Experiences with an interactive teaching approach in a first year university physics course in Ghana

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Abstract
It has been reported from many countries that the lecturing approach to physics teaching is little effective to attain deep conceptual understanding, and that interactive engagement approaches can be much more effective to attain such effect. Interactive engagement methods typically involve open and critical discussions in the classroom, with hand-on experiences and group work presentations. The question for this study is whether such techniques can be fruitfully implemented in the Ghanaian setting, where classroom resources are limited, and where politeness and respect towards the elderly are highly esteemed values. We investigated an interactive approach in a first year mechanics course in the Ghanaian university to find out about feasibility, student appreciation, and learning results. The outcome of the study shows that interactive teaching is feasible in Ghana and also results in improving students learning in mechanics concepts and quantitative problem solving. Some points on what to be taken into account for teaching in the interactive way are given.

What is the problem?

The predominant mode of physics teaching in most of Ghanaian schools places a heavy emphasis on lecturing, memorising definitions and formulas, and applying in standard problems. As a result, students are used to rote memorization of formulas and many students try to avoid questions that require qualitative reasoning and verbal explanations (Chief examiner, 2008). This traditional method of teaching by telling, does not help students to grow in their reasoning ability, which is reflected in the rather low ranking of Ghana's eighth graders (JHS 2) in the international comparison studies TIMSS (Martin, Mullis, Gonzalez & Chrostowski, 2004; Martin, Mullis, & Foy, 2008). In TIMSS 2003, Ghana's eighth graders in science took the 44th position out of 45 countries that participated in the test, while Ghana's eighth graders were last in science out of the 48 countries that participated in 2007. Whereas students might be able to solve standard quantitative problems their lack of insight become most evident in test that do require qualitative insight, such as the Force Concept Inventory (Halloun & Hestenes, 1985).

What do we learn from experiences elsewhere?

Educational researchers have been establishing that allowing learners to take active part in the teaching and learning process is a key to improve students understanding and learning capabilities, especially with the teaching and learning of science subjects like physics, chemistry and biology. They are of the view that allowing students to participate and interact in the process of constructing qualitative models and use them to predict and explain real world phenomena make them active to develop functional understanding (McDermott, 2001). A strong empirical support for this view is found in a study by Hake (1998), who made a survey of 62 introductory physics courses with about 6500 students, where pre- and post tests results were available for the conceptual reasoning tests of Halloun & Hestenes (FCI, MD and/or MBT). He classified interactive engagement methods as those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and /or instructors. Those reported by instructors who made little use of interactive engagement methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams, were classified by him as traditional methods. The main finding in this study was that teachers who made substantial use of interactive engagement methods in their teaching achieved consistently higher learning gains, about twice as large as for the traditional method.

What do we want to find out?

It has been found that interactive teaching tried in other parts of the world has been an effective strategy for helping students to learn. Collaborative peer instruction, microcomputer based laboratories, concept tests, active learning problems, and Socratic dialogue are pedagogical strategies that can allow students to interact among themselves, participate in classroom proceedings and be responsible for their own learning (Heller, Keith & Anderson, 1992; Redish, Saul & Steinberg, 1997; Mazur, 1997; Tobias & Hake, 1988; Heuvelen, 1991).

In Ghana politeness, and respect towards the elderly are highly esteemed cultural values. This might interfere with the discourse norms of an interactive engagement classroom, where students are supposed to voice their ideas. In this study, we try to investigate how we can use interactive teaching in a first year mechanics course in a Ghanaian university curriculum to effect better learning results of students.

The following research questions were used:

- How does the interactive engagement work in classroom practice?
- Do the interactions improve students' conceptual understanding in mechanics?
- How do students like the interactions used in the study?

What are the characteristics of an effective teaching approach according to the literature?

After studying the literature, the following characteristics were devised to yield more interactions among students and between teacher and students, participation in class proceedings and improve students' conceptual understanding in mechanics:

(i) Teaching necessitates the students to come prepared

For students to cooperate effectively, they have to come in prepared. Their ideas and contributions play vital roles in the teaching process. This is unlike the traditional lecture approach where student can come unprepared and remain silent. According to cognitive scientists, educational researchers and contemporary psychologists, a brief preview of text in books will improve students' ability to follow the class (Hubin & Ridell, 1977). A physics major student once remarked that after struggling through the first half of his junior level mechanics course, he felt that the course was now going much better because, he started reading the book before every class. Clearly, this student had learned something very important from pre-preparatory reading (Cummings, Laws, Redish & Cooney, 2004).

(ii) Open, high quality dialogue/discourse with peers and with the teacher

Peer instruction engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Unlike the common practice of asking informal questions during a lecture, which typically engages only a few highly motivated students, the more structured questioning of peer instruction involves every student in the class. Students are given some few minutes to formulate individual answers. They then discuss their answers with others sitting around them trying to convince each other of the correctness of their answers and report their answers finally to the instructor, which may have changed based on the peer discussions (Mazur, 1997; Crouch & Mazur, 2001; Heller, Keith & Anderson, 1992).

Mercer (1996) also suggested the use of quality discourse in teaching to promote effective learning. An experimental teaching programme was designed to enable children in British primary schools to talk and reason together and to apply these skills in their study of science. The results indicated that children could talk more effectively and talk-based activities could have a useful function in scaffolding the development of reasoning and scientific understanding. Most students in our schools have been trained to become skilful in passive listening, there is the need to find and add quality discourse or talk-based activities that will encourage and motivate students into active engagement in practical inquiry and social interaction as a means to support the developments in understanding of concepts. Questions and activities should be put in such a way, so as to engage students into interacting with partners while they still carry out their investigations. Discourse in teaching and learning serves as a tool to recognize how well students learn, how students make sense and connections of their knowledge and how students are able to relate different topics to each other.

(iii) Students are encouraged to reflect on their initial ideas and responses

According to Mason (2009), reflection is essential to learn from problem solving. He investigated how students naturally reflect in their physics courses about problem solving and evaluated strategies that may teach them reflection as an integral component of problem solving. He concludes that students who reflect with peers have a larger gain in their final examination.

Students' encouragement or motivation to reflect on their initial ideas and responses could have a relation to the Hestenes' work on modelling instruction in mechanics (Hestenes, 1987). After the students have made an attempt to bring out their initial ideas on the conceptual reasoning questions, the most interesting part is to look back on the answers provided and the procedure they followed to see whether they can add anything new or can improve on it, especially with some of the new knowledge they may acquire during the interactive teaching and from their colleagues.

(iv) Relate and practice physics concepts to multiple real-world contexts

Making physics relevant in students' learning is an important aspect of physics education. This involves the ability to draw in examples from daily contexts to begin with the learning or to apply concepts learnt to familiar everyday phenomena that students observe and experience around them. Making explicit connections between course materials and everyday physics in order to increase students' belief in the relevance of physics to the real world and develop their problem-solving skills in order to apply their physics knowledge outside the classroom is very useful (Martinuk, Moll & Kotlicki, 2010).

Relating physics concepts to multiple real-world contexts reveals the shortcomings of students' current conceptual frameworks and can help to wean students from erroneous beliefs on how reality operates. Thus instruction based on multiple real life contexts can help students' existing mental models to evolve into more accurate conceptions of reality (Feurzeig & Roberts, 1999).

(v) Hands- on experience with real objects and/or computer tools

Hands-on experiences with computer tools have become possible and fruitful in our senior high schools and universities. For example, students often have conceptual difficulties in interpreting graphs. Thornton and Sokoloff (1997) suggested possible means of remedying students' problems of interpreting distance-time, velocity-time and acceleration-time graphs, through the use of microcomputer-based laboratory tools. Students use this tool to collect physical data that are graphed in real time and that can be manipulated and analyzed. This encourages students to take an active role in their learning and to construct physical knowledge from observation of the physical world. Many instructors have found that lectures become more useful when students become active participants in the lecture (Heuvelen, 1991). The tools provide convenient and effective means for collecting and displaying physical data in a form that students can remember, manipulate and think about.

Using computer simulation becomes a powerful activity for engaging students in doing and thinking about science, particularly physics. By setting up a simulation in which students can vary parameters and see the effect of these variations, their view of an equation is powerfully enriched (Christian & Belloni, 2001). Simulations can also act as effective means of stimulating curiosity in students. They help students to understand their environment.

Educational research has demonstrated repeatedly that students learn much more effectively when they themselves are in control of such tools to find knowledge (Wieman, Perkins & Adams, 2007).

(vi) Constructive learning processes are being scaffolded

Knowledge construction where scaffolding is not provided could be disadvantageous to students by taking too much time, which is the situation in most cases, but going in the wrong direction is also a possible consequence. For example, if you just put students in the world to discover Newton's laws, they are unlikely to discover the laws within their lifetimes; hence we need to guide the process (Kirschner, Sweller & Clark, 2006). Thus, for constructive learning processes, students need to be scaffolded by the teacher. It could be in a form of providing hints or asking leading questions for the learner to see his or her way through. Guidance can be provided to students in class discussions, problem solving, modelling and microcomputer based laboratories.

In a traditional lecture approach, the way the teacher is thinking about how the topic will be coped or understood by the students, is mere assumption. The teacher who has no interaction with the students cannot check whether coping or understanding really takes place on the spot, because he or she is talking alone and does not do any interaction to realize if he or she is successful or not. Traditional teachers, who are fond of teaching this way, often think that the students are learning a lot, like Mazur (1997). After using standardized tests he realized later that the students were not learning as expected. In situations where students are taught by this approach, just a few of them benefit.

(vii) Creating a safe, inviting and ambitious classroom culture

Creating a safe, inviting and ambitious classroom culture is a necessary condition for all interactive approaches: collaborative peer instruction, concept tests, Socratic dialogue inducing labs, overview case studies, modeling and microcomputer based laboratory. Students' full participation is needed under these circumstances, and it is up to the teacher to create the necessary atmosphere in the classroom that would invite students to participate, make them eager to answer questions, motivate them to read and solve problems on their own and let them feel safe, without being threatened, in contributing their quota during the teaching and learning process (Stewart, 2003). This requires creating an atmosphere that values individual contributions and addresses the learning needs of each of the students (Cross, 1992).

In summary, a number of conditions of teaching process are listed as:

- Teaching necessitates the students to come prepared.
- Open, high quality dialogue/discourse with peers and with the teacher.
- Students are encouraged to reflect on their initial ideas and responses.
- Relate and practice physics concepts to multiple real-world contexts.

- Hands-on experience with real objects and/or computer tools.
- Constructive learning processes are being scaffolded.
- A safe, inviting and ambitious classroom culture.

These conditions have been used in designing activities that may maximize classroom interactions and students' learning.

Is it possible to increase interactivity by using the designed activities?

In this section we consider how these conditions of teaching were structured into a series of activities: *concept quiz, conceptual reasoning question (CRQ), interactive teaching, reflection, application question and tutorial/problem solving* in order to promote students' participation, interactions and understanding in mechanics. A chronological account of how the activities were used in the classroom process is provided.

(1) Concept Quiz

This technique was adopted from Mazur (1997). Students were required to complete short quiz questions on some concepts they were to study in each lesson, and this was done at the beginning of every class in every week. The concept quiz tested whether the pre-class reading was done by students. Some questions were specifically based on concepts, not solvable by relying on equations (in most cases), have multiple-choice answers (sometimes), unambiguously worded and neither too easy nor difficult. The concept quizzes formed part of the students' continuous assessment (20% of the final mark). This aided students who lack the initiative to read before attending lectures to do some reading in order to take active participation in class discussion. Some of the concept quiz questions were selected from Mazur's book, (Mazur, 1997).

Example of concept quiz questions with some multiple choice answers on Newton's laws of motion.

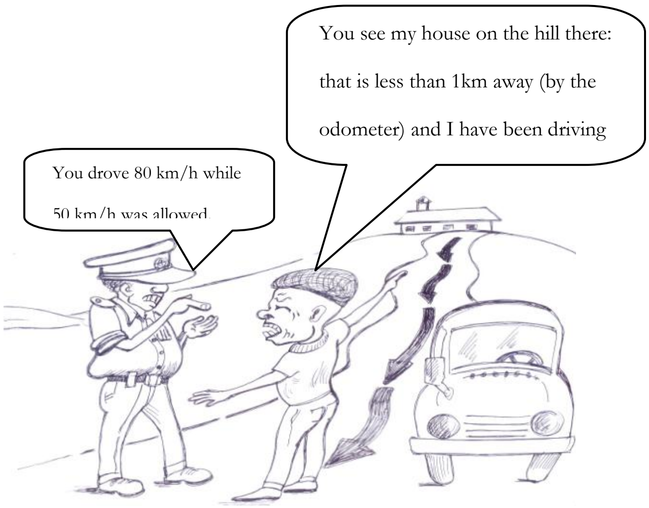
1. Which of these laws is not one of Newton's laws? (a)Action is reaction, (b) F=ma (c) All objects fall with equal acceleration, (d) object at rest stay at rest.
2. The law of inertia (a) is not covered in the reading assignment. (b) expresses the tendency of bodies to maintain their state of motion. (c) is Newton's third law.
3. (i) State Newton's 2nd law of motion and explain. (ii) Consider the interaction between a foot and a ball, which interact simultaneously (at the same time). Identify the pair of action-reaction forces.

(2) Conceptual Reasoning Questions (CRQ)

Conceptual reasoning questions do not demand a straight-forward answer by the use of laid down regulations, where students have to just follow a specific routine and come out with a definite result as the answer to a question. In conceptual reasoning questions, students were required to analyze, reason, synthesize, test and support their answers with an

explanation. It was used to elucidate students prior ideas on concepts. Some of the CRQs were taken from Hewitt's book (Hewitt, 2010) and Hewitt's Next Time Questions (http://www.arborsci.com/Labs/CP_NTQ.aspx*)*.
Cartoon-style drawings with questions on specific concepts for students to put forward a range of viewpoints were sometimes given. These are called concept cartoons, used to support conceptual reasoning questions.
An example of a conceptual reasoning question on the topic of instantaneous and average speed is given:

Conversation between a policeman and a driver who was charged with over speeding:



Comment on the conversation between the police officer and the driver.
Note: The road is winding, it is not straight as it is shown in the picture.

(3) Lecture/Interactive Teaching
In this activity, a short lecture was given with the purpose to introduce new conceptual information to students by giving real life examples and explanations. In order to make the teaching more interactive, it was interspersed with predictive and explanatory questions where students had to supply the answers. In some cases microcomputer-based laboratory (MBL) tools were used to collect physical data that are graphed in real time, to be manipulated and analyzed. With this method, students were able to relate graphs to their physical movements. Similarly, students were able to predict the relative size of forces that two identical carts exert on each other when they collide, and the forces two unequal (mass) carts exert on each other in collision. This MBL method was used by Thornton and Sokoloff (1997) to improve learning in students.

Example of lecture/interactive teaching and the use of MBL on Newton's third law:

Newton Third law of motion

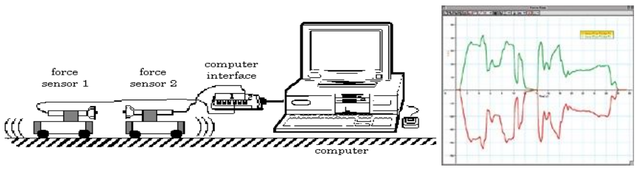
State Newton's 3rd law and use 1 daily life example to support your answer.

Students' response:………………………………

Application of Newton's 3^{rd} law of motion
Give some examples of Newton's third law in real life situations.
Students' response:…………………………………

Everyday examples of Newton's third law of motion (discussion)
Propulsion of a fish through the water.
Flying motion of birds. A bird flies by use of its wings.
The motion of a car on the way to school.
Walking on the ground.
A person swimming in the pool.

The use of Microcomputer Based Laboratory Tool (MBL-coach VI and force sensors) to explain Newton's 3^{rd} law
Students are guided to connect the two force sensors to two low-friction carts (as shown below) and observe the result of their interaction on the graph on the computer by going through the following processes.



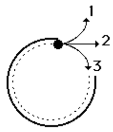
- Observe the forces that two identical carts exert on each other when one collides with the other; let students compare the two graphs formed and relate the forces being exerted.
- Observe the forces two carts exert on each other when one collides with a second weighted with a metallic block; let students compare the two graphs formed and relate the forces being exerted.

(4) Reflection
During reflection, students were given another chance to reflect on their initial ideas on CRQ and revise them if necessary after the lecture/interactive teaching. For example, the conversation between the police officer and the driver in the CRQ activity, was again given to them to discuss in groups to see whether they were satisfied with the answers they provided at the initial stage. If not, they have to improve or revise their answers after discussing with their group members. It is required of students to improve their answers with new knowledge they may have gained from the interactive teaching. In so doing they may replace their common sense knowledge with suitable Newtonian concepts.

(5) Application Question
These are questions related to what has been discussed in the CRQ, interactive teaching and reflection, but at higher order level, where students have to apply or transfer the knowledge gained to solve or explain questions. The purpose of this activity was to enable the teacher

to see whether students have acquired problem solving abilities Thus the activity allowed the teacher to be sure whether students had understood what they had been taught and discussed, and could apply the acquired information in dealing with new but similar problems they encounter. To make it more interactive, group discussions, plenary sessions, think-share-present activities and presentation were used. Some of the application questions were selected from Hewitt's book (Hewitt, 2010).

Example of application question on Newton's first law of motion:



> A group of physics teachers are taking some time off for golf. The golf course has a large metal rim which putters must use to guide their ball towards the hole. Mr. Boakye's guides a golf ball around the metal rim. When the ball leaves the rim, which path (1, 2, or 3) will the golf ball follow?

(6) Tutorial/Problem solving session

Each lesson was followed by a tutorial/problem solving session. It was a session where students were meeting to solve selected conceptual, qualitative and quantitative problems. The questions were given to students about a week before the session. It was done some days after the completion of each meeting, so as to allow students to engage in discussing the questions among themselves and consult other books for solutions, before the session for the discussing of the problems. Students were to solve some of the questions as assignment and submit. The assignment constituted 10% of the continuous assessment. It helped the teacher to know the fluency of students' problem solving ability. The use of problem solving had been suggested by many physics education researchers especially in situations where little can be changed in lecture due to constraints (McDermott, Shaffer & Somers, 1994; McDermott and Shaffer, 1992).

During the tutorial/problem solving session, all the students gather to ask for explanation and justification from their colleagues, who would be answering a question at a particular time. This mutual critique helped students to think about correct physics concepts and principles to be used and applied to the problems (Heller, Keith & Anderson, 1992). The teacher comes in to help or guide students, by providing hints or explanations, in questions where students find it difficult to comprehend or in areas where the approach or explanation is wrong. The number of questions in each tutorial/problem solving question was at least 20. Some tutorial/problem solving questions were selected from Hewitt (2010) and Hewitt's Next Time Questions.

Examples of some questions for problem solving on kinematics:

> 1. Daniel moves 5 km to the East and 12 km to the north, all by bike. What is Daniel's (a) distance? (b) displacement?
> 2. An automobile starts from rest and accelerates to a final velocity in two stages along a straight road. Each stage occupies the same amount of time. In stage 1, the magnitude of the car's acceleration is 3.0 m/s^2. The magnitude of the car's velocity

at the end of stage 2 is 2.5 times greater than it is at the end of stage 1. Find the magnitude of the acceleration in stage 2.

3. A motorist wishes to travel 40 kilometres at an average speed of 40 km/hr. During the first 20 kilometres, an average speed of 60 km/hr is maintained. During the next 10 kilometres, however, the motorist goofs off and averages only 20 km/hr. What should be the speed of the motorist to drive the last 10 kilometres?

Other helpful teaching techniques which were adopted

(i) Projects and presentation

Projects are usually extensive tasks undertaken by students to apply, illustrate, or supplement the classroom lessons. Projects were assigned to students in groups of three or four members to deliberate on and present to the class. The task was given to students about a week before the presentation session. Some of the tasks were selected from Hewitt's conceptual physics book (Hewitt, 2010). The groups were expected to report their findings to the class for questions, explanations and clarifications. This encouraged students to do group work. It helped students to learn how to find things for themselves or how to research into finding solutions to problems. When students are working in groups, they interact with their peers and also share ideas for better solutions to the task ahead of them. It had been shown to be an effective technique for helping students learning a complex skill (Collins, Brown & Newman, 1989; Lunetta, 1990). Students share their conceptual and procedural knowledge as they discuss the task together.

An example of a project on vectors

Group (3 or 4 members) presentation on the use of "walking through the lawn" and "Pythagorean Theorem" to check whether $A^2+B^2=R^2$. Students to use Pythagorean Theorem to check whether $\boldsymbol{A^2+B^2=R^2}$.

(a) Students search for lawns where people have walked through/across where the application of Pythagorean Theorem is possible.
(b) Students measure the horizontal distance, ***A***, and the vertical distance, ***B,*** (all on the ground), meeting perpendicularly, that make up the length of the path through the lawn with metre rule or tape measure and record.
(c) Students find the sum of the square of the horizontal distance, $\boldsymbol{A^2}$**,** and the square of the vertical distance, $\boldsymbol{B^2}$*.Thus* $\boldsymbol{(A^2+B^2)}$
(d) Students find the square of the path length through the lawn, $\boldsymbol{R^2}$.
(e) Students compare the two values and come out with their conclusions.
(f) Students use a chalkboard protractor to measure the angle between the path length (through the lawn) and the vertical distance; and the angle between the path length (through the lawn) and horizontal distance.
(g) Students calculate these angles using the appropriate trigonometry sign;

$$\sin\theta = \frac{opposite}{hypotenuse}; \quad \cos\theta = \frac{adjacent}{hypotenuse}; \quad \tan\theta = \frac{opposite}{adjacent}$$

(h) Students find the resultant, ***R***, using a scaled vector diagram.

(ii) Think-Share-Present

Think-Share-Present is adopted from "Think-Share-Pair" which was proposed by Lyman (1981). In think-share-present, the instructor poses a question and gives students about three minutes to think about the question and write the answers down. This was necessary because it gave students the chance to start to formulate answers by retrieving information from long-term memory. Students then shared with a neighbour sitting nearby and discuss their ideas about the question for about two minutes, before they presented whatever they come out with, to the entire class, during general discussion. The think-share-present structure gave all students the opportunity to discuss their ideas. This is important because students start to construct their knowledge in these discussions and also to find out what they do and do not know.

For example, in finding out whether all students have conceptual understanding of "work" as it is applied in physics, the following questions were given to them to use think-share-present to answer:

> Read the following statements and answer with explanations whether or not they represent examples of work.
> (a) A teacher applies a force to a wall and becomes exhausted.
> (b) A book falls off a table and free falls to the ground.
> (c) A waiter carries a tray full of meals above his head by one arm straight across the room at constant speed.
> (d)A rocket accelerates through space.
> (e) A man is holding a bucket full of water vertically and moving horizontally through a distance.

(iii) Scaffolding and creation of safe classroom culture

There were two other strategies which were relevant to most of the activities described for better understanding of concepts and full participation of students. These were:

Constructive learning process is being scaffolded
Scaffolding was provided in the activities where students would answer questions or solve problems, and would not get the opportunity to tackle it again. In such circumstances, where students were finding it difficult to get the correct answers or understanding, the teacher would scaffold students' efforts in the form of providing hints or further explanations. Scaffolding was mostly used with the interactive teaching, reflection, application question and tutorial/problem solving sessions.

Creation of a safe, inviting and ambitious classroom culture
A safe, inviting and ambitious classroom culture was provided in all the activities. For students to contribute their quota in the teaching and learning of physics, there was the

need to create a congenial atmosphere in the classroom that will allow students to talk freely without any fear and to participate fully.

Method

The research was carried out in the Department of Science Education, University of Education, Winneba (UEW). Participants in the study were all first year UEW students who took the mechanics course in the first semester. Twenty (20) students were involved. The lecture room was equipped with computers and white board. The room was furnished with laboratory benches and stools. The fixed nature of the benches made group discussions more difficult to arrange but students managed when there was the need to do so. One complete semester was the duration for the study, and the course was taught by one of the researchers. Research instruments used to gather data include the force concept inventory (FCI), the mechanics baseline test (MBT), a questionnaire and observation of classroom lessons through the use of video recordings.

Students were made to answer FCI before the beginning and after the end of the lessons in mechanics (Hestenes, Wells & Swackhamer, 1992). Pre FCI refers to the mean proportion correct score of students before the beginning of the lessons. Post FCI, refers to the mean proportion correct score of students after the new approach has been used on students. FCI is a multiple-choice standardized "test", which consists of 30 questions with common misconceptions as distractors designed to assess students understanding of the most basic concepts in Newtonian mechanics. Students used 30 minutes to answer pre- and post-FCI

Students had to answer the MBT only after the end of the lessons (Hestenes & Wells, 1992). The MBT is more quantitative, which requires some tuition and improved conceptual understanding before one can solve. Unlike the FCI, some computation was required in MBT. MBT is a standardized test to assess students' understanding of the most basic concepts in mechanics. MBT comprises 26 multiple-choice questions with possible answers. The Baseline is recommended as an FCI companion. Students used 45 minutes to complete the test. Students' scores in pre and post FCI, and MBT were converted into mean proportion correct scores and presented in Table 1.

Students were made to answer a five-point Likert scale questionnaire items on the activities used in the lessons, and on attitude towards physics and learning environment, after completion of the lessons. All the 20 students took part. They used 35 minutes to complete the exercise. Statistical data on students' responses on the activities is shown in Table 2, while that on students attitudes towards physics and learning environment is shown in Table 3.

Recorded videos of classroom teaching and learning proceedings were observed and analyzed by researchers. They did reveal more students' interactions in the classroom through the use of interactivity evoking nature of the activities and improved students' conceptual understanding by the way they answered qualitative questions.

Results

Which activities worked well?

The design of the various activities used in the classroom teaching did achieve its intended purpose of students' interactivity, participation in class, and improving on their conceptual understanding in mechanics. Thus, CRQ did bring interactions in the classroom, evoked students' misconceptions and created awareness in students for the need to learn; more examples and questions used in the interactive teaching gave students the opportunity to relate concepts to everyday activities in their surroundings; the demonstrations, using MBL, were meaningful in explaining the concepts that were quite difficult for students to accept, for example in Newton's third law of motion related to the collision of two objects with different masses; most students did revise their ideas during reflection for a more acceptable scientific idea that can explain concepts; and most students could apply, transfer and generalize ideas into finding solutions for tutorial/problem solving questions, projects and assignments. So the activities mainly did work well as expected.

Which problems have been experienced and solved?

However, one needs to be careful with the type of question which should be given to students for a particular activity. If it is confusing or ambiguous, it takes more time for students to discuss, hence students cannot work within the stipulated time. Sometimes, two or more questions might not be necessary as they will require more time to discuss, and if targets of questions are not clear to students, it becomes difficult to reveal students' prior conceptions. To work within time and avoid confusion among students' discussions, the teacher had to use one question (with sub-questions where necessary) which is clear in its demand and could reveal students' prior conceptions.

Also, because students are encouraged to talk in class, they sometimes asked too many questions to seek clarification, which made it difficult for the teacher to complete the lesson as planned. In order not to inhibit students from talking in class and to complete the lesson as planned, it will be desirable to ask students to write all bothering questions down, to be discussed after the lesson or at the problem solving session.

A question which confused students by not getting the exact target and as a result extended the discussion by invoking different laws to explain the phenomenon is shown together with some protocols of how students answered them:

Question: To dislodge ketchup from the bottom of a ketchup bottle, it is often turned upside down and thrusted downwards at high speeds and then abruptly halted. Which of the Newton's laws of motion explains this phenomenon? Explain.

1. **Bismark:** Sir, we chose all the 3 laws.
2. **Teacher:** … Why?
3. **Bismark:** In the first law, a body will remain at rest unless external force is applied to it. The ketchup was inside the bottle and it was at rest. So when you turn it like this *(demonstrating upside down)*, that means the first law has taken

place. And then you shake, then you give the ketchup force… you have exerted force on the ketchup for the ketchup to come out. So in this case we think the first law can apply here. And the third law too, action and reaction are opposite. Since there is a high speed and then it stops, there is a change here, so the 2nd law the rate of change of momentum ... can be applied here. And when we come to third law, ..., since we are applying force, force that we apply, the ketchup will also react by coming out of the bottle.

4. [...]
5. **Victus:** Sir, actually we had two ideas. It's like the ketchup when it is in the container and you try to move it down *(demonstrating the process)*, and it doesn't want to come out. It's like the tendency not to move. But when you suddenly stop it, it jerks forward so comes out. So I concluded that it's the first law.
6. **Teacher:** What is the other one? You said you had two reasons.
7. **Frank:** That is the third one. In the course of the third one, we said action and reaction is equal and opposite in that, eh, when we were trying to dislodge the ketchup, you realized that as it was turned down and we exert, we move it suddenly, the bottom of the container will exert force on it, and the ketchup will also exert upward force on it. But the moment you suddenly stop, the ketchup will get dislodged. So…
8. **[…]**
9. **Frank:** And when you stop, all of a sudden it will move down. The ketchup will get dislodged.

Research question 1: How does the interactive engagement work in classroom practice?
In order to promote interactive engagement we introduced series of activities that will stimulate interactivity among students and call for students' maximum participation during class meetings through the use of the design guidelines. The major questions with regard to the classroom process were how to make sure that students come for the meeting prepared, ensure quality dialogue/discourse among peers and with the teacher, relate and practice physics concepts to multiple real-world contexts, encourage students to reflect on their initial ideas and responses, scaffold students' constructive learning process and create a safe, inviting and ambitious classroom culture? We used the observational data of how students responded to the activities which were based on the design guidelines to assess these.

The teaching necessitated the students to come prepared; the observation was that initially the students were not well prepared, and after a while they came to the meetings better prepared. The key element or explanation to that could be due to the quiz, which was part of their assessment. Also, with the tutorial/problem solving session, students did a lot of preparatory work before coming as the meetings progressed because they were made to submit some of the questions as assignment, which also formed part of their assessment and were called to provide answers or explanations to questions during the problem solving session.

Open high quality dialogue/discourse with peers and the teacher; the observation was that students were either finding it difficult or feeling shy to voice out their opinions at the initial stages of the meetings as they were not used to that, but as the meetings progressed they were able to express their opinions with some increase in the quality of how they substantiated their views. The explanations to the reason of voicing their opinions could be due to the activities that stimulated them to speak up. The elements that promoted the quality of their discourse could be the use of interactive teaching to the lecture method and clear tasks. Thus with the use of the interactive teaching, the teacher could ask some interactive questions that will cause students to think deep to justify their answers. Also, the use of clear tasks enabled students to have open high quality discourse among themselves due to its devoid of ambiguity which could call for divergent opinions and answers.

Relate and practice physics concepts to multiple real-world contexts; the observation was that initially students were not interested in some of the real world contexts. Some examples looked foreign and quite confusing. For instance, examples based on skating on the ice and the use of a falling parachutist to explain certain physics phenomena, whereas there was no ice/snow, skating on the ice and few isolated cases of a falling parachutist in Ghana. These looked quite strange to students and made it difficult for them to appreciate with better physics understanding. With the use of real world examples that are found within students' environment, it gave them better understanding especially when there was the need for them to apply to solve problems. This was evident in the quality of answers they provided.

Hands-on experience with real objects and/or computer tools; the observation was that students in some cases were still not showing good understanding of concepts despite several examples in relation to real world activities. The key element which made students have hands-on experience with real objects and/or computer tools was to let them verify a phenomenon to ascertain the truth or accuracy of a phenomenon or law by doing it themselves. For instance, some students did not believe that when two unequal masses collide the force that is exerted on each other should be equal. After they had a hands-on experience with the use of MBL tool to verify the situation, they did believe that unequal masses of vehicles exert equal forces on each other, when they collide.

Students are encouraged to reflect on their initial ideas and response; the observation was that students stuck to their original ideas (prior misconceptions) at the initial stages, but as the meetings progressed they revised their originally held opinions. The key element to the revision of their initial ideas could have been due to the way scaffolding was provided to promote students' learning in the answering of questions during the interactive teaching. Thus scaffolding by providing hints, clear explanation of questions/tasks and asking further probing questions during the interactive teaching made students understand concepts better and change their initial ideas at the revision level (during reflection). This was the main reason why we changed the traditional lecture approach in the first round of teaching into the interactive type of teaching during the second round.

Constructive learning processes are being scaffolded; the observation was that students found it difficult to work as planned sometimes, in terms of conceptual understanding and time limit. The key element to scaffolding students' ideas was the need to engage students in interactions. The need to dialogue with students to enhance their conceptual understanding because of their failure to grasp concepts on their own and also work within time.

Creating a safe, inviting and ambitious classroom culture; the observation from the critical friend was that teacher was too harsh sometimes and students ridiculing their peers inhibited their maximum participation in class. The key elements that led to the creation of a safe, inviting and ambitious classroom culture were to make the teacher friendlier and allow students to express their opinions without any apprehension of fear of being ridiculed so as to come out with their maximum cooperation and participation.

Research question 2: Do the interactions improve students' conceptual understanding in mechanics?

To answer this research question, students were made to answer pre and post FCI, and MBT. Their mean proportion and Hake's scores for FCI were calculated and the results are shown in Table 1.

Table 1: Mean proportion correct scores of pre FCI, post FCI, Gain and MBT

Academic Year Group	N	FCI		Hake Gain (SD)	MBT (SD)
		Pre (SD)	Post (SD)		
2010/11	20	0.31 (0.10)	0.66 (0.08)	0.51(0.15)	0.52 (0.11)

Students gain in conceptual understanding of Newtonian mechanics was measured by the pre- and post-force concept inventory (FCI). The mean proportion correct score of pre FCI was low, indicating that students had conceptual difficulties before the beginning of the lessons. There was considerable improvement in the post FCI score. This shows that students had improved in their conceptual understanding in Newtonian mechanics.

Also, the average gain, which is the ratio of the difference between Post FCI and Pre FCI to the difference between 1 and Pre FCI, $\langle g \rangle = \frac{(\text{Post FCI} - \text{Pre FCI})}{(1 - \text{Pre FCI})}$, was about 0.5. A gain of about 0.5 falls within Hake's medium-g courses, $0.7 > (\langle g \rangle) \geq 0.3$ (Hake, 1998). This gain signifies a substantial use of interactive engagement approaches during the teaching process.

Students showed an improvement in their quantitative problem solving skills in the mechanics baseline test (MBT). Their fairly high mean score in the baseline test was an indication that they have gained fluency in their quantitative problem solving, as the MBT emphasizes concepts that cannot be grasped without formal knowledge about mechanics. It could further be explained that their improvement in understanding concepts helped them to have the high score in MBT.

The study further revealed that students' way of answering qualitative questions, in terms of reasoning, analysing and evaluating improved over time. In most instances, students upon conviction could reject their previously held belief and accept the more scientific and meaningful explanation that is applicable to all situations. This was an affirmation to the fact that they no longer hold on to their previously held misconceptions.

Students' interactions with microcomputer based laboratory tools, made them visualize some concepts they found difficult to understand. Students could answer questions on "How do we know…?", "Why do we believe…?", and explain the outcome of a demonstration using qualitative reasoning without equations.

Research question 3: How do students like the interactions used in the study?

To answer this research question students were made to answer a five-point Likert scale questionnaire as to how they liked the activities that promoted interactivity in classroom and how the interactions have affected their attitude towards physics and learning environment. Students' perceptions on the activities used for interactive teaching are presented in Table 2 and their perceptions on attitude towards physics and learning environment are shown in Table 3. The tables show the statistical description of their responses and the alpha reliability (α) in the Ghanaian context.

Table 2: Students' responses on activities of the lessons

Activities	Year	N	Mean	Std. Dev.	Std. Error Mean	Alpha reliability (α)
1. Concept quiz	1	20	4.34	0.72	0.16	0.73
2. Concep. Reason. Que.	1	20	4.40	0.57	0.13	0.89
3. Lecture/Inter. teaching	1	20	4.46	0.60	0.13	0.89
4. Reflection	1	20	4.51	0.57	0.13	0.84

5. Application 1 question	20	4.56	0.51	0.11	0.94
6. Tutorial/Prob. 1 solving	20	4.51	0.62	0.14	0.92

The mean values for the activities were greater than four (out of 5). This signifies that students consented that all the activities were appreciated by them. Thus they liked all the activities used in the interactive teaching.

In evaluating the questionnaire, students indicated that they did like the interactive engagement approach. Thus they enjoyed all the activities that promoted classroom interactivity, and were of the view that the activities did help them to participate actively in class, which in their view contributed to their conceptual understanding in mechanics.

Students' perceptions on attitude towards physics and learning environment

Table 3: Students' mean values on their attitude towards physics and the learning environment

	N	Mean	Std. Dev.	Std. Error Mean	Alpha Reliability (α) for Pre and Post
1. Students' attitude towards physics teaching	20	4.31	0.80	0.18	0.72
2. Students' cohesiveness	20	4.28	0.66	0.15	0.75
3. Instructor's support	20	3.97	0.64	0.14	0.87
4. Students' cooperation	20	4.39	0.67	0.15	0.90

Mean values of students' responses on attitude towards physics teaching, cohesiveness, instructor's support and students' cooperation were about the same (almost 4). This affirms that interactive teaching improved students' attitude towards physics and that students appreciated the learning environment.

They added that interactions (student-student, teacher-student and around the use of computer tools) in classroom had led them to improve students' cohesiveness. Thus they have become friendlier to their peers and worked well with them, helped other students and also got help from other students, and liked other students. Cooperation among their peers had also improved; sharing of books and resources with other students when doing assignments, there was team work in group assignments and projects, and more cooperation with other students on class activities. On attitude towards physics and learning, students were affirmative that the interactions were fun and lively, and motivated their interest in physics. They further added that teacher-student interactions improved the instructor's support; made the teacher take personal interest in them, helped them when they were in trouble, interested in their problems and understood them, and moreover his questions helped them to understand concepts better.

Reflecting on the major research question, we were in advance not too sure if the implementation of interactive engagement teaching would work well in the Ghanaian classroom, given the context of respect of elders (students feeling disrespectful in answering back to the teacher), passive nature of students who are so used to the traditional mode of teaching, where they listen always to the teacher alone and authoritarian teaching style. However, the use of interactive engagement approach in teaching in Ghana seems to be feasible, as students did contribute effectively and appreciated with this type of teaching and learning.

Conclusions

We have described how the characteristics of an interactive teaching process have been systematically structured into a sequence of activities for the development of an interactive engagement curriculum in a Ghanaian university context. It is concluded that this new curriculum is feasible within the university context in Ghana. We noted more students' participation in class, high interactions among the students and also between the teacher and the students. Furthermore, students showed good conceptual gains in mechanics concepts, especially in their post-FCI and MBT, which seem to confirm that the use of IE methods in the classroom can increase mechanics-course effectiveness well beyond that obtained in traditional practice (Hake, 1998). Students did appreciate all the activities used in lessons and were of the opinion that they enhanced their attitude towards physics, cohesiveness and cooperation among their colleagues as well as support from the instructor.

Some important points to be taken into account when teaching interactively have been outlined for teachers setting up physics courses in a similar context.

Recommendations setting up interactive physics courses in a similar context

These suggestions apply to courses which make considerable use of interactive engagement approaches. They have been grouped under various headings:

Activities to enhance interactions and learning

- To motivate students to come prepared, you should adopt the use of concept quizzes. This will encourage them to do the reading assignment before they come to class.

- Unequivocal conceptual reasoning questions with clear aims could promote discussion and allow students to work within time, whereas ambiguous questions could extend the time limit and prolong arguments. These discussions reveal to the teacher students' misconceptions and their level of understanding.

- Interactive teaching could improve students understanding of concepts which could make them change their initial wrong conceptions. Students could also get convinced, where they see real happening of situations, especially by the use of MBL tools.

- Students could be made more responsible for their own learning through group discussions, sharing of ideas, cooperating with peers and with some guidance from the instructor when appropriate problems/questions, projects and assignments are designed for them.

Creating a safe, ambitious and inviting classroom atmosphere

- Students ridiculing each other are detrimental to a safe, ambitious and inviting classroom environment, so teachers should take care that students refrain from such behaviours. Reasons should be given to students why they should desist from such practices.

- Students perceived by most peers to be knowledgeable within a group usually will be doing the talking most of the time. To avoid such practices, the teacher could adopt the style of calling any member within a group to give the group's response. In so doing all students will give special attention to the group's discussions.

- Teacher should learn and call students by their names. This would make them feel recognized as being part of the class and contribute their quota effectively to the class activities.

- The teacher should be seen as friendly as possible for the students to put their confidence in him. Once they entrust their confidence in the teacher, they come out and participate well in all interactions.

Time and preparation

- In order to work within the stipulated time in class, teacher should encourage students to write down their questions to be discussed at the tail end of every lesson. Often most of the students' questions are answered in the process of teaching and discussions within a lesson.

- Interactive teaching could be time consuming when the teacher is not well prepared. Therefore the teacher has to prepare adequately before the start of the lessons. His lesson notes, preparation of power points slides (if available) and the demonstration or teaching materials should be fully prepared in advance. Fortunately there are numerous examples from the internet and books with questions, simulations and animations which the teacher could browse and use.

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