Learner Metacognition and Instruction: An Interactive Conceptual Approach in Newtonian Mechanics Instruction in Secondary Schools.

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Abstract: Since physics is one of the most important of the physical sciences and plays an important role in technological development, poor performance in the subject in National Examination has been of primary concern. Further assessment on the level of understanding of a concept immediately after instruction has disappointed even the most experienced of teachers on how little their students have learnt especially when instructed using the traditional approaches. As such this study sought to compare the performance of learners instructed using interactive-engagement conceptual approach (IECA) and those instructed using Traditional Approaches (TA). The theoretical framework for the study was based on the constructivist learning theory of Jerome Bruner. The theory lays emphasis on guiding learners as they build on and modify their existing mental models. The study population was students in all secondary schools in Uasin Gishu County. The sample size was seventy eight students in four secondary schools that were purposely sampled; thirty six in experimental group and forty two in control group. The new teaching approach was assessed using force Concept Inventory (FCI). The data obtained was analyzed using one-way ANOVA statistical technique at 0.05 level of significance and Hake's normalized gain. I believe the finding offers compelling evidence of enhanced student learning gains obtained as a result of using the interactive-engagement conceptual approach (IECA).

Key words: FCI, IECA, TA, and Newtonian Mechanics.

1. Introduction:

Although Newtonian Framework is essential to understanding non-relativistic motion, it is common for more than 80% of the students to answer most questions from a non-Newtonian point of view after an introductory course when traditional instruction is used in dynamics force and motion.

Such students may believe, for example that a net force is required in motion at a constant velocity, that there is a residual force (impetus) on an object that has been pushed and released that keeps it moving and that acceleration must increase as the velocity increases. In contrast, those using a conceptual framework based on Newton's laws of motion understand that a body moving at a constant velocity requires no net force to keep it moving and so no residual forces are required [1]. Research has shown that traditional instructions commonly change the conceptual point of view of an average of 10% of the students. This phenomenon is almost universal [2].

There is considerable evidence collected by researchers in physic as teaching and learning that traditional instructional methods – largely lecture and problem-solving coupled by a few laboratory experiments are not effective in promoting conceptual learning in

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physics. Previously also many lectures/teachers believed that when a student was capable of solving standard quantitative problems it was an adequate criterion for functional understanding of a concept, but when asked to relate the numerical problems with how they understood the concepts, many students could not relate the two adequately and in an understanding way, especially when they had been instructed using the traditional approaches where rote use of formulae is quite common. Researches from different sources and using different techniques have established that a coherent

conceptual framework where students can make connections among concepts, formal presentation, diagrammatic, graphical and the real world are often lacking after traditional instruction [3]. In fact many teachers are always surprised that despite their best efforts, students do not grasp fundamental ideas covered in class even some of the best students give the right answers but are only using correctly memorized words. When questioned closely, these students reveal their failure to understand fully underlying concepts. Students are often able to use algorithms to solve numerical problems without completely understanding the underlying scientific concepts. There [4] were reports that students in his physics class had memorized equations and problems-solving skills, but performed poorly on tests of conceptual understanding.

The teaching method: Interactive-Engagement Conceptual Approach (IECA).

The teaching method that was used was referred to as interactive-engagement conceptual approach that was developed to meaningfully develop conceptual understanding of the underlying concepts in force and motion. The philosophy behind this is that to develop a deep understanding of physics concepts and specifically mechanics require an interactive process in which learners are given opportunities to talk about and think through their ideas with the teacher and other learners [5].

2. Interactive-Engagement Conceptual Instruction had five aspects.

The first aspect was investigating the initial common sense beliefs of the learner on a given concept: this is the principle of concept first [6]. New ideas are first developed at conceptual level with little or no mathematics though investigating what learners really knew about the concept. This is done by carefully interviewing the students by letting them describe what they thought about a particular situation and have them work through a problem. Much effort goes into identification of fundamental concepts and student difficulties in specific areas in kinematics.

The second aspect of the IECA involve promoting different forms of classroom interaction and is based on the premise that mean making is a dialogic process where students benefit from talking through their developing ideas [7]. Here peer instruction is used to exploit student interaction during teaching and focusing students' attention on underlying concepts [3,8]. The third aspect involves use of research-based materials. Question-and-answer conceptual exercises designed by the teacher are used in the early stages of meaning making. The exercises give constant feedback on developing students understanding as advocated by Mazur. Research-based exercises serve as diagnostic tools which allow for more reliable formative assessment [9].

The fourth aspect involve modified use of textbooks: Here learners will not make ordinary lesson notes but instead make additions, remarks and underlining text/notes. In addition the students are asked to read the relevant section of the text prior to the lesson, thereby releasing them for active discussion.

Finally, the other aspect involves concept maps constructed by the teacher and used for summarizing sections of work. The concept maps allow the students to see the big picture and the relations of key ideas in a concise form [10].

3. Description of Research

Seventy eight form three students took part in the study; thirty six in experimental (E) group and forty two in control (C) group. A pre-test (FCI) was administered to both groups and the scores awarded. As expected, the scores for both groups were dismally low since the topic tested had not been covered by the subjects in any of the two groups. The means of the two groups were closely comparable. The experimental group was then instructed using IECA. The students in the control group were exposed to the same physics content through traditional Approaches (lecture, demonstrations and experiments). When the two groups had adequately covered the topic, a post-test (FCI) was administered. The pre-test results analysis is on table 1. The analysis of variance (ANOVA) of the post-test scores is presented on table 2.

Table: Comparison of Means Scores (MS), Standard Deviations (SD) and Mean Gain (MG) obtained on the FCI.

Scale	**E**	**C**
	(N=36)	(N=42)
Pretest mean	18.7	18.2
S.D	9.3	11.2
Post-test mean	36.7	27.05
S.D	7.74	9.67
Mean Gain	18.0	8.85
Hake’s normalized gain	0.22	0.108

Table 2: Analysis of Variance (ANOVA) of the post-test scores

Source of variation	Sum of squares (SS)	Degrees Freedom	Mean square (MS)	F-Ration	Significance
Between samples	739.38	1	739.38	10.52	0.05
Within samples	5,343.62	76	70		

For the current study the calculated F value is 10.52

From F distribution the critical value for dfb = 1, dfw = 76 and x = 0.05 is 4.0. the calculated value is therefore statically significant, it far exceeds the critical value of 4.0 needed to reject the hypothesis HO1 which stated:

There is no significant difference in the learning gains between students instructed using interactive-Engagement Conceptual Approach and those instructed using traditional approaches.

4. Discussion of Findings

The objective was to compare the level of performance and learning gains for students instructed using IECA and those taught/instructed using the traditional approaches that are often employed by teachers. The research findings show that the students in experimental group did better than the control group in the post-test. It must be borne in mind also that the mean of the pre-test for both groups were comparable and learning gains were due to the instruction. In related studies Savinainen [5,11] and Hake [12] found out that there were significant learning gains and profound understanding of mechanics when teaching approaches are developed that involve the aspect of interaction between learners and learners, learners and instructor. The teaching approach should consider the initial stage of the learner and the preconceptions that they usually have before instruction. Further Hake's normalized gain for the experimental group was 2.04 times that of the control group.

This suggests that traditional approaches of instruction fail to convey much basic conceptual understanding of Newtonian Mechanics to the average student [13].

5. Recommendations

The findings of the current study suggest that teaching of Newtonian mechanics and by extension any physics topic require interactive-engagement methods which are designed in part to promote conceptual understanding through interacting and engaging learners in head-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors. Such strategies give better learning gains [13, 14], [15], [1, 16], [17], [2,18].

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