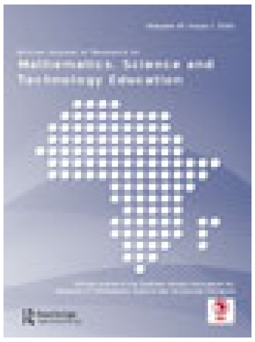

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# The Effectiveness of Teaching Energy in a Secondary School Using the "Factory of Ideas" Teaching Approach

**Sechaba Koma [a*], Ts'epo Mokuku [a], Tiisetso J. Makatjane [b], Christel Balck [c], and Jan Sermeus [d]**

[a] *National University of Lesotho, Department of Science Education, Lesotho*
[b] *National University of Lesotho, National University of Lesotho, Lesotho*
[c] *Odisee University College, Sint-Niklaas, Belgium*
[d] *Katholieke Universiteit Leuven, Leuven, Belgium*
**Corresponding author. Email: komasechaba@gmail.com*

**This study investigated the extent to which the proposed Factory of Ideas (FOI) teaching approach impacted on students' understanding of energy based on their prior knowledge. The FOI is a didactic approach that, unlike the classic cognitive conflict approach, employs a variety of activities to offer students a scientific conception for comparison with their own, and to expose students to several contexts in which the concept is applied. A total of 122 Grade 8 students participated in the study. A quasi-experimental research design with both a pre–post-test and a control and experimental group was employed. The control group (an intact class, *N* = 58) was taught using traditional teaching methods while the experimental group (an intact class, *N* = 64) was taught using the FOI teaching approach, which is underpinned by tenets of argumentation theory. The content-based pre- and post-test produced quantitative data that were analysed using SPSS. Based on the *t*-test comparing the mean scores of the two groups after the intervention, the experimental group was consistently found to outperform the control group on the correct understanding of energy concepts. Thus the FOI teaching approach impacted significantly on students' understanding of energy concepts. However, for some students, the FOI did not significantly change the students' use of alternative conceptions related to the law of conservation of energy. It is concluded that the FOI strategy is in general an effective teaching strategy, with the potential to facilitate learning of new scientific concepts, particularly if supported by a number of relevant science applications, and by laboratory and visual resources.**

**Keywords:** *Energy; prior knowledge; argumentation; scientific conceptions; Factory of Ideas*

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## Introduction

Energy is one of the major topics in Physics and underpins every process in life. Energy is a cross-cutting concept that plays an important role in other sciences (Nordine et al., 2018). Energy issues have personal, social and environmental implications that may help to enhance students' interest in learning (Domenech et al., 2007). However, it is difficult to explain what energy is. Millar (2014) argues that

> teaching energy ideas poses a greater challenge to science teachers and educators than other science topics. For most topics, there is broad agreement about what would constitute an appropriate understanding of the topic at different stages of the education process. For energy, this is not the case. (p. 1)

National Examiners' reports on Physical Science in Lesotho show that students' performance on "energy" is unsatisfactory. Students perform poorly in the questions related to energy conversions and calculations (Examinations Council of Lesotho, 2017). The challenge is not unique to Lesotho though; studies from other countries show that students' understanding of foundational ideas of energy is somewhat limited (Dega & Govender, 2016; Solbes et al., 2009). In Lesotho, this situation could be attributed to the dominance of teacher-centred strategies in science lessons (Khanyane et al., 2016). These strategies hardly lead to students' meaningful learning since they seldom consider students' prior knowledge (Qhobela & Moru, 2014). The examiners' reports call for the implementation of an effective teaching approach, particularly because energy is a major topic in the Lesotho curriculum (Examinations Council of Lesotho, 2017).

To improve performance in science, the current study proposes a teaching approach that begins with a focus on students' prior knowledge and progresses to scientific conception through dialogical engagement of students or argumentation (Chen & Wang, 2016; Zhou, 2010). This teaching approach, coined the "Factory of Ideas" (FOI) teaching approach (Balck et al., 2017), elicits and respects students' prior knowledge. By respect, we mean that students' prior knowledge is considered to be rich in generative ideas that serve as conceptual resources for developing scientific conceptual understanding (diSessa, 1993; Hammer, 1996). Unlike the classic cognitive conflict approach (Posner et al., 1982), the FOI approach offers the scientific conception for comparison with the students' held conceptions, and provides them with several contexts in which the concept is applied. The FOI approach has been used successfully in Europe where there are 20–25 students in a class (Sermeus et al., 2019). The present study explores its implementation in an African context where classes are relatively large, with sometimes more than 55 students per class (Onwu & Stoffels, 2005). The FOI approach has six stages that help students comprehend any concepts under study —these stages are elaborated in the Methodology section.

Against this background we set out to investigate the following research question:

> To what extent does the proposed FOI teaching approach impact on students' understanding of energy?

Thus the null hypothesis was that

> There is no significant difference in the students' understanding of energy between the experimental and the control groups as a result of the use of the FOI teaching approach.

## Literature Review

Learning of concepts in science can occur under at least three dissimilar conditions of prior knowledge (Chi, 2013). The first condition is learning that entails adding new knowledge; this occurs when prior relevant knowledge is missing. The second condition is learning that focuses on gap filling; this occurs when prior relevant knowledge is incomplete. The third condition is learning that aims at changing knowledge that is "in conflict with" the to-be-learned concepts and it is, therefore, a conceptual change kind of learning (Chi, 2013). Driver et al. (1985) state that it is important to consider students' prior knowledge when planning and delivering science lessons so that specific activities that challenge students' prior knowledge are performed. In addition, Hattie and Donoghue (2016) urge that prior knowledge helps students to think critically and logically in science lessons. Therefore, taking account of students' prior knowledge is an imperative feature for promoting learning (Riesen et al., 2018).

Many studies on the teaching and learning of energy have reported that students have serious misunderstandings about the energy concept (Duit, 2014; Fortus et al., 2019), including students in Southern Africa (Dega & Govender, 2016; Lemmer, 2011; Meiring & Webb, 2012). In this study, scientifically incorrect conceptions are referred to as "alternative conceptions" as described by Hewson and Hewson (1983) and Chi (2013). Students' ideas about energy come from different sources, i.e. everyday written or spoken discourse, science texts and lectures, economics and politics, and their own interpretation of nature (Millar, 2014).

Studies show that some students have prior knowledge that only objects that are moving have energy (Nordine, 2016). In his review of literature on energy teaching and learning, Duit (2014) found that students referred to energy as an abstract accounting quantity, as the ability to perform work, causing changes or producing heat. Similarly, it has been reported that students consider energy as a physical substance that can be accounted for, can flow, can be carried, can change form and can be lost (Lancor, 2014). Trumper (1990) found that, even after formal lessons on energy, students continued to hold the same alternative conceptions as before.

Whereas problems on energy forms, sources, transformation and transfer seem to be performed fairly well (Liu & Park, 2012; Neumann et al., 2013; Park, 2019), students tend to struggle with solving problems related to energy conservation and degradation. Difficulties in solving these problems are said to emanate from the way energy concepts are taught to students, starting from primary school level (Millar, 2014).

There are numerous instructional procedures suggested by different researchers on the teaching and learning of scientific energy concepts. Duit (2014), Neumann et al. (2013) and Solbes et al. (2009) together argue that energy should not be taught disconnectedly; the aspects of energy (energy transformation, energy transfer, energy conservation and energy degradation) should not have separate lessons. This suggests that one aspect may be understood if all others are also understood or some fundamental ideas about them are comprehended. Millar (2014) points out that proposing an energy teaching approach is challenging as the topic is itself abstract. However, he further argues that energy teaching should present energy as a measurable quantity from as early a stage (primary school level) as possible. At the early stage, equations and formulae should not be introduced, but rather quantitative energy information from food labels and other objects may be used. Teaching should also introduce energy dissipation together with energy conservation so as to make the quantitative aspect of energy easy to understand (Millar, 2014).

There is a need for a didactical approach that builds on students' prior knowledge in the teaching of science, in particular, the teaching of energy. This approach should facilitate the conceptual shift from their prior knowledge to scientific concepts, treating this knowledge as context-dependent "knowledge-in-pieces" (diSessa, 1993, 2018). In this study, we explore how such a teaching approach can effectively facilitate students' construction of scientifically acceptable conceptions of energy. The approach embraces the students' prior knowledge, fosters development of knowledge by comparing their prior knowledge with scientific conceptions and proposes various contexts where the knowledge can be applied.

## Theoretical Framework

This study explored the use of a teaching approach that entails both conceptual change and dialogue to enhance students' acquisition of a scientific conception of energy. According to Hewson and Hewson (1983), conceptual change may occur under the following four conditions: when one feels dissatisfied with the held conception; when the conception is no longer necessary; when the conception is irreconcilable with the new concept which cannot be ignored; or when the conception is found to violate some epistemological standards. If any of these occur, a new, intelligible, plausible and fruitful conception must be available so that the old conception may be exchanged with the new one (Posner et al., 1982). Accordingly, the teaching approach used in this study attempted to elicit students' held conceptions and engage them in an exercise that examines the status of their conceptions (Hewson & Hewson, 1983). In addition, the approach respects and builds on students' prior knowledge. diSessa (1993) perceives this knowledge as being made up of productive fragments called phenomenological primitives (p-prims) that form the foundation for scientific knowledge growth. This study draws on "knowledge in pieces" epistemology that considers students' prior knowledge as productive and contextual. These pieces, which appear in some contexts and not others, are rich and helpful in developing scientific understanding (diSessa, 2018). The knowledge growth is guided by comparison of students' prior knowledge and scientific knowledge and provision of situations where the scientific knowledge is applicable.

The teaching approach further involves a Socratic dialogic interaction, wherein students ask questions, explain their ideas and comment on the ideas of their peers with focus on an initial question asked by a teacher who acts as a facilitator of the dialogue (Alexander, 2008; Rossem, 2006). This dialogue parallels the scientific “argumentation theory” which involves students (arguers) explaining, testifying, defending and convincing opponents to “buy their ideas”. Nonetheless, the arguers remain open-minded and try to understand the side of their opponents and stay ready to modify their ideas (Chen & Wang, 2016; Zhou, 2010). In this study, the teacher asks a question, then invites students’ ideas, who in turn discuss the ideas of one of them; in the process, the teacher avoids introducing her/his opinion, directing or intervening in the content of the dialogue (Rossem, 2006). At the end of a Socratic dialogue, the teacher ensures mutual agreement by the students through asking them to repeat or recap their dialogue and agreement. However, there is no final answer at the end of a Socratic dialogue. This paves the way for the teacher providing the scientific knowledge; the teacher is the “arguer” who represents scientific knowledge (Zhou, 2010).

## Methodology

A quasi-experimental research design was employed involving pre- and post-tests for the control and experimental groups (Cohen et al., 2013). The experimental group received the FOI teaching approach, while the control group received the traditional teaching approach. The research participants were not randomly selected; instead the experiment occurred with intact class groups (Creswell, 2012). The pre-test served to measure the equivalence of the control and experimental groups, and to examine students’ ideas about energy before instruction.

The sample consisted of 122 Grade 8 students (boys and girls) from one high school. The sample consisted of students in two different intact classes, to which students were assigned by the school. The control group had 58 students and the experimental group 64 students. The principal researcher taught the experimental group, guided by the FOI approach, and the control group was taught by a teacher with equivalent academic qualifications who employed the traditional interactive-lecture method. The lessons followed the school timetable which allocated the two teachers to those classes. This experiment followed the blind experiment design to reduce the Hawthorne effect. According to Cohen et al. (2013), a blind experiment is one in which the participants are not told whether they are in an experimental or a control group.

### *Characteristics of the Sample*

Table 1 bears evidence that the two groups had similar characteristics in terms of gender, Primary School Leaving Examination (PSLE) pass level obtained and PSLE science grade obtained. The PSLE is a national examination taken by the respondents at the end of the previous school year.

**Table 1.** Distribution of respondents by gender and Primary School Leaving Examination (PSLE) performance

| Characteristic | Category | Control group (%) | Experimental group (%) | All pupils (%) |
|---|---|---|---|---|
| Gender | Males | 32 (55) | 36 (56) | 68 (56) |
| | Females | 26 (45) | 28 (46) | 54 (44) |
| PSLE pass level obtained | First class | 8 (14) | 10 (16) | 18 (15) |
| | Second class | 21 (36) | 22 (34) | 43 (35) |
| | Third class | 29 (50) | 32 (50) | 61 (50) |
| PSLE science grade | 1 | 12 (21) | 16 (25) | 28 (23) |
| | 2 | 23 (40) | 21 (33) | 44 (36) |
| | 3 | 19 (33) | 22 (34) | 41 (34) |
| | F | 4 (7) | 5 (8) | 9 (7) |
| Total | | 58 (48) | 64 (52) | 122 (100) |

Note: At PSLE, highest grade achievable in any subject is “1”, followed by “2”, then “3” while “F” denotes fail.

### *The FOI Classroom Activities*

The FOI (Balck et al., 2017) teaching approach involved facilitation of knowledge construction, with particular attention given to students' prior knowledge and dialogic engagement. The approach has the following six stages: *wake up*, *identify*, *shake*, *introduce*, *secure* and *use*. *Wake up* is the stage in which the teacher asked students questions that sought to find out what their ideas were about energy. Students were asked to write their ideas regarding energy on small pieces of paper, pass their notes to their neighbour and add to the ideas of their neighbour. This is the stage in which the students' ideas were elicited and "respected"; the teacher avoided showing whether the ideas where scientifically correct or not. In the *identify* stage, the students' ideas were classified and discussed. One class of concepts was discussed at a time. Pictures and some material objects were presented to the students, asking them to separate them into two categories: those that have energy and those that do not have energy. These included objects like a rubber band, stones, a toy car and a circuit board, and pictures of animals and carcasses and water in a lake and a waterfall. The students classified some of these objects under the "does not have energy" category. In the *shake* stage, students' prior knowledge conceptions (claims) were challenged through argumentation to examine whether they were scientifically correct or not. Argumentation included dialectic moves such as agreement, support, rebuttal, opposition and concession. The students performed experiments and demonstrations to justify their claims. These involved demonstrations such as pulling a rubber band and holding a stone and then releasing it. The opponents had to identify the origin of the kinetic energy the stone seemed to have, and thus were prepared for the scientific explanation. When the students could not come up with experiments to validate their claims, the teacher designed such experiments. In the *introduction* stage, the teacher (proposer of scientific knowledge) explained energy transfer and transformation in relation to the law of conservation of energy. The scientific knowledge was offered in a comparison with the students' prior knowledge. The *secure* stage involved students performing experiments to test both the prior knowledge concept as chosen in the *identify* stage and the scientific concept as introduced in the *introduce* stage. At this stage, students, among others, dropped a stone on a floor and accounted for the sound heard, and connected a bulb to a cell and described the energy changes that occurred. In such cases, the teacher acted as a facilitator. In the *use* stage, students used the scientific explanation in solving different problems provided; for instance, the teacher challenged students' understanding of the scientific concept through questions that required them to explain energy changes in different scenarios and calculate potential and kinetic energy when objects were dropped from different heights. This was done to provide various contexts in which the scientific knowledge is applicable.

### *Traditional Teaching Approach in the Control Group*

The traditional lessons were interactive lectures, wherein the teacher presented energy content, asked students questions, performed demonstrations to illustrate taught concepts and used the chalkboard for giving notes and solving problems. The demonstrations performed here were mostly done by the teacher to verify the scientific concepts instead of challenging specific students' prior knowledge. The students in turn answered and asked questions. The main aim of the instruction was to help students understand the concept of energy as prescribed by the science syllabus. The dialogue in these lessons was from the teacher to students or students to teacher, which involved non-argumentative actions such as elaborations, requests for information and provision of information.

## Data Collection and Analysis

Data were collected using a test with 19 open-ended questions. The questions were diagnostic in that they were assessing the students' understanding of energy and identifying the alternative conceptions that they had. In Section I of the test, students had to explain what happens to energy in different situations such as when a car moves and when a cup of tea cools down. In Section II, they were provided with pictures of different objects (such as a torch, burning wood and a wind turbine) to choose those that "make" energy and give the reasons behind their choices. Section III of the test had pictures of inanimate and animate objects as well as moving and stationary objects and students had to choose those that possessed energy and provide reasons for their choices. The last section of the test had the following questions which were adopted from Heron et al. (2009):

Q1. What do you know about energy? Write at least three points.
Q2. As far as you know, are there things that make energy? Explain.
Q3. As far as you know, are there things that have/possess energy? Explain.
Q4. Is energy conserved? In your answer explain what is meant by "conserved".
Q5. Can energy be transformed? Explain.
Q6. Can energy be lost? Explain.
Q7. What types of energy do you know about?

A pilot study was carried out to determine the construct validity of the test items, in terms of their clarity and their ability to measure what they were intended to measure (Cohen et al., 2013). The Statistical Package for the Social Sciences (SPSS) was used to perform the statistical analysis while Microsoft Office Excel was used for coding data in a scoring protocol that was developed from the findings of studies on energy such as Duit (2014), Heron et al. (2009), Lancor (2014) and Millar (2014) and from the outcomes of the pilot study. The codes that were used are eight scientifically acceptable conceptions (energy is a property; energy is a measure of possible change; everything has energy; the total amount of energy is conserved within a system; there are many forms of energy; energy can be converted from one form to another; energy can be transmitted; and energy can be stored) and five alternative conceptions (only living things have energy; only what moves has energy; energy can be lost; energy can be created; and energy is some form of matter).

In each of the questions, student answers were scored by marking with a "1" each scientifically acceptable conception or alternative conception that the students showed concerning the concept of energy. A mark of "0" was scored if a student did not indicate that they had drawn on a particular scientifically acceptable conception or alternative conception in his/her response. Inter-rater reliability (Cohen et al., 2013) was applied in the data analysis process by engaging five researchers for coding to ensure agreement and consistency on the generated categories into which the data were entered. An inter-rater agreement of 87% was achieved. A follow-up workshop on dealing with disagreements was conducted so that the researchers reached consensus on data analysis.

In answering the research question, the mean scores of different scientifically acceptable conceptions or alternative conceptions mentioned from the 19 open-ended questions were compared between the pre- and post-test. The scientifically acceptable conception and alternative conception overall knowledge variables were created by summarising all scientifically acceptable conceptions and alternative conceptions from the questions at the pre- and post-test stages of the study. The overall mean scores of the conceptions were then compared between the pre- and post-test. The comparisons were done separately for the control and the experimental groups. For all the comparisons, the independent samples *t*-test was performed to establish if the mean differences between the pre- and post-test were statistically significant.

## Limitation of the Study

A limitation of this research design is that there is a possibility that change in the experimental group or control group performance could have been due either to the intervention or to the pre-test (Cohen et al., 2013). This may be reduced by the Solomon three groups design which consists of two control groups and one experimental group. Another limitation could be the fact that the two groups were taught by two different teachers. Moreover, the findings of this study cannot be generalised to other schools, albeit transferrable to similar contexts, as they were only drawn from students in one high school.

## Results

The findings show that students from the two groups held eight scientifically acceptable conceptions about energy, in both the pre- and post-test (See Table 2). The most popular conception of energy was “everything has energy”. This was the case for both groups in the pre- and post-test. “Energy is a property” occupied the second position for the control group in both the pre- and post-test. For the experimental group “energy is a property” was in second position at pre-test while at post-test “there are many forms of energy” was ranked second. The least mentioned scientifically acceptable conception was “total energy is conserved within a system” for the control group at pre- and post-test. For the experimental group this was the case at pre-test while at post-test “energy can be stored” was the least mentioned.

Comparing the differences in the mean scores for scientifically acceptable conceptions in Table 2, the initial statistical differences in favour of the control group changed into statistical differences in the post-test in favour of the experimental group. In particular, these differences were found to be statistically significant in favour of the control group for the following three conceptions at pre-test: “energy is a property”, “everything has energy” and “there are many forms of energy”. At the post-test, the mean scores for the experimental group were statistically significantly higher for all eight scientifically acceptable conceptions except for the following three: “energy is a measure of possible change”, “energy can be transmitted” and “energy can be stored”. It is noted that for all the three conceptions the initial higher score for the control group changed to higher score of the experimental group. It is further noted that the scores of the control group only improved for the scientifically acceptable conception “energy is a measure of possible change”. Overall, at the pre-test the control group outperformed the experimental group while the opposite occurred at post-test level.

Table 3 shows the mean scores for five alternative conceptions of energy that the students held in both groups. The scores are very low for the two groups at both pre- and post-test levels. The mean differences in the scores between groups are only significant in favour of the control group for the alternative conception “energy can be lost” at pre-test level. At post-test, the differences between groups are not significant for any of the five alternative conceptions.

Table 3 indicates that the alternative conceptions “only living things have energy” and “only what moves has energy” were not been affected by any of the interventions, and the alternative conception “energy is some form of matter” no longer featured for any of the groups. Only the alternative conceptions “energy can be lost” and “energy can be created” were still used, in particular the latter, by the students in the experimental group.

**Table 2.** Mean scores for the scientifically acceptable conceptions: comparison of the groups during pre- and post-test

| | Pre-test | | | Post-test | | |
|---|---|---|---|---|---|---|
| Energy concept | Experiment | Control | *t*-Value | Experiment | Control | *t*-Value |
| Energy is a property | 1.97 | 2.90 | −2.358 (0.020)* | 3.50 | 1.74 | 4.285 (0.000)* |
| Energy is a measure of possible change | 0.86 | 1.05 | −0.686 (0.494) | 1.59 | 1.29 | 1.421 (0.158) |
| Everything has energy | 2.14 | 4.48 | −6.700 (0.000)* | 6.56 | 3.59 | 5.214 (0.000)* |
| Total energy is conserved within a system | 0.08 | 0.09 | −0.161 (0.872) | 0.52 | 0.02 | 3.090 (0.002)* |
| There are many forms of energy | 0.56 | 1.24 | −3.770 (0.000)* | 3.83 | 1.05 | 6.046 (0.000)* |
| Energy can be converted from one form to another | 0.14 | 0.22 | −1.133 (0.259) | 2.53 | 0.21 | 6.297 (0.000)* |
| Energy can be transmitted | 0.56 | 0.79 | −1.207 (0.230) | 0.48 | 0.43 | 0.332 (0.740) |
| Energy can be stored | 0.09 | 0.16 | −0.899 (0.370) | 0.08 | 0.02 | 1.556 (0.122) |
| All correct concepts (overall) | 6.40 | 10.93 | −5.411 (0.000)* | 19.09 | 8.35 | 7.521 (0.000)* |

Note: the *p*-value in bracket corresponds to independent samples *t*-test and * denotes significance at 5%.

**Table 3.** Mean scores for the alternative conceptions: comparison of the groups during pre- and post-test

| | Pre-test | | | Post-test | | |
|---|---|---|---|---|---|---|
| Energy concept | Experiment | Control | $t$-Value | Experiment | Control | $t$-Value |
| Only living things have energy | 0.00 | 0.02 | 1.051 (0.295) | 0.02 | 0.03 | 0.667 (0.506) |
| Only what moves has energy | 0.00 | 0.05 | 1.420 (0.158) | 0.02 | 0.05 | 1.115 (0.267) |
| Energy can be lost | 0.84 | 0.31 | −3.275 (0.001)* | 0.23 | 0.38 | 1.333 (0.185) |
| Energy can be created | 0.73 | 0.93 | 0.824 (0.412) | 0.91 | 0.67 | −0.875 (0.383) |
| Energy is some form of matter | 0.05 | 0.16 | 1.523 (0.130) | 0.00 | 0.01 | 1.709 (0.090) |
| All alternative conceptions | 1.62 | 1.47 | −0.518 (0.605) | 1.18 | 1.14 | 0.210 (0.834) |

Note: the $p$-value in bracket corresponds to independent samples $t$-test and * denotes significance at 5%.

## Discussion

According to the findings of this study, the experimental group outperformed the control group in understanding of the energy concept. The statistically significant difference between groups in the use of five of the eight scientifically acceptable energy conceptions after the interventions in favour of the experimental group could be attributed to the use of the FOI strategy with the experimental group. Thus the hypothesis of the study is rejected. The results of this study concur with Meiring and Webb's (2012) finding that the use of curriculum materials (such as toys and apparatus) in teaching energy is central in helping students understand energy concepts. The scientifically acceptable conceptions in which the scores are significantly higher for the FOI teaching strategy include "total energy is conserved within a system" and "energy can be converted from one form to another". The increase in the mean scores for these conceptions implies that the understanding of the law of conservation of energy improved for the students using the FOI strategy, although a smattering of related alternative conceptions remained, such as "energy can be lost" and "energy can be created". It is worth noting this improvement since the literature abounds about students' failure to understand the law of conservation of energy (Park, 2019).

For three scientifically acceptable conceptions, the mean scores were not significantly different between groups at post-test level, i.e. "energy is a measure of possible change", "energy can be transmitted" and "energy can be stored". Even so, the difference in scores between groups in the pre-test in favour of the control group changed to a difference of scores between groups in the post-test in favour of the experimental group. It seems that a weaker learning effect for these conceptions may be related to the fact that the FOI *use* stage could not be satisfactorily applied: there were only a few contexts in which these conceptions could be applied to enhance understanding. In addition, experiments or demonstrations at both of the *shake* and *introduce* stages were inadequate for those conceptions (Heron et al., 2009; Sermeus et al., 2019).

The ultimate goal of teaching and learning of energy (and perhaps of science overall) is to eliminate the use of alternative conceptions and reinforce scientific conceptions by providing students with a variety of contexts where the scientific conceptions could be used (Domenech et al., 2007). In this study, as stated by Trumper (1990), some students stuck to their alternative conceptions even after the interventions. Some students from both groups continued to hold the same alternative conceptions related to the law of conservation of energy at post-test. This is in consonance with Millar's (2014) argument that students do not shift from everyday understanding to scientific understanding easily. Consequently, the FOI activities seemed ineffective regarding the students' alternative conceptions about energy. These could be concepts that are "in conflict with" the students' experience and require greater attention for conceptual change to occur (Chi, 2013).

In the control group scores increased from pre- to post-test in the scientific conception "energy is a measure of possible change" only. This suggests that the focus of the traditional teaching strategy relied heavily on numerical and formalistic treatment of the concepts. This strategy did not result in increased understanding of other conceptions of energy, as also pointed out by Millar (2014).

Overall, scores on scientifically acceptable conceptions decreased significantly in the control group from pre- to post-test while in the experimental group, they increased significantly. Meiring and Webb (2012) found that, in the attempt to develop students' understanding of energy, the students sometimes get confused, leading to a decreased performance. Occasionally, in the process of improving scientific concepts, new alternative conceptions emerge or students lose scientifically acceptable conceptions when experiencing conflicting world views. In contrast, it can be concluded that the FOI approach helped students to construct scientific meaning of energy conceptions despite the large size of the class which, according to Onwu and Stoffels (2005), may negatively impact the effective teaching and learning of science.

## Conclusion and Recommendations

The FOI teaching method seems to have helped students to develop knowledge on scientifically acceptable conceptions about energy and to use scientific energy conceptions when explaining phenomena related to energy. When the FOI was used in energy class, students' alternative conceptions were confronted and they began to show an increased use of the scientifically acceptable conceptions. The use of a few alternative conceptions, however, were tenacious and could not be changed by the teaching method. It is possible that some limitations in the employed FOI activities, owing to limited resources, could have attenuated their effectiveness.

It is therefore recommended that science teachers should adopt the FOI approach in their teaching of energy and other similarly challenging science topics, such as force and thermal physics. A longitudinal study on students' ideas about energy could also shed more light on the conceptual change trajectory in relation to the topic.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

## ORCID

*Sechaba Koma* http://orcid.org/0000-0003-1811-9715
*Ts'epo Mokuku* http://orcid.org/0000-0001-9207-1794
*Tiisetso J. Makatjane* http://orcid.org/0000-0002-4848-1291
*Christel Balck* http://orcid.org/0000-0001-7894-5643
*Jan Sermeus* http://orcid.org/0000-0002-5191-2590

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