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# Investigating Strategies for Teaching Critical Thinking in Physics Classrooms

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***Abstract***

*The aim of this investigating is to obtain an insight into how physics teachers, who teach the Lebanese curriculum, understand teaching critical thinking. It also aims at discovering which strategy these teachers use to teach critical thinking, if they do. To investigate these, two research questions were addressed: "How are teachers using strategies to teach critical thinking in physics classrooms?" and "What are the best strategies that teach critical thinking in physics classrooms?" To answer these questions, an exploratory study was conducted where the descriptive data revealed that the most widely used strategy in physics classrooms is lecturing; yet the way it is being implemented does not cater for students' acquisition of critical thinking skills. Professional development regarding teaching critical thinking in physics classes is recommended.*

***Keywords:*** *Critical thinking, teaching strategies, physics education, Lebanese physics curriculum, problem solving, simulations, labs, hands-on, lecture and discussion.*

Towards the end of the 20th century and the beginning of the 21st century, there was an exponential increase in availability of information accompanied by an ease of access and dissemination of knowledge. This brought us face to face with the need to re-evaluate the function of schooling in particular and the purpose of education in general. This situation created many questions and issues for educators to tackle. Among these are questions related to developing curricula, which will prepare learners to become independent thinkers having complex decision-making skills and capable of critical evaluation of information and data. This implies that we need learners to develop higher order thinking skills such as analyzing, synthesizing and evaluating information and to develop their decision making and problem-solving skills (Snyder & Snyder, 2008). The issue the researchers focused on in this study has been that, even though analytical skills are necessary for everyone, "in recent years, educational specialists have been concerned about the inability of students in critical thinking skills" (Atabaki, Keshtiaray & Yarmohammadian, 2015, p 93). The concern raised by educational specialists regarding underdeveloped critical thinking skills makes it imperative for educators to confront and find solutions for this issue.

Today, as we experience a constant influx of data and information, which mixes the useful and valid with the obsolete and irrelevant, educators should play a role in preparing learners to properly evaluate data and information. It is, therefore, the role of educators to develop the curricula and incorporate the teaching of critical thinking skills. Developing a curriculum in particular and building an educational system that caters for the need of preparing future citizens with higher order thinking skills is not only relevant today but is imperative. This is because learners today, in general, seem to be passively acquiring and recycling knowledge and not actively involving themselves in the learning process, particularly with the invention of AI tools such as ChatGPT and Gemini (Vallor, 2024). Consequently, this is resulting in graduates from schools with underdeveloped critical thinking skills (Snyder & Snyder, 2008; Erceg, Aviani, & Meˇsi´c, 2013). From one of the researcher's years of experience in the field of physics education and participation in the Lebanese National Center for Educational Research and Development (CRDP[1]), the researcher can say that the situation described (Diepreye & Odukoya, 2019; Erceg et al, 2013; Snyder & Snyder, 2008) also applies to learners in Lebanon, particularly for learner studying physics in middle school and high school or intermediate and secondary cycles, respectively. For example, the researcher has observed and documented those learners of physics, in general, do well in test items that are straightforward applications of physics laws, yet they find solving problems related to authentic real-life situation involving complex analysis more challenging and difficult to tackle.

Developing learners' critical thinking skills allows them to effectively and efficiently solve complex or practical real-life problems, whether these problems are of social or of scientific nature. However, do we need to teach critical thinking or is it an innate ability which needs developing? According to Haber (2020), Maloney (2015) and Snyder and Snyder (2008), we need to incorporate teaching critical thinking into the curriculum since it is a learned ability and not one that we are born with. Moreover, we need to find ways to teach critical thinking in

[1] National Center for Educational Research and Development is given the acronym CRDP based on its French name

physics classrooms since most of the current physics textbooks and consequently physics teaching methods and techniques are not very successful at preparing learners in critical analysis and problem solving, at least not in the way physicist or scientists do (Cáceres et al, 2020; Rapi et al, 2022; Loper, 2010), as observed by the researchers when it comes to teaching physics in the Lebanese context. For example, the exercises in the Lebanese physics textbooks of grades 11 and 12, humanities, sociology and economics sections, published by CRDP are straightforward and at the level of knowledge and comprehension; they do not involve higher order thinking skills such as analysis or synthesis. Similarly, most of the exercises in the books of the scientific sections are at the level of application and rarely do they require analysis and synthesis. Incorporating critical thinking into the physics curriculum raises the question of which teaching strategies are teachers adopting or should adopt to develop learners' critical thinking skills?

To answer this question, we must revisit the purpose of education in general and science or physics education in particular. The purpose of education in general and physics education in particular, is to use content as a tool to help learners develop the ability to reflect and make meaning of the knowledge acquired so they can be used to critically think about and analyze new real- life situations faced beyond school (Bailin, 2002; Etkina & Planinšič 2015; Jonassen & Carr, 2020; Wiggins & McTighe, 2008;). Hence, the aim of this study was to discover how teachers are developing learners' critical abilities as they teach the Lebanese physics curriculum.

The design of the Lebanese curriculum groups teaching materials into separate isolated subjects with no integration required. For example, if we take the middle school (intermediate cycle) and high school (secondary cycle), we find that sciences are taught as separate subjects and contents in physics, chemistry and biology thinking. Mathematics is also taught as a separate subject (CRDP, 1997). Integration is rarely practiced since it is not required for the national exams. Integration is significant in this context since teaching physics by utilizing authentic real-life context allows learners to find physics more relevant for them and therefore creates engagement and increases their motivation (Banda & Nzabahimana, 2021; Popescu & Morgan, 2007). For example, physics topics can be taught by integrating them with social issues that are associated with science and technology, hence making them more relevant and thought provoking for the learners. Furthermore, teaching physics within the context of science, technology, engineering and mathematics helps develop learner's higher order thinking skills and creative abilities, all of which are needed in today's world and especially in today's economy (Wheeler, 2015). Education should be about the right balance between teaching theory or knowledge and practice or real-life application; teaching the right amount of content material while allowing learners to explore and interact with it is necessary for critical thinking and creativity (Cáceres et al, 2020; Loper, 2010; Rapi et al, 2022; Wheeler, 2015).

Strategies and activities that should be used to teach in order to achieve learners capable of higher order thinking, as mentioned above, necessitate teachers' training as part of professional development. Teachers' development should include training in critical teaching strategies and questioning techniques that stimulate higher order thinking such as analysis and synthesis of ideas. Science teachers should be trained to turn their classrooms to include "inquiry-based learning, model construction, conceptual understanding, problem solving, critical thinking, and experimentation" (Turpen, 2010, p. 1), all of which help create an authentic environment similar to the one in which scientists work (Loper, 2010). This will then lead learners to be capable of making valid judgements related to topics and concepts studied (Black, 2018; Vieira et al, 2011). Moreover, preparing teachers for this task is vital since it can be shown that learners do not develop these skills on their own and because the current books and the curricula, which present knowledge in the form of isolated topics and subjects, do not stimulate or emphasize the development of critical thinking skills and abilities (Black, 2018; Vieira et al., 2011).

Mathematical equations are used by physicists to interpret physical laws, yet, in physics education, we find instances where learners are taught to use these same equations for simpler tasks such as computing answers during exams. As such, learners use equations as tools and not as an end in themselves, which limits their ability to think as scientists actually do in real life. "There exists a gap in the literature regarding how and to what extent a conceptually based mathematical intervention will help students think like scientists and improve critical thinking in high school physics" (Loper, 2010, p. 4). In this case, for example, problem-based learning, as a strategy, is useful for many reasons including developing learners' ability to improve their understanding of concepts and integrating new knowledge with acquired ones (Loper, 2010; Sulaiman, 2011; Sulaiman, 2013). Similarly, other strategies, such as lecture with discussion and hands-on, may be used to serve the purpose of developing deeper understanding and higher order thinking.

In the Lebanese context, most physics teachers as one of this study's researchers has observed, follow the process where they teach learners the key concepts before engaging them in real-life situations where these concepts apply. For example, the teacher goes to class, defines gravity, introduce the statement and equation of the law of gravity before engaging the learners with a real-life situation where the law applies. This is practiced instead of the inquiry-based learning where the learners study the real phenomenon of interactive attraction between masses and then reflect, infer, evaluate, use inductive and deductive reasoning to come up with a hypothesis or conclude relationships related to gravity. Teachers usually mention, as an excuse, the quantity of content needed to be taught in preparation for the exams is time consuming and does not leave enough time for real-life applications. Consequently, learners are taught knowledge content with little or no involvement in real-life situations. This does not allow for development of their critical thinking skills. Good pedagogical practices are those that require students to learn through discovery, practice making mistakes and learning from them (Doyle, 2023; Wiggins & McTighe, 2008). These methods should also be applied in physics classes.

## Conceptual Framework: Teaching Critical Thinking in Physics Classrooms

**1. Introduction to Critical Thinking:** Critical thinking is widely regarded as an essential skill for success in the 21st century, characterized by a capability to process information critically and reflectively from it allows one multiple perspectives on what might be happening (Willingham, 2007). It involves a series of cognitive skills, including analysis, evaluation, and synthesis of information that are crucial for making informed decisions and solving complex problems (Haber, 2020)

**2. The Role of Critical Thinking in Physics Education:** Critical thinking which is deeply connected with Physics demands high-level cognitive skills required to understand complex concepts beyond introductory level courses (Maloney, 2015; Emir, 2013). The effectiveness of physics education is significantly enhanced when both learners and educators engage in critical thinking which can influence the way concepts are taught and assimilated (Demir, 2015; Engstrom & Carlhed, 2014; Viennot & Décamp, 2020).

**3. Teaching Methods for Critical Thinking in Physics:** The literature presents various methods for promoting critical thinking within physics classrooms:

- **Problem-Based Learning (PBL)**: This strategy requires tutors to provide students with realistic problems that need critical thinking in order to solve them. PBL encourages inquiry and active learning hence facilitating development of higher order cognitive skills such as analysis and evaluation (Sulaiman, 2011; Pease & Kuhn, 2010; Roslina et al, 2022).
- **Technology and Simulations:** The use of technology in the form of virtual labs and simulations has made it easier for learners to understand complex physical processes through interactive and engaging learning experiences (Banda, & Nzabahimana, 2021; Daineko, Dmitriyev, & Ipalakova, 2016; Wieman & Perkins, 2005). Other online resources that are similar to WebQuest also help in enhancing critical thinking through inquiry-based learning (Zhou et al., 2012).
- **Inquiry-Based Methods:** These kinds of methods lead to a student questioning and exploring the physics concepts independently, thus increasing retention and deeper understanding (Greenwald & Quitadamo, 2014). This category also includes tools like the calibrated peer review (CPR), which promote critical engagement with content (Herayanti, et al, 2022; Reynolds & Moskovitz, 2008)
- **Interactive and Collaborative Learning:** Practicing peer reflection as well as group discussions are some techniques that can be used to enhance understanding and provide a basis for actively developing critical thinking skills (Mason & Singh, 2010; Setyowidodo, 2020; Slisko & Cruz, 2013).
- **Lecture and Socratic Methods:** It has been shown that although traditional lecturing is less effective when combined with Socratic questioning it results in more involvement on the part of the learners thus leading them to deeper thoughts (Herterbran, 2007; Nilson, 2010; Salaoru, 2020).

**4. When it Comes to Learning Outcomes, How Does Critical Thinking Affect Them?** Research shows that students with improved academic performance and increased problem-solving abilities benefit from critical thinking instruction (Howard, Tang, & Austin, 2015). In addition, it has been discovered that critical thinking instruction also contributes to improved psychological well-being among teenagers (Rezaei et al., 2013).

**5. The Implications for Education and Suggestions:** In order for education on physics fields to succeed, instructors should possess critical analysis skills and be able to incorporate them into their teachings (Serin 2013). As such educational systems must give priority to nurturing both learners' and teachers' capacity towards critical thinking by means of structured and well-advanced curriculum as well as professional advancement opportunities (Etkina & Planinsic 2015; MacKnight 2000).

Critical Thinking Skills included in Physics Education not only enhances learners' comprehension of the subject material but help in preparation for solving more intricate problems encountered in real-life situations. To promote these skills effective strategies ought to be implemented on a large scale as revealed through evidence-based studies.

## Research Context

Within the Lebanese curriculum, the middle school or the intermediate cycle is divided into 3 classes called grades 7, 8 and 9 and the high school or the secondary cycle is divided into 3 classes called grades 10, 11 and 12. Furthermore, when learners reach grade 11, they are grouped into sections based on what they want to specialize in at university and based on their performance. Therefore, grade 11 has two sections, a humanities section and a scientific section. Similarly, grade 12 is divided into 4 sections. These sections are the general science section, which, as an example, is joined by learners who wish to study engineering; the life science section, which includes learners who wish to become doctors; the economics and sociology section and the literary and humanities section, which are sections where learners who wish to study business administration, law or literature, as examples, study. Physics, in the Lebanese curriculum, is taught as a separate subject starting from grade 7 and continues till grade 12. It is also required that all sections of grades 11 and 12 study a course in physics. Learners in classes lower than grade 7 study general science as one subject which include physical and life sciences (Scolaro database, 2024).

Physics teachers employ different strategies to teach physics. Although these strategies can all be used to teach critical thinking yet, utilizing these strategies for that purpose is not clear or well documented. Turpen (2010) confirms this and states that "while research-based curricula and instructional strategies in introductory physics are becoming more widespread, how these strategies are implemented by educators is less well understood" (p. iii). In this current study, the investigation of these strategies took place in intermediate and secondary schools in Beirut, which teach physics using the Lebanese curriculum.

For the purpose of this study, the definition of critical thinking includes the following aspects mentioned by Loper (2010):

- Applying reflective thinking when evaluating multiple solutions
- Using evidence and/or facts to deduce, infer, evaluate and support conclusions

- Employing logical reasoning and strategies in problem solving
- Utilizing deductive and inductive reasoning
- Viewing a problem effectively from multiple sides including other people's perspectives" (p. 9)

Therefore, the critical thinking skills that I focused on in this study include analysis, interpretation, reflection, evaluation, inference, explanation, problem solving and decision making. These skills can be taught using strategies of problem-based learning, hands on and lecture and discussion.

The research purposed of this study is to discover whether teachers use strategies to teach critical thinking in physics classrooms and which strategy they consider as best in helping learners develop critical thinking skills. To address this issue, the following questions were tackled:

- How are teachers using strategies to teach critical thinking in physics classrooms?
- What are the best strategies that teach critical thinking in physics classrooms?

## Methodology

This study explored the strategies teachers used to teach critical thinking in physics classes. For this purpose, the researchers used the qualitative approach and particularly the case study method. Qualitative research served the study's purpose since it is used to investigate situations where observers or researchers are involved and are part of the investigation (Denzin & Lincoln, 2005). While, in the case study method "a single individual, group, or important example is studied extensively and varied data are collected and used to formulate interpretations applicable to the specific case or to provide useful generalizations" (Fraenkel, et al., 2012, p. 13). In addition, case study method allows the researcher to "select a small geographical area or a very limited number of individuals as the subjects of study" (Zainal, 2007, p. 1). Furthermore, researchers in qualitative research seek to get a better view of how people understand, interpret, construct and give meanings to their experiences (Denzin & Lincoln, 2005; Merriam, 2009). This allows qualitative researchers to get an understanding of a specific aspect being researched. Qualitative research focuses on process, understanding and meaning of the subject, it makes the researcher the major data collector and analyst, the research process is inductive and the results of the study are very descriptive (Merriam, 2009).

Since it was one of the researcher's observations of physics classes that triggered the need for this study, formal observations were the first source of questions for this investigation. The need for these questions to be discussed with the teachers arose. To investigate further, formal observations, interviews and questionnaires became necessary. In fact, questionnaires and interview are "a valid and productive way to assess the accuracy of observations" according to Fraenkel et al. (2012, p. 594). This investigation used questionnaire, interviews and observations. The three methods of data collection are needed for triangulation, which adds value and validation to the data collected and to the analysis and conclusions of the study (Morgan, 1988; Fraenkel et al., 2012). It is worth noting here that "triangulation can work with any subject, in any setting, and at any level. It improves the quality of the data that are collected and the accuracy of the researcher's interpretations" (Fraenkel et al., 2012, p. 517). The aim of this study is to gain better insight into how teachers understand critical thinking, whether they teach critical thinking, and what they consider as the best strategy to teach it.

### Sampling

According to Merriam (2009), statistical generalization is not a goal of qualitative research, hence purposive sampling can be utilized. Therefore, for the purpose of this study, a sample of 10 schools in Beirut were conveniently selected. These were schools where the researchers had acquaintances. This helped them reduce the time needed for travel, since they work in Beirut, or to get permission to contact teachers. Thirty physics teachers in these schools were purposively selected. Although purposive sampling may have some errors in areas related the researcher's judgment or representativeness of the sample, according to Fraenkel et al. (2012), this was not an issue for the purpose of this study since the study only needed teachers who would provide data that would help explore which strategy they believe is best to teach critical thinking. Purposive sampling would serve the goal of discovering and gaining understanding and insight about the topic of the investigation (Merriam, 2009).

Some of teachers who participated in the study were teachers who one of the teachers worked with and others were teachers introduced by them therefore by using snowball sampling (Fraenkel et al, 2012). It was important for this study that teachers who filled the questionnaires and those considered for observation or interviews had knowledge of the Lebanese physics curriculum and are currently teaching it. Classroom observations of 10 teachers, from those who filled the questionnaires, was done. The teachers were chosen to represent each of the classes in both the intermediate and secondary cycles. So, five teachers who taught intermediate classes and five teachers who taught secondary classes were chosen. Eight of the ten teachers (80%) were selected with backgrounds in physics and only two with science education background but not majors of physics. The researchers took this ratio so it would be compatible with the ratio of teachers who were given questionnaires. Almost 75% of them were teachers with majors in physics. The teachers observed all taught at the schools where one of the researchers worked, which were four schools in five locations. Five of the ten teachers observed work full time at the institution where the researcher worked and the other five are part-timers. The part-timers teach at other schools, four private schools and one public school. These selections were made purposively to be as representative as possible of the various experience in teaching that are conveniently available. Out of the ten teachers observed, five teachers participated in semi-structured interviews. Two teachers from the intermediate section and three from the secondary. Two of these teachers were full-timers and three were part-timers. One of the part-timers teaches at a public school in Beirut and the two teach at other private schools. The teacher who taught at the public school shared the strategies used in the public school and explained the strategies used at the school where the researcher observed their teaching. Even in small samples, when resources are limited, one can select appropriately to obtain enough data to answer the questions related to one's study (Patton, 2002). The three methods of data collection were used to validate and to triangulate the results.

The teachers who participated in the study were all physics teachers in the intermediate and secondary sections. Their years of experience ranged between three years up to 40 years. Some of the physics teachers were not physics majors although they did a major in one of the sciences. The non-physics majors were selected on purpose since not all physics teachers are physics majors, especially in the intermediate cycle. The researcher has observed this at some schools in Beirut including the schools where the researcher worked. Although rarer than in the intermediate cycle, few schools in Beirut have secondary teachers who are non-physics majors. One of the teachers who participated in the questionnaire is a grade-12 physics teacher who studied engineering. The non-physics majors were also asked to take part in this study to make the sample as representative as possible of physics teachers.

**Observations**

For the purpose of this study, observations were done using an instrument adapted from the Reformed Teaching Observation Protocol (RTOP), which was designed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) to observe the implementation of educational reforms. The report is published online in the ACEPT Technical Report No. IN00-3 and the authors clearly stated in it that they welcome researchers to use the RTOP if they wish to (Piburn & Sawada 2000). The adapted observation instrument was piloted by asking colleagues for their feedback about the validity and then finalized accordingly.

The reforms required teaching critical thinking through constructivist and inquiry-based methods (Piburn & Sawada, 2000). The protocol, RTOP, and its instrument provide reliability and validity for the information related to teaching of science according to the reforms in middle and high school (Goe, Bell & Little, 2008). The protocol, RTOP, was adapted by keeping only items related to the eight critical thinking skills and the three teaching strategies investigated. The critical thinking skills includeed analysis, interpretation, reflection, evaluation, inference, explanation, problem solving and decision making, while the strategies involve hands on/labs/simulations, lecture and discussion and problem-based learning. Observation of teaching was done, in addition to interviews and questionnaires.

**Interviews**

Interviews are commonly used in educational research. During one-on-one interviewing session, the interviewer is in control of the interaction taking place (Kaplowitz & Hoehn, 2001). Semi-structured interviews were conducted to build on the teacher's answers. According to DiCicco-Bloom & Crabtree (2006), in such interviews, responses may be used to ask for further information and the interviews give the researchers insights into shared understanding of the particular group being observed or participating in the study. In this case, the interviews with the participating teachers were used to gain insight into the teachers' attitudes towards critical thinking and how they teach it. Notes were taken, during the interviews, about the main ideas, attitudes, practices and keywords regarding the focus of the investigation. The questions in the interviews focused on elaborating the main objectives of the questionnaire, which is to elaborate what teachers think about teaching critical thinking and how they practice it.

**Questionnaires**

Questionnaires are used in research to explore and describe areas or questions involving researched topics in social sciences and in education, especially in exploratory and descriptive research. Questionnaires are used since they can easily access a large population and therefore are useful to collect large data with relatively low cost (Saunders, Lewis, & Thornhill, 2007). They are used to obtain answers and thoughts from respondents who are involved in the topic being studied (Gillham, 2000).

In order to have a low number of non-responsive participants, thereby, getting results that are useful, certain steps were taken based on Fraenkel et al. (2012), among them: selecting participants that have some idea about the topic, clearly explaining the objectives of the research, providing choices as answers to as many of the questions as possible and as little free response questions as possible and finally, asking the opinion of a small group of colleagues about the instruments as a pretest. The questionnaire used in this study was adapted from Steffen (2011) and targeted teachers' opinions and practices regarding teaching critical thinking

**Data analysis**

The data collected from the questionnaires and observations were analyzed using Microsoft Excel to compute averages and frequencies. Comparisons and descriptive analysis of the data followed based on the results obtained. The interview transcripts were checked for themes and patterns. An inductive approach was followed where the results of the data were analyzed to discover patterns and relationships and then conclusions developed. The data collected from all three instruments were analyzed and summarized. Moreover, they were synthesized in order to obtain an overall understanding of the research problem (Baxter & Jack, 2008) and to provide recommendations and conclusions.

**Statement of Informed Consent**

All participants signed an informed consent and submitted it to the researchers to guarantee them anonymized information when published in this study.

## Results and Discussion

The data collected revealed the following information:

First, regarding the teachers and their perception of critical thinking and teaching it, 27 teachers participated in the study by filling questionnaires (Table 1). The teachers' years of experience ranged between 3 and 40 years with an average of 14 years. The teachers' degrees varied from teaching diploma/license to master's degree. Out of these 27 teachers, seven did not have physics background or a degree in physics; they teach physics based on degrees in chemistry, biology, biochemistry or engineering. This fact is important because of its implications on teaching physics and critical thinking since these teachers may be more inclined to direct their efforts towards teaching to the test (Diepreye & Odukoya, 2019; Snyder & Snyder, 2008).

An evident result from the teachers' questionnaire (**Tables 2, 3, 4, 7, 8, 11, 12 and 13**, ***see all tables in the Appendix)*** is that they do not all have a common understanding of the requirements of teaching critical thinking (Demirs, 2015; Serin 2013; Viennot & Décamp, 2020); even more, some do not have an understanding of what critical thinking skills are. The open-ended question in the questionnaire (**Tables 4 and 13**), where teachers were asked to define critical thinking, supports this conclusion. Some of teachers were unable to provide a clear definition of critical thinking on their own; they resorted to internet sources and merely copied the definition(s). Some of those who tried to give an answer of their own, went out of topic. Howard et al. (2015) argues that for teachers to teach critical thinking, they must be critical thinkers themselves or at least be taught about critical thinking.

When it comes to teaching critical thinking, some of the teachers believed that they include instances where they require their students to think critically (**Table 2**), yet when asked if their students can use critical thinking skills, they admitted that their students cannot always perform critically (**Table 3**). This was clear by comparing the results of the two tables. Table 2, which is about the frequency that teachers include critical thinking skills in their lessons shows that the teachers believe they give students instances to reflect and think (average 4.3), to express understanding of the purpose of the lesson (average 4.8), to think clearly (average 4.7) and to think deeply (average 4.3). The answers also show that teachers are undecided if they are teaching students the differences between assumptions, inferences and predictions (average 3.4) and are not sure if they are teaching students to consider multiple sides of an argument (average is 3.9). Yet when these results were compared with the teachers' perception of their students' ability to use critical thinking skills, they responded that their students used critical thinking skills but got stuck in the middle of the process (Table 3). The teachers' responses show that they cannot decide if their students can make inferences all the time (average 3.2), analyze argument (average 3.2), use decision making skills (average 3.2), determine reliability of sources (average 3.2) or explain reliability of sources (average 3).

**Table 4** shows sample of answers found in **Table 13**, which contains the definition of critical thinking given by the teachers as discussed earlier.

**Table 1**: Some of the answers from **Table 13** showing answers to the open-ended question in the questionnaire "To me critical thinking is: ...."

| **To me critical thinking is:** |
|---|
| an important vital strategy in the learning process |
| the most important skill any teacher can teach to make a difference in his/her students |
| is the property physics students must possess to excel in later studies |
| ability to use data in a situation to predict the outcome by using suitable laws of physics |
| to go out of the box and define the sky as the limit of thinking |
| is one of the best ways of learning, it motivates imagination and recall information that might be not used |
| the process of actively and skillfully applying, analyzing, synthesizing and evaluating information gathered from observation or communication as a guide to belief and action |
| the foundation of constructivist approach in learning and teaching which includes general skills, integrated with each other according to the developmental level. These skills include making judgement and formulating arguments based on certain evaluation, critical comparison of conditions, drawing conclusion from certain interpretations, inquiring about the trustworthiness of information provided from authorities or resources, evaluate the quality of evidence, consider the epistemology aspect of knowledge construction and nature of knowing/learning when reading a certain piece of information. |

To further investigate teachers' perception and practice of teaching critical thinking, classroom observations were done. Table 5 shows background information about the teachers whose classes were observed. Ten observations took place. The observed teachers came from various educational backgrounds with an average teaching experience of 8.4 years. Eight of these teachers have physics background while 2 have degrees in biochemistry and biology.

The observations indicated that most teachers did not plan their lessons to include teaching critical thinking (Tables 6, 10 and 11). The teachers were the center of the sessions (average 1.3) while the students were mostly passive although receptive (Table 6). Table 6 also shows that students did not explore the new ideas before the presentation of the lesson (average 2.5). One possible interpretation for teachers wanting to be the center of their classes may be attributed to teachers lacking in-depth understanding of physics concepts (Engstrom & Carlhed, 2014), therefore preferring to take control of their lessons and classes and allowing minimum interaction for students, if at all. It could also be because some of these teachers, as Table 5 reveals, are not physics majors, which may contribute to the students' lack of engagement in class since the teachers may be focused on teaching for the test and not for concept understanding (Diepreye & Odukoya, 2019; Snyder & Snyder, 2008).

To further explore the results of the questionnaires and the observations and to delve deeper into teachers' perception of critical thinking and the best strategies to teach it, five interviews took place with five teachers from different schools (Table 7). Four of the teachers interviewed have physics backgrounds and one has a degree in biochemistry. Three of the teachers teach secondary, while 2 teach intermediate.

The teachers' responses to the interview questions are summarized in Table 15. The table reflects key concepts or words that the teachers used as answers to questions related to how they teach critical thinking. One of the 5 teachers mentioned that s/he does not teach critical thinking in class and that the learners achieve critical thinking skills naturally after learning the lessons because it shows in their results. Three out of the five teachers mentioned that they never received any training on how to teach critical thinking in physics classes. As for what they believed was the best strategy to teach critical thinking, three out of the five teachers mentioned labs and hands on, one teacher said that the Socratic method used in lecture and discussion works and another teacher mentioned that problem solving is the best. Although these same teachers mentioned that they also use other strategies.

The interviews also revealed results that contradict those found in the questionnaire. According to the interviewed teachers, the best strategies to teach critical thinking are lab, problem solving, hands-on activities and the Socratic method of discussion (Table 15). Yet, Table 8 reveals that lecturing and discussion is widely used among the teachers. As mentioned before, one of the interviewees admitted that s/he does not teach critical thinking. This can be explained by the fact that teachers do not teach critical thinking in their classrooms because it is difficult to do so (Lai, 2011; Willingham, 2007). Another finding worth noting is that among the five interviewees, only two attended *one* workshop on critical thinking each. Part of being able to teach physics properly and to prepare classes where students can acquire and develop critical thinking skills, is for teachers to constantly seek professional development (Engstrom & Carlhed, 2014; Ennis, 2018; Serin, 2013;).

This brings us to the first research question: *How are teachers using strategies to teach critical thinking in physics classrooms?* According to the results of the questionnaire, teachers use one main strategy in their classrooms, which is lecture and discussion (Table 8), and problem-solving to a lesser extent (Table 9). The teachers use these strategies in solving exercises, in explaining concepts and giving instructions. Lecturing is used in all physics topics and on daily basis. Table 9 shows the results of the teachers' answers to how and when they use problems-solving method in their classes. Seventeen teachers indicated that they use problem solving in exercises, one said in assessment, one in individual and group work while six stated that they use it by giving real life problems; two teachers gave out of context answers. Fourteen of the participants indicated that they use problem-solving method as a strategy to teach critical thinking on daily basis, while ten teachers indicated that they rarely use problem-solving to teach critical thinking.

Observations revealed that teachers are not utilizing lecture and discussion properly as a strategy to teach critical thinking. Teachers were dominating the classes and giving their students few or no instances of reflecting on their knowledge (Tables 6). Moreover, by using lectures in the form of direct instructions, teachers were barely able to prepare their students to relate the topics to real-life situations (average 3.5) or to use elements of abstraction (average 3.2) as seen in Table 10. The conclusion is that the teachers were not fully successful in achieving the goal of teaching students how to apply critical thinking skills.

The observations of the classrooms also revealed that the students were mostly passive, although receptive, and rarely communicated their ideas (average 2) as shown in Table 11. The students also rarely discussed the topics at hand (average 2.4) and did not have a say in how the lesson proceeded (average 2.6). These results, when compared with the teachers' responses in the questionnaires, regarding their perception of teaching critical thinking skills, show a contradiction between the responses and the practices. This validates further the conclusion that was made earlier that teachers are not using strategies properly to teach critical thinking in their classes.

Moreover, teachers also stated that they use simulation and lab experiments in their lessons (Tables 12 and 13). Table 12 shows the results of the teachers' answers to how they use simulation as a teaching method in their classrooms. Only six teachers use this method frequently, with 21 either using it rarely or just once. Those who do only use this method when the concept they are teaching is difficult for students to visualize.

As for labs and demonstrations (Table 13), 18 teachers mentioned that they use this method with 9 stating that they rarely use it. Fourteen teachers stated that they use labs to test, analyze, hypothesize and apply scientific method while 9 use labs to introduce, explore, explain, understand and answer questions.

The teachers responded that they occasionally use simulation to discuss concepts with their students; concepts that would otherwise be difficult to understand (Ceberio et al, 2016; Daineko et al. 2016; Ma & Nickerson, 2006). They also occasionally use lab experiments to test, analyze, introduce new concepts and apply the scientific method. Both methods play a positive role in providing students with desired science knowledge (Ceberio et al, 2016; Daineko et al., 2016; Ma & Nickerson, 2006) when applied properly. However, the observations indicated that the teachers might not have been totally accurate in their responses except for three of them who gave no responses. According to observations, teachers mainly used lecturing, although the topics given during the observations could have been taught interactively in labs, either virtual/simulation labs or hands-on labs. This contradiction deserves further observations and investigations.

The second research question: *What are the best strategies that teach critical thinking in physics classrooms?* was answered best in the interviews. All five teachers did not state lecturing as a method for teaching critical thinking. They considered hands-on lab experiments, problem solving and the Socratic method as the best tools for teaching critical thinking in physics classrooms. Even the teacher who admitted that s/he does not teach critical thinking, believed that lab experiments and problem solving would be the strategies s/he would use if s/he were to teach the skills (Banda, & Nzabahimana, 2021; Herterbran, 2007; MacKnight, 2000; Nilson, 2010; Roslina et al, 2022; Salaoru, 2020; Sulaiman, 2011; Sulaiman, 2013). None-the-less, the results from the other instruments contradicts the teachers' interview responses.

If we consider only teachers' practices to answer the second research question, we can conclude that the best strategy to teach critical thinking is lecturing and discussion. However, the observations and questionnaires indicate that students are not being taught critical thinking, even by this strategy, that's why the students do not seem to perform well when critical thinking skills are involved. This can be attributed to the fact that teachers use lecturing in the form of direct instructions, which cause the students to be demotivated and passive in class (Banda, & Nzabahimana, 2021 & 2023; MacKnight, 2000; Herterbran, 2007; Nilson, 2010).

The contradictions found when comparing the responses of the interview questions and questionnaires, with the classroom observations and students' classroom performance and interaction deserve further in-depth investigation.

## Conclusion and Recommendations

In conclusion, the aim of this study was to investigate whether physics teachers were teaching critical thinking skills within the context of the Lebanese physics curriculum and if so, which strategy did they consider as the best to do that. The results of the study show that there is a need to continue with the curriculum reform that the ministry of education has embarked on. This reform, mentioned in the purpose and rationale section, seeks to include teaching 21st century skills in the Lebanese curriculum. This study shows that the reform is necessary since, currently, the implementation of the curriculum allows students to pass and graduate despite the exclusion of teaching critical thinking skills. Furthermore, the results show the need for teachers' development to include training in critical thinking teaching strategies. Fortunately, at the moment, the CRDP is undergoing curriculum reform to address the issue (Saba'Ayoun et al, 2024).

However, the study has limitations which include the convenient and purposive sampling, which may yield results that might not be generalized. In addition, the limited number of interviewee and observed classes increase the margin of error of the results. Based on the results of this investigation, it is recommended that Physics teachers be provided with teacher development programs that include the following:

- training in understanding critical thinking skills and how to utilize critical thinking;
- training in how to teach critical thinking;
- training in pedagogical approaches where they implement strategies that are inquiry based and can improve students' critical thinking skills;
- training in using technology-based teaching such as wikis (Mohottala, 2013), WebQuests (Zhou, 2012) and other web-based applications;
- training in how to properly use problem-based learning and problem solving to develop learners critical thinking skills (Sulaiman, 2011; Sulaiman, 2013).
- Training is using the latest AI tools to render their lessons more interactive (Vallor, 2024).

Finally, it is recommended that teachers who will teach physics should have a physics degree in addition to at least a teaching diploma in science education.

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## Appendix

### Tables

**Table 2**: Background information of participants in the questionnaire.

| Number of teachers | Range of years of teaching | Average range of years of teaching | Educational level and background | Grade level teacher |
|---|---|---|---|---|
| 27 | From 3 years to 40 years | 14 ears | - 8 with Masters in Physics<br>- 1 with Engineering<br>- 4 with TD and MA in Education<br>- 3 with TD in Education<br>- 2 with MSc in Biochemistry<br>- 3 with BSc in physics<br>- 2 with license in physics<br>- 1 with BSc and TD in Chemistry<br>- 1 with BSc in Chemistry<br>- 2 with BSc in Biology | - 12 Secondary teachers<br>- 7 intermediate teachers<br>- 7 intermediate and secondary teachers<br>- 1 did not respond |

**Table 3**: Averages of participants' answers to the questionnaire about teaching critical thinking in classrooms.

| Never | 1 to 3 times a term | Undecided | 2 to 3 times a month | Daily |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |
| How often does your instruction require students to think to understand the content? | | | | 4.3 |
| How often does your instruction explain different types of critical thinking in a way that your students can explain and understand them? | | | | 4.3 |
| How often does your instruction make clear to your students the reason why they are doing what they are doing (the purpose of the lesson)? | | | | 4.8 |
| How often does your instruction make clear to your students the precise question, problem, or issue at any given time in your lesson? | | | | 4.7 |
| How often does your instruction help your students learn how to find reliable information relevant to answering questions in the subject? | | | | 4.3 |
| How often does your instruction help your students learn how to make inferences justified by data or information? | | | | 4.3 |
| How often does your instruction help your students know the differences between assumptions, inferences, and predictions? | | | | 3.4 |
| How often does your instruction enable your students to think more clearly? | | | | 4.7 |
| How often does your instruction enable your students to think more deeply? | | | | 4.3 |
| How often does your instruction enable your students to consider multiple sides of an argument? | | | | 3.9 |

**Table 4**: Averages of participants' answers to the questionnaire about students' actions in classrooms.

| **Not at all** | **They can sometimes do this but need help** | **They can do this but get stuck in the middle** | **They can do this most of the time** | **They can always do this** |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |
| Use problem solving skills to find the best solution. | | | | 3.8 |
| Use inferential skills to explain solutions | | | | 3.2 |
| Use decision making skills to consider possible options and decide what might happen as the result of the decision. | | | | 3.2 |
| Reflect on possible results or solutions | | | | 3.8 |
| Make predictions based on possible and actual evidence | | | | 3.5 |
| Interpret solutions based on evidence | | | | 3.8 |
| Compare and contrast by considering how something is alike with regard to their differences and any significant patterns. | | | | 3.8 |
| Analyze arguments by finding reasons and conclusions and uncover assumptions. | | | | 3.2 |
| Determine the reliability of sources by considering questions to ask about the information obtained and deciding if it is reliable or unreliable. | | | | 3.2 |
| Explain the reliability of sources | | | | 3 |

**Table 5:** Background information of teachers observed.

| | |
|---|---|
| Announced observation? | Yes |
| Teacher's years of teaching | - Years of teaching range from 3 to 16<br>- Average: 8.4 years |
| Teacher's educational level and background | - 5 Masters in physics<br>- 1 TD in physics<br>- 1 MA in physics education<br>- 1 BSc in Biology + TD + MA in science education<br>- 1 BSc in physics<br>- 1 Masters in Biochemistry |
| Grade level | - range from grade 7 to grade 12;<br>- 5 intermediate and 5 secondary |
| Description of event | topics included various physics lessons: heat, sound, waves, electricity, mechanics etc. |

**Table 6:** Observation of lesson design and implementation.

| **Never Occurred** | **rarely** | **average / half of the time** | **frequently / most of the time during session** | **Very descriptive** |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |
| The instructional strategies and activities encouraged students to activate prior knowledge in order to reflect on and question preconceptions and explore misconceptions | | | | Average: 3.5 |
| In this lesson, student exploration preceded formal presentation. | | | | Average: 2.5 |
| This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. | | | | Average: 3 |
| The focus and direction of the lesson was often determined by ideas originating from students. | | | | Average: 1.3 |

**Table 7:** Interviewees background information.

| | |
|---|---|
| Teacher's years of teaching | - Average 9.6 years<br>- Range from 4 to 15 years |
| Teacher's educational level and background | - 2 license in physics and MA in physics education<br>- 1 Masters in physics + TD<br>- 1 BSc in physics<br>- 1 Master in Biochemistry |
| Grade level | - 2 intermediate<br>- 3 secondary |

**Table 8:** Lecture and discussion strategy answers of teachers in questionnaires.

| | |
|---|---|
| To what extent do you use each strategy to teach critical thinking: | - 18 always/daily/mostly<br>- 4 to introduce, summarize, answer questions<br>- 2 sometimes and rarely<br>- 3 no response. |
| How do you use each strategy to teach critical thinking | - 2 during exercises and problem solving<br>- 16 to explain, give directions, discussion with CT questions, how and why, summarize, relate lesson to life<br>- 2 to discuss the results of lab or discuss video or simulation<br>- 5 no response<br>- 1 yes<br>- 1 traditional |
| Where in the curriculum do you use each strategy and for which classes (example) | - 19 for all topics in all classes<br>- 1 G12 nuclear<br>- 1 during introduction of topics<br>- 1 social, technological and environmental problems related to political and social issues and aspects<br>- 5 no response |

**Table 9**: Problem solving strategy answers of teachers in questionnaires.

| | |
|---|---|
| To what extent do you use problem solving to teach critical thinking | - 14 always/daily<br>- 1 no-response<br>- 2 at the end of the unit<br>- 1 in assessments<br>- 1 partially<br>- 1 per term<br>- 2 often<br>- 2 mostly<br>- 1 enough to understand<br>- 1 yes |
| How do you use problem solving to teach critical thinking | - 17 in exercises to understand concepts and assignments<br>- 1 in assessments<br>- 1 in group work and individual work<br>- 6 by giving real life problems to solve –<br>- 1 yes<br>- 1 out of context |
| Where in the curriculum do you use problem solving and for which classes (example) | - 14 all<br>- 8 electricity or mechanics or both<br>- 1 environmental issues<br>- 1 G12<br>- 1 real life examples<br>- 2 no-response |

**Table 10**: Observation of classroom culture.

| **Never Occurred** | **rarely** | **average / half of the time** | **frequently / most of the time during session** | **Very descriptive** |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |
| Students were involved in the communication of their ideas to others using a variety of means and media. | | | | Average: 2 |
| The teacher's questions triggered divergent modes of thinking. | | | | Average: 3.4 |
| There was a high proportion of student talk and a significant amount of it occurred between and among students. | | | | Average: 2.4 |
| Student questions and comments often determined the focus and direction of classroom discourse. | | | | Average: 2.6 |
| There was a climate of respect for what others had to say. | | | | Average: 3.8 |

**Table 11**: Observation of propositional knowledge.

| **Never Occurred** | **rarely** | **average / half of the time** | **frequently / most of the time during session** | **Very descriptive** |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |
| Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. | | | | Average: 3.2 |
| Connections with other content disciplines and/or real world phenomena were explored and valued. | | | | Average: 3.5 |

**Table 12**: Simulation (computer) strategy answers of teachers in questionnaires.

| | |
|---|---|
| To what extent do you use simulation to teach critical thinking: | - 6 always/frequently<br>- 11 occasionally<br>- 3 when labs are not possible<br>- 2 rarely<br>- 1 motivation<br>- 1 yes<br>- 1 out of context<br>- 1 no response |
| How do you use simulation to teach critical thinking | - to discuss, understand, reflect, infer, analyze, conclude, hypothesize<br>- 4 to visualize difficult concepts or when labs not available<br>- 2 group work, homework and classwork<br>- 1 yes<br>- 1 using computers<br>- 1 out of context<br>- 1 through real life application<br>- 1 no-response |
| Where in the curriculum do you use simulation and for which classes (example) | - 9 all classes and topics<br>- 14 topics that are difficult to visualize like waves, oscillations, buoyancy, some electricity and mechanics<br>- 2 when no labs<br>- 1 G12<br>- 1 no-response |

**Table 13:** Lab strategy answers of teachers in questionnaires.

| | |
|---|---|
| To what extent do you use each strategy to teach critical thinking: | - 8 frequently<br>- 10 occasionally<br>- 4 rarely<br>- 1 (4 (most of the time))<br>- 3 no response<br>- 1 motivation + assessment |
| How do you use each strategy to teach critical thinking | - 14 to test, analyze, hypothesize, scientific method<br>- 9 to introduce, explore explain, understand and answer questions<br>- 1 group<br>- 1 (3 (they can do it but get stuck in the middle))<br>- 2 no response |
| Where in the curriculum do you use each strategy and for which classes (example) | - 20 all topics and level<br>- 4 no respons<br>- 2 whenever materials are available |

**Table 14**: Open ended question in the questionnaire "To me critical thinking is: ...."

| **To me critical thinking is:** |
|---|
| the foundation of teaching and education and learning. Teachers learn and should learn from students too. |
| the intellectual ability to reason correctly |
| knowledge, comprehension, application, analysis, synthesis then taking action |
| a skill our learners should develop not only in physics but in all subjects |
| to go out of the box and define the sky as the limit of thinking |
| the ability to think clearly, to promote creativity, think outside the box |
| thinking about thinking, by making the unseen more visible and clear. Or thinking while examining all the aspects of the situation by describing, analyzing and evaluating data and information to come out with a solution or a reason to the cause of events. |
| an important vital strategy in the learning process |
| CT and problem solving skills are the mean objectives of physics classes; to teach students how to use known data and apply then to new situations to come up with useful solutions |
| the capability of being analytic and a good evaluator |
| being able to make assumptions, predictions, checking them and evaluating the results. |
| the ability to make decisions based on acquired knowledge, evidence, observations, and being able to extend further |
| ability to use data in a situation to predict the outcome by using suitable laws of physics |
| the foundation of constructivist approach in learning and teaching which includes general skills, integrated with each other according to the developmental level. These skills include making judgement and formulating arguments based on certain evaluation, critical comparison of conditions, drawing conclusion from certain interpretations, inquiring about the trustworthiness of information provided from authorities or resources, evaluate the quality of evidence, consider the epistemology aspect of knowledge construction and nature of knowing/learning when reading a certain piece of information. |
| is one of the best ways of learning, it motivates imagination and recall information that might be not used |
| ability to join two or more concepts or abilities to explain and study a complex situation |
| is the property physics students must possess to excel in later studies |
| is more than just thinking clearly or answering the question correctly, it is when students can analyze each situation independently and develop his own conclusion, after making the necessary connections between previously acquired ideas and the new introduced ideas |
| is the ability to think clearly and rationally is important whatever we choose to do. Thinking well and solving problems is essential for any career. CT is understanding the logical connection for ideas. |
| to solve a problem referring always to the data given in class, orally, before writing it on paper |
| having a deep, self-reflective understanding of a question or problem and considering options and ideas for solutions to a problem |
| the process of actively and skillfully applying, analyzing, synthesizing and evaluating information gathered from observation or communication as a guide to belief and action |
| the ability to think |
| higher order thinking skills |
| the most important skill any teacher can teach to make a difference in his/her students |
| the ability to engage in reflective and independent thinking |

**Table 15**: Summary of interview answers.

| **Questions** | **Summary of answers** | | | | |
|---|---|---|---|---|---|
| Do you use strategies to teach critical thinking in your classes? | yes | Yes, problem solving, lecture and discussion | yes | Yes | No; I don't include it in lesson plans; I just teach physics concepts; but CT is developed; I know since leaners can analyze when concepts are understood; CT is a new concept for me. |

| | | | | | |
|---|---|---|---|---|---|
| What strategies, according to your experience, is best to teach critical thinking? Why? | Lab is the best then problem solving then hands on | Problem solving is the best. Teachers can evaluate students' analysis after teaching | hands on activities; using labs makes it easier for learners to understand; weekly sessions; | Socratic method is the best; asking questions; lecture and discussion; | I believe that if I should teach CT then labs and problem solving will work. lecture and discussion doesn't work especially in intermediate; discussion may be good for G11 and above but labs are better |
| Which levels or classes do you think are the best to teach critical thinking skills? | from early childhood, then whole life continuously | Secondary. Not sure about intermediate, no experience | middle school or intermediate; using hands on; high school remember what they learn in middle school when hands on is used. | in the intermediate and based on physical real life situations they can relate to | before intermediate; from the class where they start learning science; maybe G4 |
| Which lessons or units in the curriculum do you think are best to integrate teaching critical thinking skills? Why? | All topics. Although concrete non-abstract topics are better | Mechanics; has many situations that can help learners, closer to real life, personal experience, teacher more comfortable with mechanics. Electricity too; | All topics fit in physics; yet easiest is mechanics since easy to visualize; relate to real life; can be analyzed | most lessons in physics since they can relate to in real life; maybe they can't in nuclear physics; but they can in others like mechanics and elect. | it can be integrated in any lesson or unit since CT is a way of thinking. |
| What workshops, presentations and/or professional development seminars / certificates have you attended on critical thinking? | One workshop - yet nothing new was introduced | No workshops | No workshops | Yes; one | None; Values maybe but not CT. |
| If you attended then what strategies and/or techniques for teaching critical thinking skills did you learn? | none | none | none | hands on; tackling misconceptions and teaching styles; depending on objectives: to understand or pass tests | none |
| If not, how did you learn the strategies that you use to teach critical thinking? | experience / interaction with students / personal research / school / colleagues / coordinator | acquired through personal studies and at university while working on diploma and through colleagues in physics dept. | by experience; self-taught; readings | learn through personal experience and effort | Through experience in new school, and new colleagues and department |

| | | | | | |
|---|---|---|---|---|---|
| Think about a topic where you had taught a lesson, and then retaught it using critical thinking skills. How was it different and how did the students respond to it? If you haven't taught it using critical thinking skills and you wanted to do that, how would you go about doing it? | Optics in G8. used to teach using board. Now use lab activity. Leaners are more excited and analyze and remember better | Mechanical oscillation at 12LS, used to teach directly without CT; shared teaching strategy with colleague, now use that strategy involving analysis; students now understand better; no memorization; understanding instead | circular motion and normal acceleration: 1st taught in class using lecture then used lab, learners understood better and could analyze and transfer; visualizing helps in analysis | mechanical oscillation used to explain directly the graphs and teach only what is needed for them to pass the exams; now I help them analyze the situation and the graphs are the result of their analysis, they understand it better | lesson of up-thrust in grade 9, I used to teach using direct instruction, I now use demonstration and experiment, after experiment I discuss. I notice learners understand better when using hands on |
| What are some examples of changes you've made in your teaching that focused on improving student thinking? | integrate real life situation with every lesson. Ask learners to research and explore lessons | using more problems involving real life situations; included simulations; more discussions during lecture in contrast with 1st 2 years which were mostly lecture | in derivatives used to explain instantaneous velocity using math; last year learners did an activity, plotted graphs, used excel, understood better the difference between instantaneous and average velocity | during first years of teaching, not CT skills were taught, it was 6 years later, gradually, it made a difference, even though learners feel better when teachers make an effort, yet, assessments did not improve with teaching CT, maybe more practice is needed to reinforce ideas and concepts | by knowing misconceptions and preconceptions, one can teach by countering these before they become part of learners' thoughts, example: difference between equilibrium and interaction. |