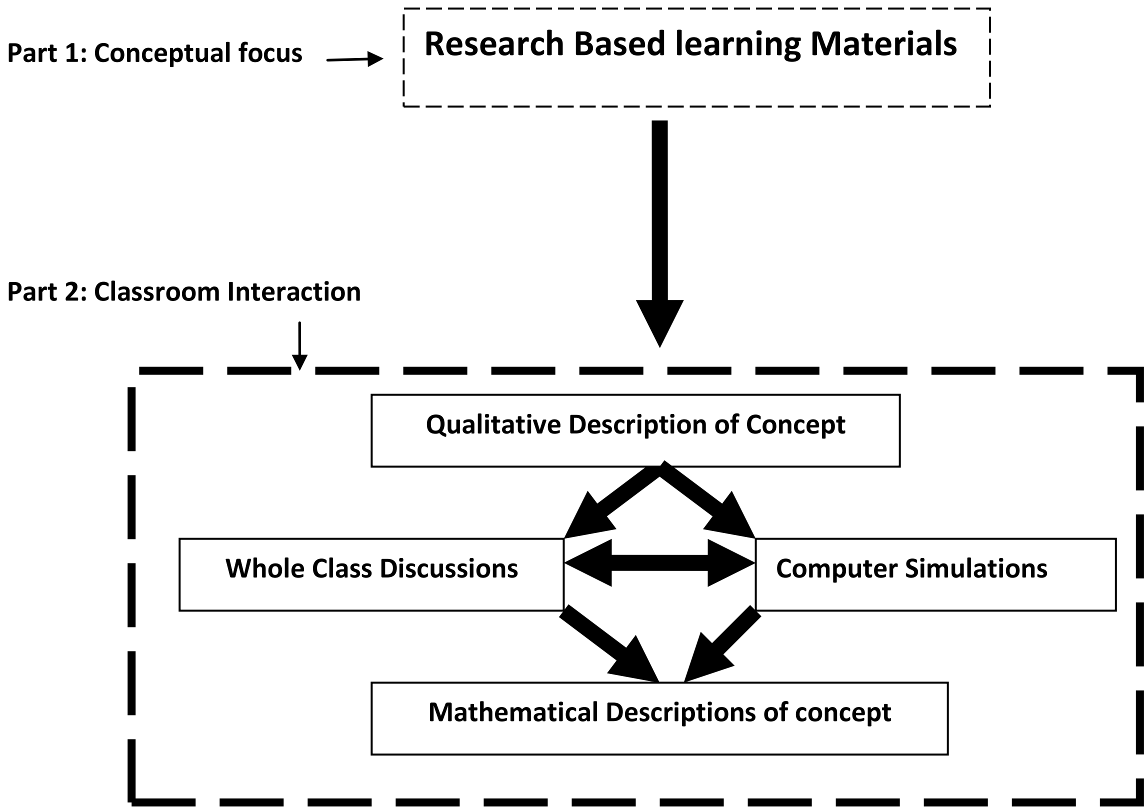
CS offers students a unique opportunity of experiencing and exploring a broad range of environments within the walls of the classrooms. Students can observe and manipulate normally inaccessible objects, variables and processes in real time. CS makes experiments which are difficult to carry out in the laboratory possible (Choi & Parker, 2003; Concari, Giorgi, and Giacosa, 2006). For example, the research which is currently in progress on tracing exactly what happens immediately before the Big Bang can only be done using simulations because the Big Bang happened many years ago. When working with simulations, students can interact with the system, modifying its state, changing parameters and observing the results of manipulations (Concari, et al., 2006). They can be good in improving students' hypothesis constructions and prediction skills (Sahin, 2006).

However, advocates of hands-on experiences in laboratory see simulations as potentially harmful to students because they lack pedagogical characteristics and real touch of the physical apparatus (Corter, Nickerson, Esche, Chassapis, Im, & Ma, 2007). Touching the real physical apparatus was regarded as important learning opportunities. They further claimed that up to date, there have been no large randomized studies which examine how these technologies might affect learning outcomes.

3. THEORETICAL FRAMEWORK

The Interactive Conceptual Instruction (ICI) Model by Savinainen and Scott (2002) was adapted to form an Integrated-Interactive Conceptual Instruction Model (IICI). In the adapted IICI model, the last component (the use of text) in the ICI model was replaced by a component called "a mathematical description of concepts". The component was included in order to show students the relationship between mathematics and physics. The IICI model, grounded by constructivism theory, is an integrated-interactive approach used in the study to enhance conceptual understanding of Newtonian mechanics and to promote students' active engagements. It consists of two parts as illustrated in figure 1.

Figure 1: An Integrated-Interactive Conceptual Instruction Model (IICIM)



Part 1: Conceptual focus stage using research based materials

The aim of this part is to develop conceptual understanding using research based materials as the link. Research-based materials are carefully selected by the lecturer and comprises of concepts tests, questions, exercises or demonstrations to initiate classroom discussions in line with cognitive conflict strategies. The topics chosen were also informed by research and were regarded as indispensable for the future understanding of other topics and revolved around questions about position, speed, velocity and acceleration. Appropriate CS programmes selected were grounded by research on how students learn, taking student conceptual difficulties and misconceptions into account.

Part 2: Classroom-Interactions and mathematical description of concepts

This stage involves the promotion of classroom interactions using WCD and CS. Students' interaction is the key element of constructivist theory and therefore students' prior knowledge has to be taken into account. This stage focuses on the development of conceptual understanding by utilising the principle of concept first with little or no mathematics (Savinainen & Scott, 2002b). In other words, a concept is discussed through WCD or CS to gain more qualitative understanding of the concept under discussion. This stage deals with the qualitative description of the concept and only when students have a good grasp of the concept then mathematical description can be done as a summary of the concept taught. It was previously suggested that students should have some practice in qualitative reasoning about the phenomena under study before mathematical formalization is introduced (McDermott, 1998). Therefore all stages one way or another overlapped with one another. For example, the conceptual focus can be determined and is dependent on research-based resources and classroom interactions envisaged.

3.1 THE PROCEDURE FOR THE APPLICATION OF THE INTEGRATED-INTERACTIVE CONCEPTUAL INSTRUCTION MODEL (IICI-MODEL)

The procedure for the application of the IICI model was done using the following steps:

(a) Based on research, the lecturer selected suitable conceptual questions for WCD and appropriate CS programmes. Different software programs were selected because they were found to facilitate students' development of understanding of Newtonian mechanics and uses model-based reasoning (Thomas, 2001). The simulations programs were chosen because students could play around with the variables and get different results and can draw conclusions within a second. Computer simulations activities were demonstrated using a data projector in class and in other activities students individually used computers in the laboratory.

(b) Students individually or in small groups find the solution or work on the computer.

(c) Nominated or volunteered students share the solution with the whole class or students were asked to play around with the variables, get different results and draw conclusions from the computer.

(d) During WCD, the following adapted procedures from (Gunstone, McKittrick, & Mulhall, 1999) were followed.

    (i) The whole class is asked to agree or disagree with the speaker one at a time and always with reasons. For example, the moment he or she stands up, when answering, the first thing is to say: I agree or disagree with speaker **X** because of the following reasons.

(ii) The whole class again is given an opportunity to ask follow up questions or to disagree with the previous speaker etc.

(iii) During the process, the lecturer, when necessary, ask provoking questions to motivate students to further discuss the problem. The process continues until the whole class is satisfied.

(e) The lecturer would show a demonstration using CS with a data projector to either introduce a topic or reconfirm their understanding after a WCD. The lecturer then summarises the discussions and lastly discusses the mathematical concepts involved in the topic.

(f) Students are given conceptual multiple choice questions, concept questions and problems that require mathematical calculations on WebCT. (WebCT is an online virtual learning system (course tools) that is sold to educational institutions. Instructors can communicate with all students and can also add or delete the learning material placed on WebCT courses. It is accessible to where there is an internet connection by simply login your username and password.)

(g) Students discuss the problems with a Supplementary Instructor (SI) when they have difficulties in answering them or they consult the lecturer.

4. RESEARCH DESIGN AND INSTRUMENTS

4.1 Research Design

The Pretest-Posttest design was used because the aim of the study was to evaluate the impact of the models of instruction (Raffeld & Reynolds, 1977) by comparing groups with an aim of measuring change (Dimitrov & Rumrill, 2003). In order to measure change in conceptual understanding of Newtonian mechanics, participants were tested before and after interventions (Bless & Higson-Smith, 1995) by using the FCI. A CS survey and interview questionnaire was used to triangulate the results from the FCI pre- and post-tests.

4.2 Research Instruments

4.2.1 *Force Concept Inventory (FCI)*

The FCI is composed of 30 multiple choice questions designed to probe students' beliefs and how these beliefs are compared with Newtonian Concepts (Hestenes, Wells & Swackhamer, 1992). It is regarded as one of the most carefully researched tools to probe student conceptual learning in Newtonian mechanics (Steinberg & Sabella, 1997). It compels students to make a choice between common sense beliefs and the Newtonian counterpart (Hestenes, Wells, & Swackhamer, 1992). Since its publication in The Physics Teacher in 1992, it has played a major role in the development of curriculum and instructional strategies (Steinberg & Sabella, 1997). The instrument is usually used for the evaluation of instruction and as a diagnostic tool to identify and classify misconceptions (Hestenes, Wells & Swackhamer, 1992). It can help the teacher to analyse the students' thinking based on the misconceptions they have. It also " provides a potent tool not only for improving student learning but also for improving teachers understanding and approaches to teaching" (Savinainen & Scott, 2002, p. 52). Hake (2007; p. 25) noted two major advantages of using FCI tests, namely:

(a) Its multiple-choice formats facilitate a relatively easy administration of the tests to thousands of students;
(b) The questions probed for conceptual understanding of the basic concepts in Newtonian mechanics are presented in a way that is understandable to the novice who has never taken a physics course.

In addition to the advantages mentioned above, Savinainen and Scott (2002) claimed that the instrument can be used as a tool to monitor student learning and to plan teaching while Savinainen and Viiri (2008) showed that it can be used as a measure of students' conceptual coherence.

However, the instrument is said to be difficult to interpret and tend to overestimate students' learning due to its multiple choice format because sometimes students can guess the correct answer (Redish, 2003).

Based on the fact that it was administered world-wide and consistent results under different contexts were obtained, it was no longer necessary to conduct reliability and validity tests of the instrument.

The modified version of the FCI used in the study (Hake, Halloun & Mosca, 1995), took into consideration some of the comments and suggestions made on earlier versions (Redish, 2003).

4.2.2 Computer Simulation questionnaire

The first draft of the CS questionnaire was constructed and given to colleagues to check if it will serve the purpose it was intended for. After inputs and suggestions, the questionnaire was administered to third and second year students during the first term. Based on the analysis of their responses, corrections were made and the corrected version was given to first year physics students after they have done the computer simulations. The questionnaire consists of 15 questions. The first 2 questions were asked to obtain information on their general proficiency on the use of computers before they started with the simulations. Other questions probed answers as to whether CS helped them to understand concepts they did not understand in class or if they further confused them. The last question was an open-ended question that required students to comment or share their experiences or concerns regarding the use of CS in a physics class.

4.2.3 *Structured Interviews*

Structured interviews were conducted to gain an in-depth understanding of the impact of WCD and CS on the conceptual understanding of Newtonian mechanics and the overall feelings about the students' preferred models of instruction. The interview questions consisted of two conceptual questions directly taken from the FCI and one question to indicate their preference between the two interactive-engagement models used with an explanation.

5. RESULTS AND DISCUSSIONS

5.1 WCD activity

Based on research, the lecturer selected suitable conceptual questions from literature and experience and then allowed the students to find the solutions to the questions either individually or in small groups at the start of the lecture. Speed and its effect on real life are rather challenging and therefore the following activity was selected as an example. All the questions had to be answered individually. The students' responses to the first question were classified into three categories; correct, partially correct and incorrect.

Activity 1: – Speedster got caught

Read the following passage adapted from News24 (2007) and then answer all questions giving reasons.

"The founder member of a popular Radio Station is apologizing for being found on the wrong side of the law this week. While driving from the Eastern Cape on Sunday, he was stopped by the traffic official driving his Audi TT at 257km/h in a 120km/h zone."

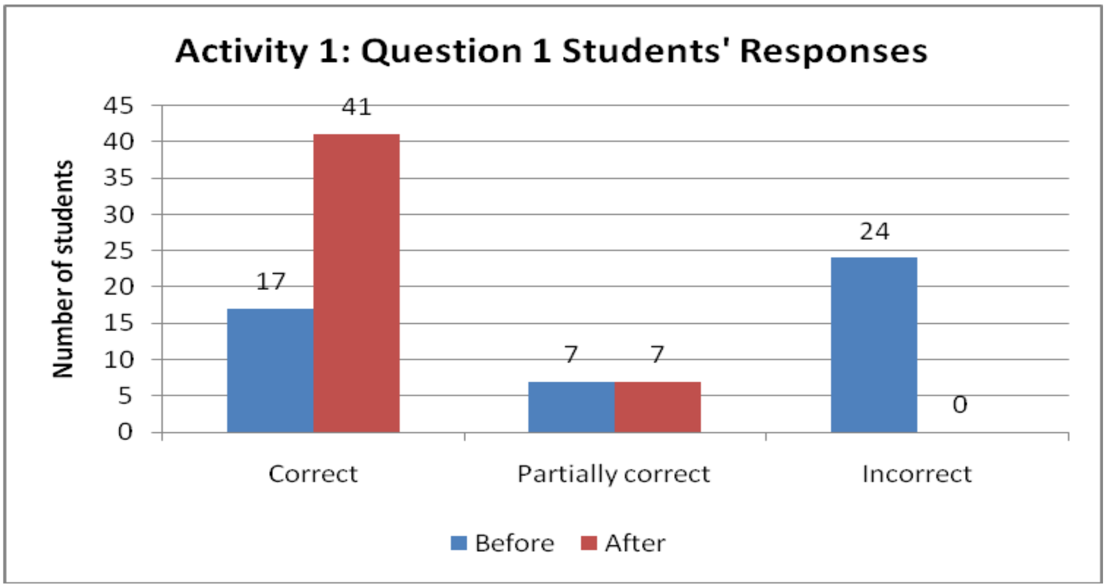
Questions:

1. Define speed using your own words.
2. Is 257 km/h he was caught driving an average or instantaneous speed? Give reasons for your answer.
3. Do you know that speed kills? Give reasons for your answer.

Correct responses were considered as scientifically acceptable, while partially correct responses were considered when a few things lacked to make them acceptable and incorrect responses were regarded as being unscientific. Figure 2 shows that only 17 (35%) students gave the correct definition of speed while 7 (15 %) got it partialy correct and 24 (50%) responded incorrectly to the question.

The activity was then discussed in a class. In an examination which was written 4 months after the WCD intervention, the same question was asked. The number of students who answered correctly were 41 (85%).

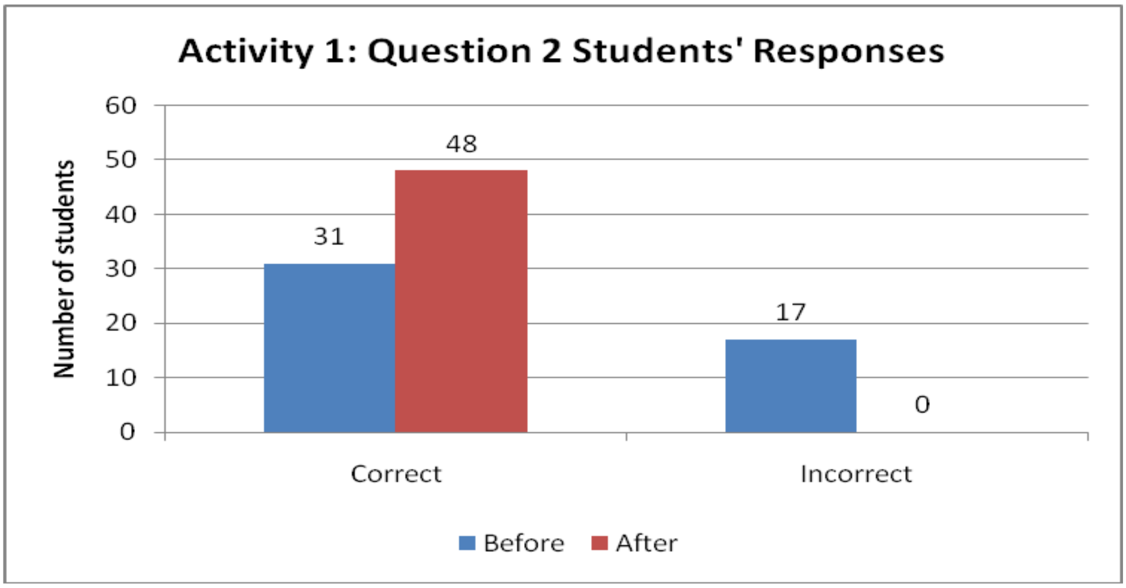
Figure 2: Results of students' understanding of speed



The findings on this question show that most students initially relate speed with anything greater than 120km/h. This finding supports Bayraktar (2008) who claimed that students' prior knowledge is sometimes different from the scientific view. Their way of thinking started to change after the WCD. The result of this activity showed that WCD succesfully helped students to understand the definition of speed and was demonstrated by the fact that 85% of the students defined speed correctly after the intervention 4 months later. The results suggest that WCD was successful in helping the students to retain their new understanding of speed for a longer time after the intervention.

The second question was correctly answered by 31(65%) before the intervention, as shown in figure 3 but only 2 out of 31 gave the correct explanation or reason. The results suggest that most students were able to choose or guess the correct answer, but had incorrect reasons. Before the intervention, most students did not understand the difference between instantaneous and average speed. For example, some students understood instantaneous speed to be a very high speed, while average is a normal speed. One can conclude that WCD helped in revealing some of the misconceptions the students had.

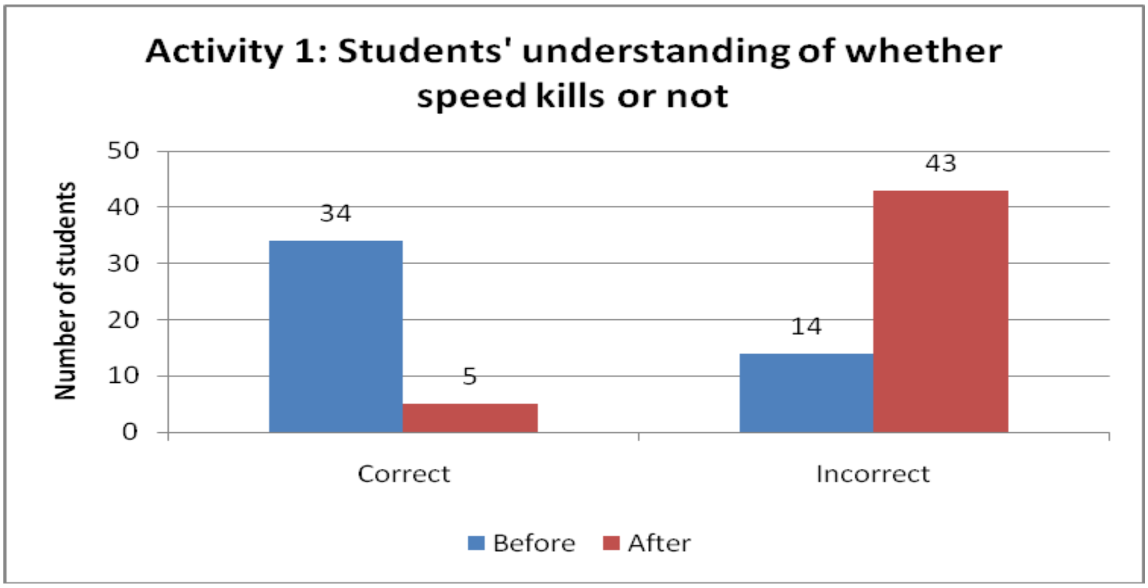
Figure 3: Students' understanding of the difference between instantaneous and average speed



The fact that all students differentiated between instantaneous and average speed 4 months after the intervention, showed that WCD had a positive impact on the students' conceptual understanding of instantaneous and average speed. The results of this question concur with Fagen, Crouch and Mazur (2002) who claimed that students' discussions sometimes waste time, but have a considerable learning gain.

In question 3, before the WCD, 34 (71%) students in the sample as shown in figure 4, thought speed kills, but the reasons they gave were not scientific and again depended on the South African Arrive Alive campaign. After the intervention, the students were able to defend their options using reasonable scientific explanations.

Figure 4: Results of students' understanding of whether speed kills or not



One of the lecturer's conversations with students during WCD was as follows:

Lecturer: What is speed?

Student A: Change in position with repect to time or distance covered per time interval.

Lecturer: Do you think speed kills

Student B : Yes, it kills

Lecturer: O' K, you said speed is change in position with respect to time. Is that so?

Student B: Yes

Lecturer: Then look at me, I am walking from one corner of the class to another. Did I speed up?

Students: Some said yes and some said no

Lecturer: For those who said no, why?

Student A: Because it was slow and you did not reach 120 km/h.

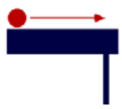
From the conversation, it was clear that the students had memorised the definition but don't know its meaning. After the conversations, students endend up realizing that speed is just a change in position with repect to time. After the intervention 43 (90 %) students changed their ideas and said speed alone does not kill. The results support the idea by Mbajuiorgu and Reid (2006) about some of the skills that are developed through the learning of physics. According to them students who are studying physics should be able to learn to weigh evidence and take reasonable decisions. From the conversation above, students made decisions by weighing evidence and came to a sound scientific conclusion that speed alone does not kill. The results of this question seems to be consistent with those of Heron, Shaffer and McDermott (2007) who found that students deepen their understanding of difficult concepts when they first go through reasoning development strategies. These reasoning development strategies are also possible when using WCD instructional model.

5.2 Combined WCD and CS activity

In this activity, both WCD and CS were used to show how the two models can be integrated. Students were asked to predict answers for the following question:

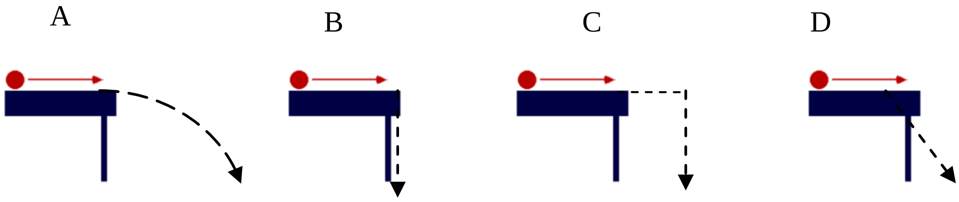
Question:

Predict and draw the path of motion of the ball immediately after it reaches the edge of the table.



Their predictions were categorized into A (the accepted scientific path), B (the ball falls directly downwards), C (the ball first travel in a straight line and then falls down) and D (the ball falls at a fixed angle to the ground) as shown in figure 5

Figure 5: Predicted paths of the ball



A summary of some of the notable interesting reasons given by the students for selecting their options were as follows:

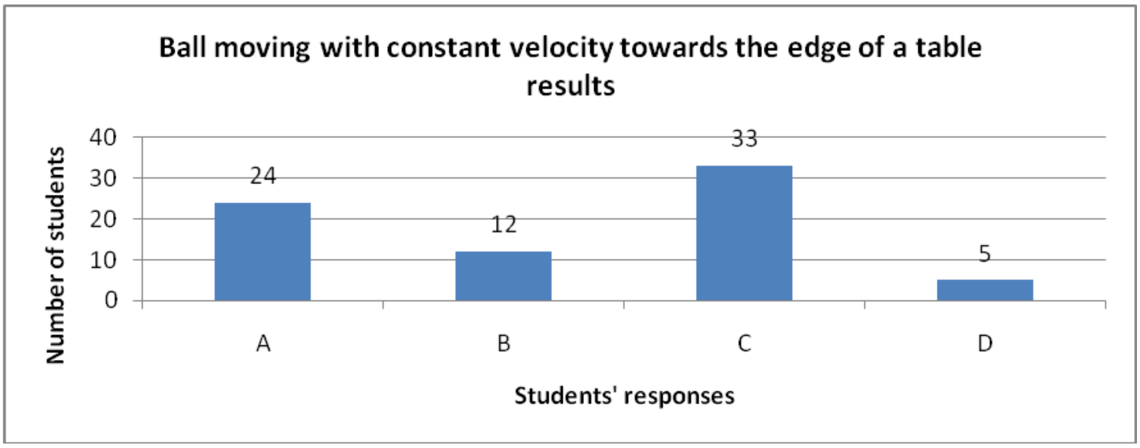
Option A: Air resistance makes the ball to curve and the gravitational force changes its original direction.

Option B: The only force that is acting is of gravity that usually acts directly downwards

Option C: The ball will continue moving with 2 m/s just after it leaves the edge of the table and stop at certain point and then due to gravity the ball will go down with g.

The results of predictions indicated that 24 (34%) students got it right as shown in figure 6.

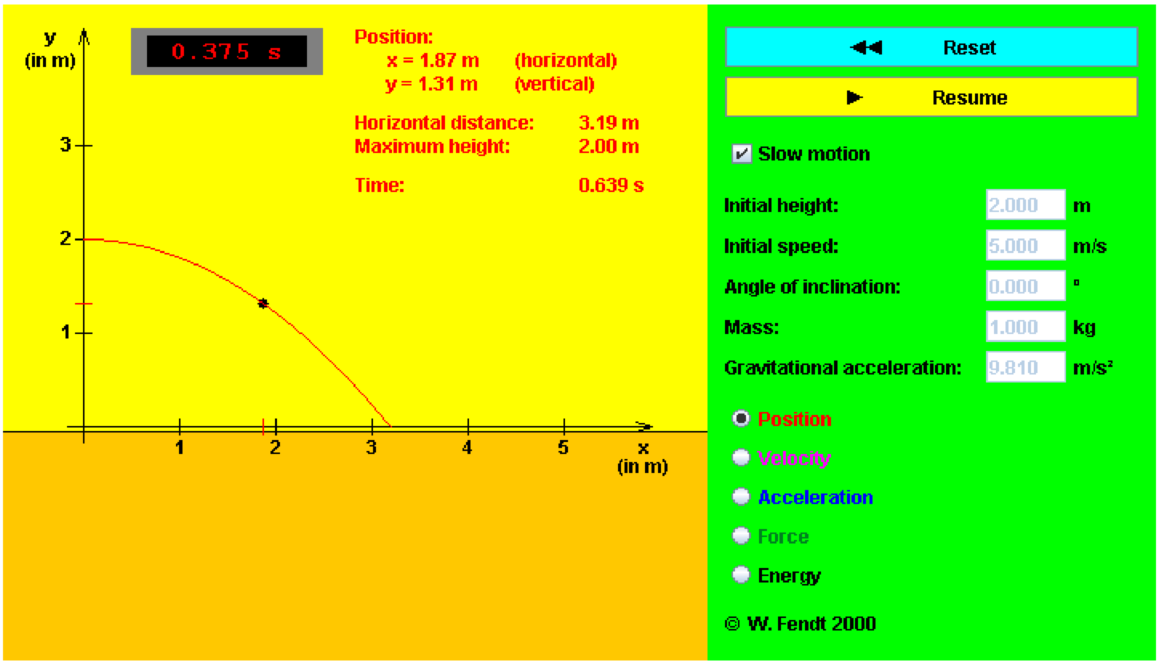
Figure 6: Ball moving constantly towards the edge of a table results



The reasons given by students were not new in Physics Education Research (PER), especially A and C. They were similar to those reported by Halloun and Hestenes in 1985. Those who selected option D were not able to explain their reasons, and were therefore not included in the discussion above.

After students discussed their responses through WCD, the activity was then repeated as a demonstration using a CS shown with a data projector. The display on the screen is shown in figure 7

Figure 7: Ball moving constantly towards the edge of a table computer simulation display screen *http://www.walter-fendt.de/download/ph14dl.htm*



After looking at the screen, students were again instructed to reconsider their previous answers and then in pairs, give reasons for sticking to their answers or for changing them. The ball was represented by the black dot on the simulation. After students observed the path of the black dot as shown in figure 7, they nodded their heads and some even said: "*Ahaa! Now I can see why*."

In this activity, steps of the IICI model was followed by choosing a critically challenging question to alleviate possible misconceptions, evaluate the students' answers by categorizing them, then introduce both interactive-engagement models. The fact that half of the sample got it correct in the post-test shows that the intervention through both WCD and CS simulations helps students to apply knowledge in different contexts, which is a sign of understanding.

5.4 Results of FCI

The 2007 FCI pre and post test results indicated that no students managed to get at least 15 (50%) as shown in table 1. The percentage class average score of 60% in FCI is regarded as an entrance score for students beginning to comprehend Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992). Students got the mean of 21% and 27% in pre and post-tests respectively. Even in 2008, the FCI pre-test mean was 21% with the same skewness of magnitude 0.45. Results from the baseline FCI test and the 2008 FCI pre-test indicated that students did not master Newtonian mechanics during their high school years.

Table 1: Summary of 2007 and 2008 FCI results

Variable	N	Mean	StDev	Minimum	Maximum	Skewness
FCI Pretest 2007	39	6.38	2.79	1	13	0.45
FCI Posttest 2007	39	7.97	2.94	1	14	0
FCI Pretest 2008	48	6.15	2.66	2	12	0.45
FCI Posttest 2008	48	9.52	2.68	5	16	0.51

N: The number of participants for each variable.
Mean: The average value or the arithmetic mean for the variable.
StdDev: The standard deviation - an indication of how closely values are clustered around the mean.
Minimum: The smallest value obtained for a variable.
Maximum: The largest value obtained for a variable.
Skewness: An indication if the distribution of values are symmetrical or not

An analysis of all the responses in the FCI questions indicated that students had misunderstandings regarding certain concepts, which could be the consequence of common sense knowledge that they possess about the concepts.

When evaluating models of instruction, the percentage class average normalized gain was used because it is recognized by PER as a figure that can be used to determine the extent to which the intervention is effective (Hake, 2007; Redish, 2003). The effectiveness of the models of instruction was classified according to the average normalized gain as follows:

High-g courses: $\langle g \rangle > 0.7$

Medium-g courses: $0.3 < \langle g \rangle < 0.7$ and

Low-g courses: $\langle g \rangle < 0.3$

According to the classifications suggested above, low-<g> courses are associated with traditional models of instruction which were operationally defined by Hake (1998) as “those that relied primarily on passive-student lecturers, ‘recipe-following’ laboratory sessions and algorithmic quantitative problem solving examinations”. The high <g> courses were regarded as those that mostly used interactive-engagement models while the medium <g> courses were those that integrated both traditional models and the interactive-engagement models.

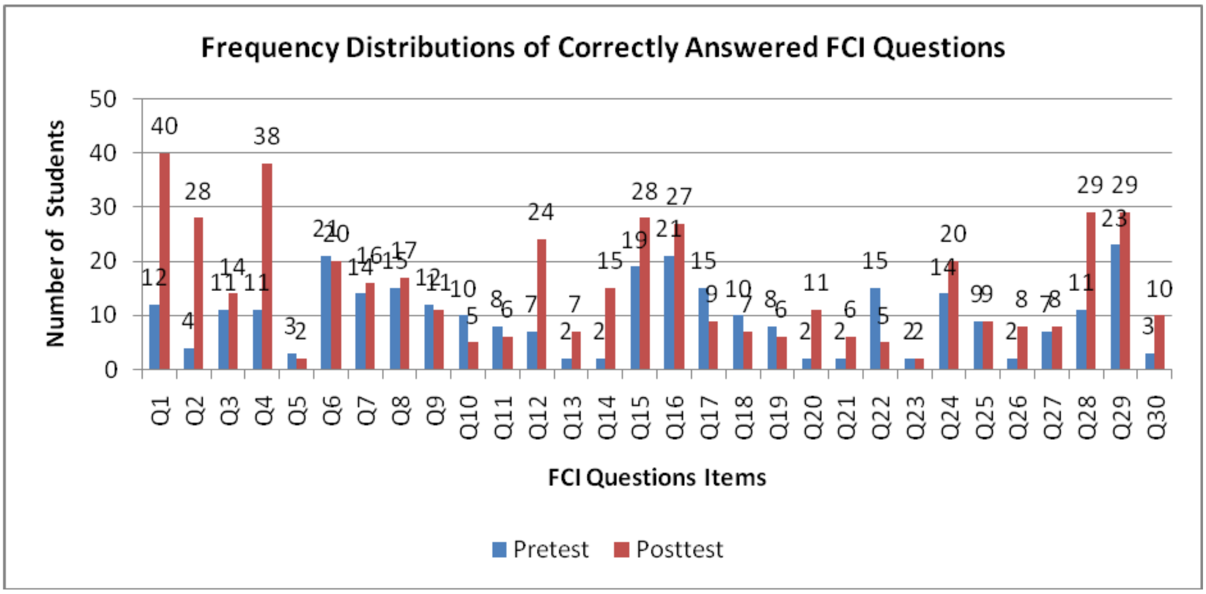
The average normalized gain for the pilot FCI test was 8 %, which is associated with traditional instructional model. The results of the pilot FCI tests and 2008 FCI pre-test support the idea of Halloun and Hestenes (1985) who claimed that traditional models do little or nothing in terms of bettering students’ conceptual understanding of Newtonian mechanics.

In 2008, pre-test scores range from 2 (7%) to 12 (40%) while the post-test scores range from 5 (17%) to 16 (53%). The percentage class mean for both the pre- and post-tests are 6 (21%) and 10 (32%) respectively. The percentage pre-test mean is less than the pre-test mean as expected from the literature. For example, the most typical class average scores for students entering an algebra-based introductory physics course in FCI pre-test are between 30% and 45% (Redish, 2003). The pre and post-test means were better when compared to means obtained in the pilot FCI results.

The skewness values of 0.45 and 0.51 in both pre and post-test 2008 respectively show that few students managed to score higher than the mean. The skewness value greater than zero, implies that both FCI pre and post-test were difficult to students. The analysis of the frequency distribution of correct answers per question on the FCI as shown in figure 8 indicated that:

- no change occurred in both the pre- and posttest (Questions 23 and 25)
- positive changes occurred in 19 questions (Questions1-4,7, 8,12 -16,20,21,24,26 - 30)
- negative changes occurred only in 9 questions (Questions 5, 6, 9-11,17 -19, 22)

Figure 8: Frequency distribution of correctly answered FCI questions



The changes in the FCI scores in the pre and post-test support the idea that the effect of distracters changes during the course of instruction (Rebello & Zollman, 2004). Negative changes that occurred in some questions could have been caused by the fact that the related content was not covered during interventions, for example, circular motion. Since all students were English second language speakers, the study cannot rule out the impact of language on the FCI test items, as the other possibility of low performances by students (Pearce & Le Roux (n.d.)

Looking at the low scores both in the pre and post-test, one could conclude that even after intervention using the WCD and CS which are interactive-engagement models, students still had some misconceptions. The study supports the idea that misconceptions are mostly resistant to change and that conceptual change is not a quick and simple process (Grayson,

2004). Amongst physics education researchers, the general agreement is that, a low FCI test score indicates a lack of understanding of basic concepts in mechanics (Hake, 1998).
The descriptive FCI results have shown that there was an improvement in average class performances because the percentage class mean changed from 21% to 32% after intervention using WCD and CS. The performance in the post-test was disappointing since only 3 students managed to get a percentage greater or equal to 50. In other words, 94% of students scored less than 50% in the post-test.

Table 2 contains the data used in calculating the average normalized gain. The calculations of the average normalized gain in the study using Hake's formula yielded $\langle g \rangle = 0.14 = 14\%$

Table 2: Data used to calculate <g>

	Mean (%)	StDev (%)
Pretest	20.5	8.86
Posttest	31.7	8.94
<G>	11.2	
<g>	15.0	

Where <G> is the actual gain, <g> the average normalized gain and StDev, the standard deviations from the mean.

Interpreting the average normalized gain using Hake's scale, a value of 0.15 (15 %) implies that this result is comparable to the results from settings of traditional models. This contradicts with the current study where interactive WCD and CS models were used. Fully interactive-engagement models of instruction are said to be associated with average normalized gains in a region greater than 0.7 or 70%. The low <g> for the FCI was also reported in South Africa by Pearce and Le Roux (n.d.) at the University of Cape Town's Department of Mechanical Engineering where both traditional and interactive-engagement models of instruction were used. The use of both traditional and interactive-engagement models is presumed to yield the average normalized gain of between 30% and 70% because they are classified under medium <g> courses (Hake, 1998).

Since the normalized gain tells about the attainment of minimal conceptual understanding of mechanics (Hake, 2002), the study shows that both WCD and CS induced minimal conceptual improvement in Newtonian mechanics. Another reason that could be the cause of the low <g> according to the literature, were the students' initial qualitative pre-knowledge and beliefs about motion and this is reported to have an impact on students' performance in physics (Halloun & Hestenes, 1985). For example, in the exercise about speed, students initially thought speeding in South Africa is travelling above 120km/h. That showed the lack of qualitative understanding of the concept speed.

FCI Paired t-test results

A *t*-test was conducted on the overall pre and post-test data to examine the possible impact of instruction. The means of the tests were statistically significantly different at the 1% level ($t = 7.45 > 2.408$; $df = 47$; $p = 0.00$). The conclusion was that the mean difference between the paired observations is statistically significant, which showed the significant difference between the means was probably due to intervention using WCD and CS. The conclusion drawn from both average normalized gain and t-test suggests that both WCD and CS models enhanced students' conceptual understanding of Newtonian mechanics. The FCI results of this study seem to support the idea that: "Teaching science for understanding is a complex issue" (Gabel, 2003, p. 75).

5.5 Results from the CS Questionnaire

The CS survey was completed by all students present at the time of writing because it was just a once-off activity done after the interactive interventions. All the students who completed the CS questionnaire were considered for data analysis. Table 3 indicates how question item numbers were grouped into axes.

Table 3: The descriptions of the axes and CS questions items

Axis	Questions probed	Question item number
1	Knowledge of working with computer before	1 and 2
2	Clarifications of physics concepts	3 , 4 and 14
3	Encouragement of independent working	5, 6, 7, 8, 9 and 10
4	Preference of when simulations can be done	13 and 14
Open ended	Students' general feelings about the use of CS	

Descriptive analysis was used and the scores were converted to a scale ranging from 0 to 4 and different questions were scored differently (See Table 4). Axis 1 and 2 had an average mean of 3.37 (84%) and 3.16 (79%) respectively. The high average means of these axes have shown that most of the students had a working knowledge of a computer from high school and they believed that CS encouraged them to work independently.

Table 4: Descriptive Analysis of CS questionnaire results

	Mean	StdDev	Minimum	Maximum	Skewness
Overall	2.98	0.39	1.90	3.80	-0.46
Axis 1	3.37	0.90	0.00	4.00	-2.00
Axis 2	3.16	0.62	1.66	4.00	-0.35
Axis 3	2.73	0.64	0.66	3.83	-0.84
Axis 4	2.25	0.53	1.00	3.50	0.02

The overall preferences for using simulations as shown by axis 4 indicates that 2.25 (56%) of the students thought that computer simulations were helpful in enhancing their conceptual understanding of physics.

The overall results of the CS about the general feelings of the students suggest that about 75 % as indicated by the overall mean results in table 4 felt that CS had a positive impact on their study of Newtonian mechanics. The students further thought that CS encouraged independent working, helped to clarify physics concepts and increased their interest in physics. The results concur with Choi and Parker (2003) who reported the increase students' interest when using CS and Perkins and Wieman (2006) who claimed that CS generate a high level of engagement, exploration and understanding among students of diverse backgrounds and ages.

From the open ended questions it was found that 20 (31%) students prefer to be taught using WCD, another 20 (31%) prefers CS and 18 (28%) students. Students' reasons in this question suggest that CS can help students to develop the following valuable skills in physics and in life such as; be able to analyse data, draw conclusions, work independent and improve their computer skills.

From the reasons given, the study seems to have confirmed McCorduck's assertion (as cited by Thomas , 2001, p. 30) that a computers increase students' usage of high order thinking strategies such as, being able to analyze and to make deductions. Some of the reasons given by the respondents who prefer both WCD and CS were the following:

Respondent 24: "In WCD we mostly listen and in CS we do".

Respondent 25: "Computer shows calculations and diagrams whereas explanations are done in WCD".

Respondent 26: "Performing experiment and discussing help to acquire more knowledge".

Respondent 27: "Simulations help to rectify some of the mistakes done in class".

5.6 Results from the Structured Interview

The structured interviews were conducted to gain an in-depth understanding of the impact of WCD and CS on conceptual understanding of Newtonian mechanics, the overall feelings about the students' preferred models of instruction and lastly to triangulate the results obtained from FCI and CS surveys.

The interview conducted to a sample of 19 randomly selected students which represent 40 % of the population. The first question was taken directly from question 15 of the FCI test. In the FCI 40% and 58% of the students answered correctly in the pre and post-test respectively. The interview results of the same question gave a different picture. Only 24 % of the sample answered the question correctly stating Newton's third law of motion. The majority of the sample (64%) believed that force is directly propotional to mass. This contradicts Newton's third law. The results of this question show that students can still have misconceptions even after interactive engagement models were used to intervene.

The second question was taken from the FCI question item no 12, the number of students who answered correctly in both pre and post-test were 7 (15%) and 24 (50 %) respectively. A similar question was also dealt with using WCD and CS (described previously), the number of students who answered correctly were 24 (34%). This again indicated the presence of misconceptions and that WCD and CS were less effective in handling these misconceptions. The results of this question again support the fact that some misconceptions are deeply rooted and can be very difficult to be replaced.

The last question asked was to determine which of the two models they thought helped them to understand physics better. 41% of the students preferred WCD to CS, while 24% preferred to use CS only. Those who preferred both models constituted 35%. The results of this question suggest that it would be advisable to use both models in order to cater for most students. The results concur with Jimoyiannis and Komis (2001), who found that CS can be used to complement or serve as an alternative to other instructional tools.

6. Conclusion

Based on students' explanations during the interview, the WCD and CS were less effective in handling some of the misconceptions students have, but good in comparison to traditional models of instruction as indicated by average normalized gain of the pilot 2007 FCI results and 2008 FCI results. The overall conclusion suggested that both the WCD and CS when used hand in hand can have a great potential to enhance students conceptual understanding of Newtonian Mechanics. The study support the broader beliefs that implementation of new technology like computer simulations is the key to improving education (Thomas, 2001).

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