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Enhancing Conceptual Understanding of Energy Through the Enerceptual Toolkit: A Participatory Action Research in Secondary Science Education

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ABSTRACT

Understanding potential and kinetic energy is essential for students' grasp of physics and energy transformation, yet secondary-level instruction often struggles to convey these concepts effectively. This participatory action research (PAR) investigated the effectiveness of the Enerceptual Toolkit, a multimodal, constructivist-based intervention designed to improve conceptual understanding and engagement among Grade 8 students in a Philippine public high school. The Toolkit integrated lecture demonstrations, animations, digital simulations, game-based learning, and structured problem-solving activities, all delivered through the 7Es lesson plan model. Conducted over two PAR cycles involving 10 students, the study employed pre- and post-tests, classroom observations, and semi-structured interviews. Baseline data showed that no participant reached the 75% proficiency threshold in the pre-test. After the intervention, all learners exceeded this benchmark, with the class proficiency level (CPL) improving from "Beginning" in Cycle 1 to "Advanced" in Cycle 2. Observational data revealed increased engagement, confidence, and self-efficacy, along with a decline in off-task behavior. Thematic analysis of student interviews highlighted positive shifts in motivation, participation, and perceived relevance of energy concepts. These findings suggest that the Enerceptual Toolkit, grounded in active learning and conceptual scaffolding, is a promising strategy for enhancing energy instruction in junior high school science. The study highlights the potential of multimodal, student-centered approaches to address conceptual gaps and promote deeper learning. Implications for curriculum integration and teacher professional development are discussed.

Keywords: *Conceptual Understanding, Enerceptual Toolkit, Participatory Action Research, Physics Education, Secondary Science*

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INTRODUCTION

Kinetic energy (KE), the energy of motion, and potential energy (PE), the energy stored in an object's position, are foundational concepts in Physics that apply to critical real-world applications. In secondary schools, students are expected to develop critical thinking skills with these concepts, investigate their relationships, and apply these skills to real-world work and knowledge-based contexts (Department of Education, 2019). Understanding KE and PE concepts is important because it allows learners to understand and quantify the ability of objects to do something useful. By comprehending these concepts, students gain insights into the behavior of objects in motion and the energy transformations that occur within systems (Empiengco and Mustacisa-Lacaba, 2022). It is considered the groundwork for grasping concepts like motion, forces, work, and energy conservation, which are central to various scientific disciplines and real-world applications (Pasquale, 2024).

However, many learners struggle with KE and PE due to their abstract nature and limited interactive resources, leading to low comprehension and weak problem-solving skills (Estipular and Roleda, 2018). National and international assessments showed that Filipino learners perform below proficiency levels in science and physics education (EDCOM 2, 2024; Mullis et al., 2020; PISA 2022 Results, 2023). Based on these articles, it is evident that the Philippine education system faces a significant challenge in improving the learning proficiency of learners.

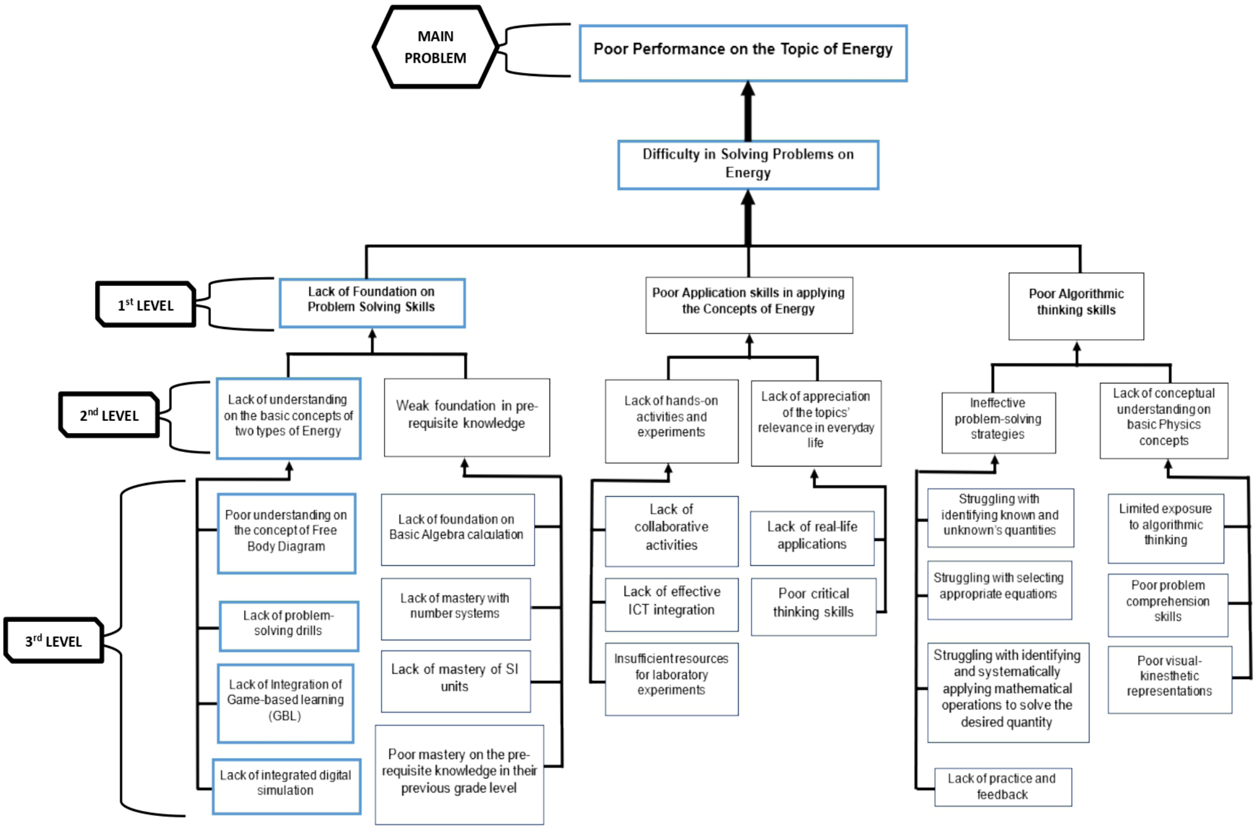

Figure 1. Problem tree.

The researchers conducted a problem analysis among Grade 8 struggling learners in a public high school who were identified by one of the researchers' cooperating teachers. Researchers' analysis revealed that the main problem was students' poor performance in the topic of energy. The main sub-problem was then outlined, which is their difficulty in solving energy-related problems. To ensure a logical flow of analysis, the problem was further broken down into three levels, which illustrated and explained the underlying connecting causes that contributed to the emergence of the main issue. Among the first-level problems, the branch highlighted in the blue box, "learners' lack of foundation in problem-solving skills", was prioritized due to its strong influence on learning outcomes. The second-level cause was identified as learners' lack of understanding of the basic concepts of potential and kinetic energy. In level 3, four causes were identified (see Figure 1), which formed the basis for the targeted interventions.

In this research, conceptual understanding of kinetic and potential energy refers to students' ability to internalize concepts, apply relevant mathematical principles, analyze and solve energy-related problems, and articulate reasoned explanations of energy phenomena (Tan et al., 2020). To address the learning gap, the researchers developed the Enerceptual Toolkit, focusing on four key components: understanding free-body diagrams, increasing problem-solving drills, integrating game-based learning, and utilizing digital simulations.

The main research question explored how using the Enerceptual Toolkit could enhance Grade 8 students' conceptual understanding of kinetic and potential energy and could improve their performance in energy-related topics. The Toolkit was implemented using the 7Es lesson plan model and tailored the strategies to align with the learners' needs. This study aligns with the teaching and learning theme of the DepEd's Basic Education Research Agenda, particularly contributing strategies and insights to improve science instruction. While addressing context-specific challenges at a public high school, the intervention offers broader implications for science education across the Philippines, empowering students through innovative and student-centered approaches.

MATERIALS AND METHODS

Research design

This study used Participatory Action Research (PAR), which promotes human purposes and establishes practical knowledge by integrating theory and practice, action and reflection, with stakeholder cooperation (Reason and Bradbury, 2008). PAR is distinguished by its democratic process and strategies that value stakeholder and participant participation and shared responsibility in the research process. The researchers adopted the action research spiral model of Kemmis et al., (2013), by implementing two cycles of planning, acting, observing, and reflecting. Each cycle allowed the researchers, together with the cooperating teachers and participants, to collaboratively plan interventions to the problem, implement interventions, observe and analyze outcomes, and refine strategies based on reflections. The first cycle provided initial insights and adjustments, while the second cycle focused on revising and enhancing the intervention based on the data and reflections gathered from the initial implementation (see Figure 2).

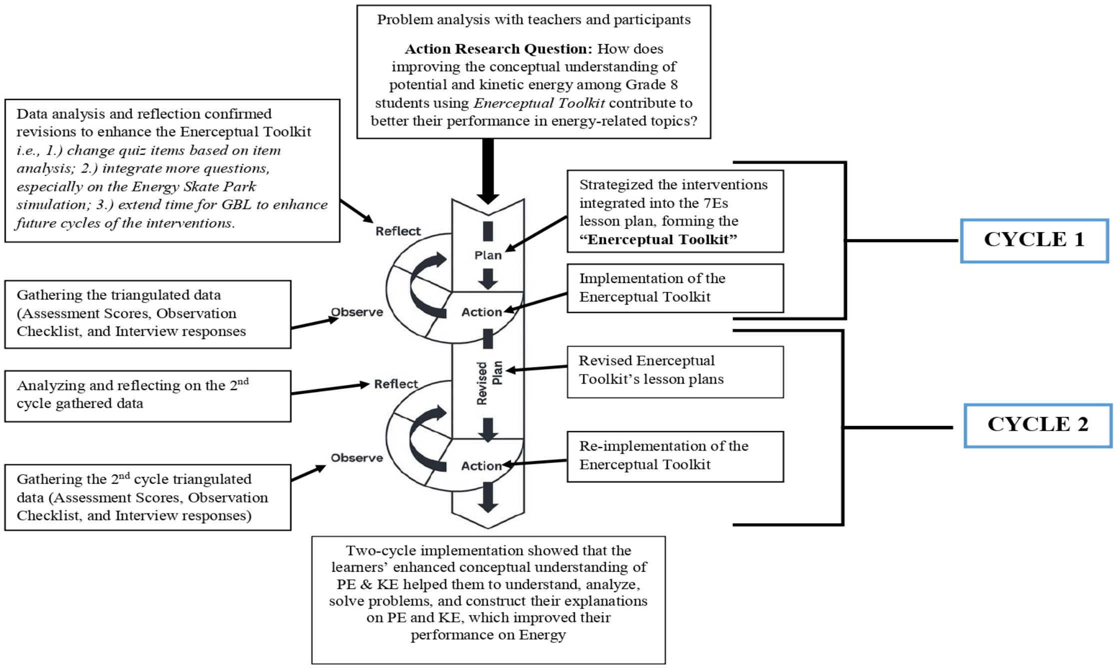

Figure 2. Action research spiral. (Kemmis et al., 2013).

Selection of participants

This study was conducted with Grade 8 learners at Gabas Integrated School, Baybay City, Leyte. Ten participants were selected using purposive sampling. Their Grade 8 Science teacher recommended them due to their low performance on KE and PE concepts from the first quarter lesson. The quality of Participatory Action Research (PAR) is driven by collaborative participation, with smaller groups of around ten being considered valid for deep engagement and reflection (Kemmis et al., 2013). Additionally, thematic saturation in PAR can still occur even with small groups if participants are deeply engaged (Ahmed, 2024).

Research intervention

In response to students' struggles with kinetic and potential energy concepts, the researchers developed the Enerceptual Toolkit, a framework composed of five activities: (1) lecture demonstrations, (2) video presentations, (3) digital simulations, (4) GBL, and (5) problem-solving drills. "Enerceptual," a portmanteau of "energy" and "conceptual," refers to a toolkit, a structured set of strategies, designed to deepen conceptual understanding of energy concepts. As a holistic intervention, it addresses specific learning gaps by integrating diverse, student-centered strategies in secondary physics education (Bande et al., 2025). FBD instruction was supported by lecture demonstrations and PhET simulations, improving interest and performance (Dietrich et al,. 2022; Macaranas, 2021). The effectiveness of video animations in enhancing conceptual understanding is well-supported to improve comprehension, retention, engagement, and student attitudes (Deparon, 2024). GBL via Legends of Learning, and PhET simulations further enhanced student engagement and retention. PhET simulations, particularly the Energy Skate Park simulation, foster engagement and conceptual understanding (Banda and Nzabahimana, 2021). Legends of Learning, using the game Little Newton in the Energy of Motion, helped students master energy concepts and problem-solving skills (Cadiz et al., 2023). Additionally, individual and group problem drills were integrated into each session to develop executive control and reasoning, as regular practice improves problem-solving skills (Amir et al., 2018). The toolkit was implemented over a two-day session in both cycles, with each intervention linked to the 7Es lesson plan model (see Table 1).

Table 1. Implementation of the enerceptual toolkit in a 7 E's lesson plan.

7 Es lesson plan	7Es lesson plan	Sequence of the 5 interventions
Day 1	Elicit	Usual classroom routine and engagement activity
	Engage	(Video presentation) about 2 types of energy
	Explore	FBD technique + hands-on activity
	Explain	Discussion proper (*PhET Energy skate park*) + *lecture*
	Elaborate	Problem-solving drills
	Evaluate	Assessment (quiz) for numerical data
	Extend	Bring home activity/drill (optional)
Day 2	Elicit	Usual classroom routine and engagement activity
	Engage	(Video presentation) about 2 types of energy
	Explore	FBD technique + hands-on activity
	Explain	Discussion proper (GBL) *little newton in the energy of motion* + *lecture type*
	Elaborate	Problem-solving drills
	Evaluate	Assessment (quiz) for numerical data
	Extend	Bring home activity/drill (optional)

Data gathering methods

This study utilized three data sources: assessment scores, classroom observations, and interviews. Pre- and post-tests were administered to 10 Grade 8 learners to measure their understanding of kinetic and potential energy before and after the implementation, aligned with the DepEd's Most Essential Learning Competencies (MELCs), and were adapted from DepEd physics modules (Samaco et al., 2020). Additional self-made quizzes and problem sets measured participants' progress along the implementation process. Assessments were age-appropriate and balanced in difficulty, with revisions after Cycle 1 to improve reliability. The Cronbach's alpha reliability coefficient of the assessment was .72, indicating acceptable reliability. Observational data derived from the Student Engagement Observation Checklist (SEOC) by Cassar and Jang (2010), which tracked effort, initiative, disruptive, and attentiveness during each session. Post-cycle open-ended interviews focused on interest, engagement, and confidence, which serve as the three key themes grounded in educational theories: Interest grows through curiosity and meaningful content (Wong et al., 2020); engagement is enhanced by autonomy, competence, and relatedness (Ryanand Deci, 2000); and confidence improves with support and self-belief (Bandura, 1997; Vygotsky, 1978).

Data analysis

In line with data triangulation (Nightingale, 2009), three analysis techniques were used. Graphical analysis tracked quiz trends, while CPL measured topic mastery before, during, and after intervention, interpreted using DepEd's five-level proficiency scale (DepEd, 2012). Pre- and post-test mean scores were also computed and graphed. Data from the SEOC were used to calculate overall means for four behavior scales. For interview data, a deductive approach using Colaizzi's phenomenological method through five steps: reading transcripts, extracting key statements, formulating meanings, clustering themes, and writing descriptions (Wirihana et al., 2018).

Trustworthiness

The researchers used triangulation involving multiple data sources to ensure trustworthiness. Triangulation was achieved by collecting data from various sources, including assessment scores for numerical data, an observation checklist, and interview responses. These multiple data sources helped to confirm any improvement observed in the students.

Ethical considerations

The identified participants voluntarily agreed to participate, and informed consent was obtained from their parents or legal guardians to ensure adherence to ethical research protocols involving minors. An orientation session was held on November 6, 2024, to ensure a comprehensive understanding of the objectives and procedures. This session included an overview of the action research framework, a detailed introduction to the Enerceptual Toolkit and its constituent components, an explanation of the intended learning outcomes, and a clear outline of participant roles, rights, responsibilities, and the scheduled timeline of intervention activities.

RESULTS

This study aimed to enhance the conceptual understanding of grade 8 learners in learning key concepts of KE and PE using the Enerceptual Toolkit. The demographic characteristics of the participants, comprising 10 individuals (five males and five females), aged 13 to 14 years, are presented in Table 2.

The pre-test results confirmed the underlying issue of learners' poor performance in the topic of Energy. Scores showed that none of the ten participants were able to get the passing score (23 out of 30 points).

Table 2. Demographic characteristics of the participating students.

Student participant	Gender	Age (years)	Science first quarter grade	Pre-test scores
SP1	M	13	76	7
SP2	F	13	75	3
SP3	F	14	80	4
SP4	F	13	71	6
SP5	F	13	86	12
SP6	M	13	85	13
SP7	F	13	86	13
SP8	M	14	81	11
SP 9	M	13	79	7
SP10	M	14	82	10

Cycle 1 assessment results, observation, and interview data

After the two-day session, the computed CPL (see Figure 3) derived from the quiz results indicates a beginning level of class proficiency in the first cycle. Results suggest that the students have limited conceptual understanding of KE and PE. Additionally, the item analysis conducted revealed that items 2 and 3 required revisions for the future cycle due to their difficulty level.

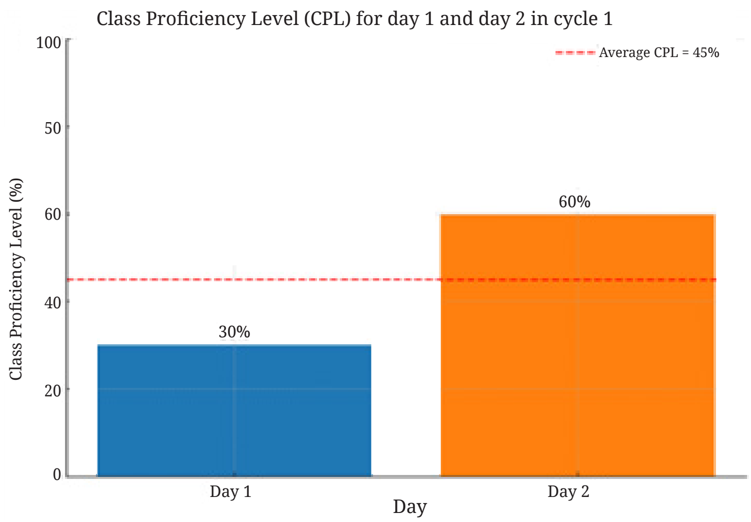

Figure 3. CPL of day 1 and day 2 in cycle 1.

Following the numerical data, Table 3 presents the computed means of the observed four engagement variables for each session. The effort (M=3.32) suggested a moderate level of effort from students. While the initiative (M=2.5) indicates a relatively low level of initiative. This indicated that the learners were not frequently taking proactive steps, such as asking questions, seeking additional information, or taking ownership of their learning during the conduct of the first cycle. Moreover, the disruptive behavior (M=3.25) points to a moderate level of interruptions. This means that certain behaviors were being observed during the session, like the learners being eager to take turns using the laptop, which caused distractions, and some also already wanted to go home. While moderate inattentive behavior (M=2.5) indicates a low level of off-task or disengaged behavior.

Table 3. Mean scores of SEOC scale for the 1st cycle of implementation.

	Effort	**Initiative**	**Disruptive**	**Inattentive**
Day 1	3.14	2	3.25	2.67
Day 2	3.5	3	3.25	2.33
Mean score	**3.32**	**2.5**	**3.25**	**2.5**

To further support the numerical and observational data, personal insights and feedback from the participants were collected through one-on-one interviews. Table 4 shows the three overall themes, and the subthemes generated.

Table 4. Pre-identified themes and corresponding sub-themes based on participants' perceptions of the topic of energy.

Overall theme	**Subthemes**
Interest of participants regarding the topic of Energy	Interest can be influenced by the enthusiasm to relearn and review the topics in their previous quarter Interest can be influenced by academic performance improvement Interest can be influenced by real-life application of knowledge *Interest can be influenced by their deeper understanding towards the topic.
Engagement of participants towards the five interventions integrated	Varied interventions for boosting student engagement Effects of interactive interventions on learners' engagement Barriers and distractions that affect learners' engagement Time limitation as a factor for student engagement * Progressive learning and enjoyment. * Social influence and peer motivation in learning environments
Confidence and perspective of the participants on their Conceptual Understanding of KE and PE before and after the interventions	Follow up reinforcement for further improved learner confidence in energy concepts Influence of topic mastery on learners' confidence * Enhancing student confidence through effective revision strategies. * Spaced repetition as an effective method of improving student confidence.

Legend: * new subthemes that emerged during the second cycle on top of the subthemes from cycle 1

Theme 1: Interest of participants regarding the topic of energy

This theme focuses more on the level of interest of the participants in the topic of this action research. One common response gathered from the participants indicated that their interest in the topic stemmed from a desire to relearn and review KE and PE in their previous quarter that they had already forgotten. This indicates that interest can be influenced by the learner's enthusiasm to relearn and review the topics. As one participant expressed, "*Yes (I am interested), because I forgot about the topic.*" (SP-2). These responses imply that interest can be influenced by academic engagement. Furthermore, the participants' interest was often associated with the desire to improve their academic performance. Instilling the belief that by comprehending and understanding the topic, learners can improve their performance on quizzes and assessments, resulting in higher grades. Such motivations illustrate how academic goals can shape student interest. As stated by two participants, "*Yes, it's important so that I can get a higher grade.*" (SP-7), and "*Yes, it's important so that my grades will improve*" (SP-6).

Additionally, learners expressed interest in the topic primarily because they saw its relevance to real-life situations. They recognized that understanding concepts like KE and PE allowed them to connect classroom learning with their daily experiences, making the lessons more meaningful and purposeful. As one participant noted, "*…I am able to appreciate that, the real-life scenarios of kinetic and potential energy*" (SP-1), while another added, "*…It can also be applied to myself, like in the activities I do every day*" (SP-8). Signifying that interest can be influenced by the real-life application of knowledge.

Theme 2: Engagement of participants towards the enerceptual toolkit

This theme focuses more on the state and level of engagement of the participants during the implementation, on whether the participants found the Enerceptual Toolkit engaging. Based on their responses, the participants had different preferences regarding the interventions implemented, indicating that utilizing varied interventions, such as lecture demonstrations, video presentations, digital simulation, GBL, and problem-solving drills, can boost student engagement. As expressed by the participants' responses: "*The interventions were good. It made the concepts easier to understand, especially when applied to solving problems.*" (SP-8).

The participants also expressed that they felt more engaged due to the integration of Enerceptual Toolkit, such as games with discussion and simulations were interactive. They specifically highlighted the positive impact of interactive elements such as games, discussions, and simulations. These engaging and interactive activities fostered active participation and enhanced their learning experience. As quoted by their responses: "*It was nice to play because one can learn a lot of things and it is interactive, like the way I can manipulate the laptop like real gamers, but with discussion.*" (SP-10). However, students also stated that they get distracted during class, like wanting to go home, banter with classmates, and even get distracted by their own thoughts. Students reported experiencing frequent distractions and barriers during the implementation of Enerceptual Toolkit, often finding their attention drawn away from the discussion, indicating the "barriers and distractions that affect learners' engagement". As quoted by their responses: "*At times, my seatmates interrupt me while I'm solving problems, which diverts my attention and affects my concentration on the task.*" (SP-6). Learners expressed dissatisfaction with the limited time allotted for each of the interventions, especially for PhET simulation and GBL, citing concerns such as insufficient time for their in-depth learning and manipulating the simulator and the game. This time constraint can hinder their ability to fully grasp the complex concepts and engage in meaningful discussions, affecting their level of engagement during the implementation of the first cycle. Indicating that "time limitation is a factor for student engagement". The learners' common responses: "*To enhance engagement, more time should be given to 'Little Newton' because it would be great at a higher level with more challenging problems to solve.*" (SP-8).

Theme 3: Confidence and perspective of the participants on the topic

This theme focuses more on the level of confidence of the participants in their conceptual understanding of KE and PE before and after the Enerceptual Toolkit was implemented. This theme is composed of two subthemes: "confidence can be influenced by scaffolding strategies used by the teachers to further improve their confidence to solve problems involving energy," and "confidence is directly linked to topic mastery."

Regarding the "confidence can be influenced by scaffolding strategies used by the teachers to further improve their confidence to solve problems involving energy," learners' confidence increases when teachers use scaffolding strategies like the toolkit used, because these provide structured support, helping students tackle problems step by step. By guiding learners through challenging concepts, teachers act as more knowledgeable mentors who simplify complex ideas into manageable parts. This process reduces anxiety and builds competence, empowering students to approach problems with a clearer understanding. As learners gradually master tasks with support, their self-belief grows, enabling them to solve problems independently. In this regard, one of the students said:

> *"I still need guidance when playing 'Little Newton' and 'Skatepark.' I also find it challenging to identify the given information and what the problem is asking during problem-solving."* (SP-8)

For the sub-theme "confidence is directly linked to topic mastery," students showed greater self-assurance when they felt they had thoroughly learned and understood the material. When learners feel they have a solid grasp of the subject, they are more likely to tackle challenges without hesitation, reducing fear of failure. This confidence stems from a sense of competence, where mastery reinforces their belief in their abilities. Mastering a topic often leads to a positive feedback loop, as success further boosts self-assurance and motivation to engage with new concepts. One of the participants shared his experiences:

> *"Before the intervention, I didn't really understand it, so I wasn't very interested in the topic. But after the intervention, I started to like it because I understood it better."* (SP-6)

Cycle 2 Assessment results, observation, and interview data

After the re-implementation of the Enerceptual toolkit, data shows the learners' improvement in their performance. The computed CPL derived from the quiz results of each cycle showed a positive learner's level of proficiency to the topic, results highlighted a gradual improvement from a beginning level of proficiency (45%) on the first cycle, to advanced class level of proficiency (90%) for the second cycle (see Figure 4).

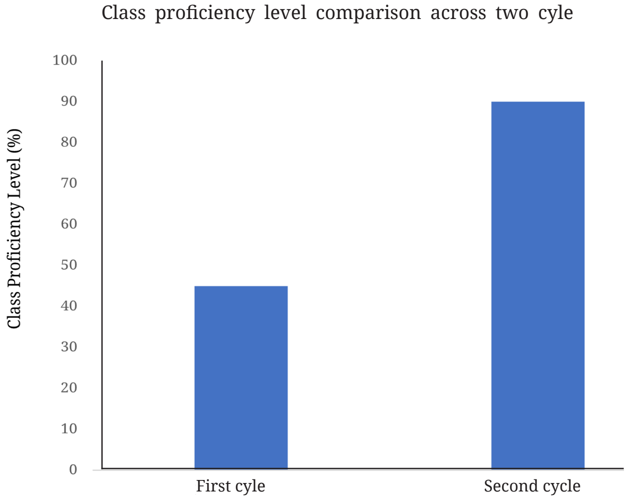

Figure 4. Comparison of first and second cycle CPL.

Figure 5 presents a graphical trend of the computed mean scores of the four engagement variables on both cycles. By incorporating student feedback and making necessary adjustments, the second cycle demonstrated enhanced student engagement. As observed in the graph's trend, both effort (M=3.83) and initiative (M=4.25) increased in both sets after the second cycle was implemented. Conversely, disruptive (M=2.38) and inattentive (M=1.33) behaviors decreased in both sets during the same period. Thus, the increased student engagement observed during the second cycle indicates that the enhanced interventions were effective in promoting a deeper conceptual understanding of KE and PE concepts.

Figure 5. First and second cycle SEOC mean scores trend.

Additional subthemes emerged from the participants' final interviews after the second cycle with asterisks (*) in Table 4.

Theme 1: Interest of participants regarding the topic of energy

Researchers found that learners' interest in the topic increased as they gained a deeper understanding of KE and PE concepts and their real-world applications. At first, the learners did not know much about the topic, but after the implementation, they got more interested as they understood more about the concept of KE and PE. They also realized how KE and PE are important in real life, which makes them even more curious and eager to learn the topic. The participants' common responses, such as:

> *"I'm more interested in the topic, now that I understand what kinetic and potential energy are, I also know that they actually happen in real life."* (SP-6)

Theme 2: Engagement of participants towards the enerceptual toolkit integrated

For the second theme, the first emerging sub-theme, "progressive learning and enjoyment throughout the implementation process", focused on students' evolving engagement during the implementation of the Enerceptual Toolkit. Initially marked by confusion, particularly during the first cycle, however, students' understanding and enjoyment notably improved in the second cycle as they became more familiar with the learning process. This transition from uncertainty to clarity reflects enhanced conceptual understanding, where students actively engage in experiences, reflect on outcomes, and find satisfaction in mastering difficult concepts. The sense of accomplishment and the real-world application of their learning fostered deeper engagement. One participant reflected,

> *"I enjoyed everything. During the first cycle, I was confused about why things worked like this or that, since it was my first time attending a research activity like this. But by the second cycle, I understood—'Ah, so that's why it's like that,' and 'Oh, this is how you solve it.' It means that in the second cycle, I enjoyed it more and learned more because I wasn't confused anymore."* (SP-1).

As the second emerging subtheme, "social influence and peer motivation in the learning environment", revealed how students' engagement was heightened when learning occurred in the company of peers. Social dynamics such as camaraderie and emotional support encouraged students to engage more confidently and meaningfully in their tasks. As shared by participants, *"I was very happy because we played here and I was with my friends,"* and *"I'm motivated when my crush is watching."* (SP-9). These sentiments underscore the emotional and motivational value of peer presence.

Theme 3: Confidence and perspective of the participants on the topic

Two new subthemes emerged under the broader theme of students' confidence and perspectives: "enhancing student confidence through effective revision strategies" and "spaced repetition as a factor for improving students' confidence". Regarding the first subtheme, students demonstrated a deeper understanding of the energy concepts and an increase in confidence due to the revisions in the discussion and lesson plan. There were revisions made, such as quiz item modification based on item analysis, inclusion of learner-centered questions, particularly using the Energy Skate Park simulation, and the extended time allotted for GBL contributed to their confidence. These strategies allowed students to have more control over their learning and bolstered their self-assurance. As one participant noted,

> *"Yes, before, the meaning of potential and kinetic energy was not specified, there were no examples. I didn't know where to apply the concepts. But now, I can grasp the concepts quickly." (SP-7)*

The second subtheme, "spaced repetition as a factor for improving students' confidence," further underscores the role of repeated exposure and review in deepening conceptual understanding and enhancing self-confidence. Spaced repetition helped students gain mastery over time, reduce cognitive load, receive consistent feedback, and perform better in assessments, thus fostering a greater sense of control over their academic progress. This is reflected in a participant's response: "*Yes, I understand it better now compared to before because it was explained more clearly, with examples, videos, simulations, and games, and it was also reviewed and taught repeatedly.*" (SP-7).

DISCUSSION

The pre-test results highlighted learners' poor performance in energy concepts, confirming the need for intervention. The ten participants failed to meet the passing score, indicating a significant gap in their conceptual understanding. This finding aligns with studies showing that traditional methods often fail to address conceptual gaps in science topics (Erduran and Dagher, 2014; Higham et al., 2022).

The first cycle's CPL (45%) revealed limited conceptual understanding of KE and PE. Item analysis indicated the need to revise certain quiz items due to item difficulty. This can be attributed to students' engagement observation results, which revealed a moderate level of effort, low initiative, moderate disruptive behavior, and occasional inattentiveness. The results suggest a minimal distinction between positive and negative indicators. While evidence of active participation was present, students' effort lacked consistency throughout the session. Low initiative was evident in passive learning behaviors, where learners relied heavily on the teacher for direction and knowledge. Moderate disruptive behavior arose from distractions or off-task activities, such as students becoming overly excited during GBL. Additionally, a moderate level of inattentiveness was observed, with some students occasionally losing focus.

Thematic analysis of interview data provided a deeper context to these numerical findings, highlighting areas of strength and identifying opportunities for improvement in future cycles. The first theme focuses on participants' interest in the topic of energy, which was influenced by (1) enthusiasm to relearn and review topics from the previous quarter, (2) a desire for academic performance improvement, and (3) recognition of real-life applications of knowledge. Studies have shown that learners' interest can be shaped by these factors, emphasizing interest as a key driver of motivation and sustained attention—both critical for effective learning and conceptual development (Erduran and Dagher, 2014; Higham et al., 2022; Lei et al., 2018).

The second theme centers on participants' engagement with the toolkit, highlighting (1) varied interventions for boosting engagement, (2) the effects of interactive interventions on learners' involvement, and (3) barriers and distractions impacting focus. Prior research supports the effectiveness of diverse strategies for enhancing engagement, such as interactive activities, collaborative projects, real-world applications, and technology integration (Buehl, 2017). Engaging activities like games, creative projects, and experiments not only sustain students' interest but also foster collaboration and critical thinking skills (Hernik and Jaworska, 2018). However, several barriers were identified. External distractions (e.g., a desire to go home or attention drawn to activities outside the classroom) and internal factors (e.g., social anxiety or peer disruptions) can reduce focus and learning (Schmidt, 2020). Furthermore, limited instructional time emerged as a challenge, restricting students' ability to fully engage with the material. Adequate time allocation is essential for meaningful learning, particularly in content-heavy subjects like physics where deep conceptual understanding requires sustained instructional support (Hofer et al., 2018; Liu, 2022). These findings underscore the importance of strategic engagement techniques combined with supportive classroom conditions to create a productive and engaging learning environment.

The third theme addresses participants' confidence in their conceptual understanding of KE and PE before and after the intervention. Confidence was influenced by (1) scaffolding strategies employed by teachers and (2) the learners' mastery of the topic. Studies highlight a positive correlation between scaffolding techniques and increased student confidence. Strategies such as step-by-step guidance, modeling, and the use of tools like PhET simulations supported learners in grasping complex concepts and bolstered their self-confidence (Potane and Bayeta, 2018). Confident students were more likely to engage actively, persevere through challenges, and explore creative applications of their knowledge, ultimately leading to improved learning outcomes (Bentayao and Ilagan, 2024). Collectively, participants' enhanced confidence became a strong indicator of their improved conceptual understanding of KE and PE following the implementation of the Toolkit.

Taken together, the first cycle results showed the need for minor adjustments and re-implementation of Enerceptual Toolkit due to participants' low CPL percentage on their quiz results, low initiative and moderate disruptive behavior of participants based on observation analysis, and the set of interview responses from the participants which generated the subtheme on barriers and distractions that affect learners' engagement. The triangulated data confirmed that further implementation of the intervention was necessary. Thus, the researchers decided to proceed with the second cycle, incorporating targeted revisions and adjustments, i.e., 1.) change quiz items based on item analysis; 2.) integrate more questions, especially on the Energy Skate Park simulation; 3.) extend time for GBL to enhance future cycles of the interventions.

After implementing the revised lesson plans across two sessions, the second cycle demonstrated significant improvements in quiz scores, student engagement, and active participation. This positive trend was reinforced by participants' responses in the final interview, which reflected deeper understanding and increased interest in energy concepts. Numerical data confirmed enhanced conceptual understanding among learners after two cycles of intervention. Learners' understanding was assessed based on their ability to identify, define, and explain potential and kinetic energy concepts and to solve related problems. Figure 4 illustrates their steady progress and improvement in performance across evaluation stages.

The pre-test and post-test scores further highlighted this progress. Initially, none of the ten participants attained the passing score of 23 points. However, after two cycles of the Enerceptual Toolkit's implementation, all participants achieved passing scores, demonstrating marked improvement in conceptual understanding. The integration of diverse instructional strategies within the Enerceptual Toolkit, especially after enhancements in the second cycle, significantly contributed to these gains. This aligns with existing studies emphasizing the need for varied teaching methods to cater to different learning styles and promote active learning (Smiderle et al., 2020). By blending traditional teaching approaches with innovative technologies, educators created dynamic and immersive learning experiences that fostered curiosity, engagement, and deeper understanding (Laid and Adlaon, 2025).

The second cycle showed increased effort, initiative, and participation, alongside a decline in disruptive behaviors. These improvements underscored the effectiveness of diverse instructional strategies in fostering engagement, motivation, and conceptual understanding, echoing the calls in educational research for combining traditional and innovative approaches for optimal learning outcomes.

Additionally, emerging subthemes from the second cycle interview further supported these findings. First, participants' interest in energy concepts was reinforced by their deeper understanding and recognition of real-world applications, which enhanced intrinsic motivation (Herpratiwi and Tohir, 2022). Second, engagement with the Toolkit grew as the refined interventions promoted progressive learning and enjoyment (Bundock, 2023). Social influence and peer motivation also emerged as critical factors; collaborative learning and positive peer relationships created a supportive environment conducive to engagement and risk-taking (DeVito, 2016; Kindermann, 2016; Fuertes et al., 2023). Moreover, enhanced confidence was attributed to effective revision strategies and spaced repetition, which allowed students greater control over their learning and bolstered their self-assurance. Studies support the superiority of spaced practice over massed practice for memory retention and knowledge transfer (Kang, 2016).

Lecture demonstrations paired with interactive simulations encouraged participation and curiosity, helping learners visualize abstract concepts and connect theory with practice (Estipular and Roleda, 2018). Video presentations also increased engagement, with students reporting greater motivation and desire to participate (Zakirman et al., 2022). Interactive simulations, such as PhET, enabled students to manipulate variables and observe outcomes, fostering a sense of agency and curiosity. This higher level of engagement, noted during observations, led to improved classroom management and reduced distractions in the second cycle (Cezar, 2024). GBL further enriched students' understanding of KE and PE concepts. Notably, students exhibited greater effort and initiative during the second cycle, particularly when using the Legends of Learning platform and playing Little Newton. One participant shared: "*…It was nice to play because one can learn a lot of things and it is interactive like the way we are able to manipulate the laptop like real gamers but with discussion.*" (SP-10). This observation supports prior research highlighting GBL's role in promoting active participation and engagement (Tinambunan and Orongan, 2023). Problem-solving drills integrated with interactive games also heightened motivation and enjoyment, differentiating them from traditional assessments (Fairfield, 2019). Students studying physics through interactive multimedia-based problem-solving exhibited stronger problem-solving abilities compared to those using conventional methods (Manurung and Panggabean, 2020). Combining video games with hands-on activities provided scaffolding that strengthened students' engagement and learning experience (Garcia, 2024).

Collectively, the revised interventions embedded in the Enerceptual Toolkit have deepened their conceptual understanding of KE and PE, which resulted in improved overall performance. As shown by the increased CPL and quiz class mean scores. Additionally, the second cycle showed increased effort, initiative, and participation, while disruptive behaviors declined, which further highlighted the shift in learner engagement. These improvements underscore the effectiveness of diverse instructional strategies in fostering deeper conceptual understanding. Moreover, the emerging subthemes identified after the second cycle provided evidence for the effectiveness of the revised instructional strategies in enhancing students' interest, engagement, and confidence contributed to the learners' conceptual understanding of KE and PE concepts. These triangulated findings align with educational research advocating the integration of both traditional and innovative approaches for optimal KE and PE learning outcomes, incorporating refinements based on student feedback.

CONCLUSION

This study aimed to enhance the conceptual understanding and performance of Grade 8 learners on kinetic and potential energy using the Enerceptual Toolkit. Implemented over two cycles of planning, action, observation, and reflection, the intervention yielded empirical positive outcomes. Pre and post-test scores indicated marked improvement in their performance and conceptual understanding, classroom observations reflected greater initiative and reduced disruptive behaviors, and interview data revealed increased interest, participation, and confidence.

The Enerceptual Toolkit, as a student-centered approach, fostered learners' meaningful engagement and deeper comprehension of energy concepts. Based on the results, its integration is recommended as an alternative instructional and learning resource for teaching energy topics in Grade 8 science. The study also affirms the value of action research as a tool for teachers to systematically investigate and refine their pedagogical practices.

However, action research carries inherent limitations when applied to multifaceted teaching strategies, as it focuses on specific classroom contexts that restrict the generalizability of findings. Hence, future research should involve more diverse groups of learners to further validate the effectiveness of the Toolkit across varied educational settings. Additionally, the toolkit's effectiveness was limited by insufficient access to technological resources, particularly computers and stable internet connectivity. To maximize its potential, schools must ensure the availability of adequate technological devices and reliable internet infrastructure. Finally, the Enerceptual Toolkit shows strong potential as an innovative, student-centered strategy to enhance conceptual understanding in science education, offering teachers a pathway to more engaging and effective instruction.

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AUTHOR CONTRIBUTIONS

P. C. T: Conceptualization, formal analysis, resources, methodology, writing – original draft, writing – review and editing, funding acquisition, J. M. S: Conceptualization, data curation, methodology, writing – original draft, writing – review and editing, D. P. L: Conceptualization, formal analysis, methodology, writing – original draft, writing – review and editing, funding acquisition, J. J. D: Conceptualization, methodology, writing – review and editing, A. G. A: Conceptualization, methodology, writing – review and editing, J. A. B: Conceptualization, supervision, project administration, writing – review and editing.

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DECLARATION

Informed consent statement

This research was approved by the university.

Conflict of interests

The authors declare no competing interests.

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