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The effect of PIQMAS application on the engagement processes of upper basic stage mathematics and science students

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Abstract

New strategies, methods and projects for the learning of the mathematics and science disciplines are needed. One such project is the project for improving quality of mathematics and science (PIQMAS) education. In the present research, we consider the project implementation in Palestine. Specifically, we examine students' engagement when implementing the project. To do that, we consider three components of engagement: the cognitive, the behavioral and the emotional. To collect the data, we used interviews and observations, which ensured the triangulation of data collection. We interviewed 13 science and mathematics teachers who carried out the project. We used deductive and inductive content analysis to analyze the interviews and observations transcripts. The research results indicated that the project impacted positively the three components of students' engagement, which indicates the importance of incorporating new teaching methods, especially PIQMAS, in the teaching of science and mathematics. It is recommended to study different aspects of students' learning in PIQMAS environment.

Keywords: PIQMAS, engagement, cognitive, behavioral, emotional

INTRODUCTION

Many different frameworks for the educational process have recently been proposed, all of which, though different, agree on four components that must be developed: creativity, cooperation, communication, and critical thinking. Teachers are being encouraged to use teaching methods that help students to develop their learning skills for the 21st century (Beswick & Fraser, 2019).

Innovative teaching strategies are needed in the 20th century (Angraini et al., 2022; Daher & Shahbari, 2020; Daher et al., 2022a; Retamal Pérez et al., 2023; Tunggyshbay et al., 2023). Since 2021, the implementation of project for improving quality of mathematics and science (PIQMAS) project's teaching strategy has commenced in select schools affiliated with the Palestinian Ministry of Education, specifically in upper basic mathematics and science classes. This implementation has prompted researchers to investigate the cognitive, behavioral, and emotional engagement processes of students during the use of this strategy. The aim is to expand educational evaluation beyond solely cognitive aspects, which focus on the knowledge retained by students, and encompass all dimensions of their cognitive abilities, skills, and emotions (Xu et al., 2023). To achieve this objective, the researchers conducted interviews with mathematics and science teachers who utilize the strategy, as well as observed classes, where the strategy is implemented.

LITERATURE REVIEW

Students' Engagement

Engagement is defined by Lewis et al. (2011) as the extent to which learners' thoughts, feelings, and activities actively participate in the learning process. According to Gunuc (2014), it includes students'

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Contribution to the literature

- The present research describes how mathematics teaching and learning in the classroom could benefit from classic tools like the blackboard, which is still used by teachers all over the world.
- The present research attracts the attention of researchers to taking account of classic tools as tools that have not, where the emphasis nowadays is on new technologies like digital ones.
- The present research points out that new methods of teaching mathematics prevail in all countries and that we need to pay attention to these methods.

cognitive, behavioral, and emotional responses to classroom activities. For the domains of engagement, this study used the classification of Davis et al. (2012): Cognitive engagement, behavioral engagement, and emotional engagement.

Cognitive engagement is manifested in simulating the cognitive processes that the student performs during the learning process, such as critical thinking, behavioral engagement in the interaction between the teacher and other elements of the educational process, as well as emotional engagement, which is concerned with the students' feelings associated with the learning process (Gunuc, 2014).

According to Saif (2018), the significance of engagement in learning lies in the fact that it encourages students to learn and commit to it by giving them a sense of accomplishment, allowing them to build strong relationships with other students, and requiring them to use higher order thinking skills and creative thinking.

The Palestinian Ministry of Education sought to improve the quality of mathematics and science education in this environment by implementing a teaching strategy that would encourage students to engage cognitively, behaviorally, and emotionally. According to Archambault et al. (2020), high-quality teaching strategies are essential to improving students' emotional, behavioral, and cognitive engagement in school. To improve the quality of mathematics and science education in this environment, the Palestinian Ministry of Education sought to implement a teaching strategy that would encourage students to engage cognitively, behaviorally, and emotionally.

PIQMAS Project

The Palestinian Ministry of Education's 2017 baseline report showed that students in the fifth grade perform on average 42.4 percentile points in mathematics and 44.3 points in science. His outcome demonstrates the need for additional development (Ministry of Education and Higher Education, State of Palestine, 2017). The Japanese International Cooperation Agency (JICA) provided technical support for assistance in the field of education in the Palestinian territories in 2016, beginning with the support of textbooks and a review of the mathematics and science curricula (JICA, 2016).

PIQMAS was established in March 2019 to improve student learning in mathematics and science (JICA, 2016). In cooperation with school administrators and teachers, 60 schools were chosen as the project's target schools, which will start operating in Ramallah, Hebron, Nablus, and Gaza in the summer of 2021. In the summer of 2022, the number of targeted schools was increased to 500 schools throughout Palestine (Ministry of Education and Higher Education, State of Palestine, 2017). PIQMAS strategy for the classroom includes interactive exercises, the method of writing on the board, and the method of writing on the board (JICA, 2016).

This project aims to enhance creativity and critical thinking skills among students by developing science and mathematics education in schools, providing technical support to teachers and supervisors, and developing assessment tests for mathematics and science researchers. It also depends on effective interaction between students, their peers, and their teacher (JICA, 2016). Through social interactions, people begin to move towards individualistic thinking, leading to assimilation and independence of thinking (Jawad et al., 2021).

PIQMAS project's teaching strategy is a model based on Vygotsky's (1978) social constructivist theory, called the social constructivist learning model. PIQMAS teaching strategy incorporates the theory of educational scaffolding to help learners close the gap between them and others. This strategy is based on Vygotsky's (1978) social constructivism theory and peer learning theory's adoption of the area of proximal development of the mind, where the learner needs to obtain support and educational assistance in activities, questions, or others to become an independent individual capable of carrying out the same activities alone (Rehman et al., 2021).

RESEARCH RATIONALE GOALS & QUESTION

Little research has investigated the impact of using PIQMAS on students' engagement. This is especially true in Palestine, as it was recently implemented in the Palestinian schools, providing an opportunity for researchers to conduct additional research on the subject by considering different variables or conducting comparative research.

Table 1. Demographic characteristics of participants

Participant	Gender	Specialty	Location	YE
1	Female	Sciences	Bethlehem	29
2	Female	Mathematics	Bethlehem	24
3	Male	Mathematics	Ramallah	15
4	Female	Sciences	Ramallah	17
5	Male	Sciences	Nablus	23
6	Female	Mathematics	Nablus	15
7	Female	Sciences	Nablus	10
8	Male	Sciences	Ramallah	11
9	Female	Mathematics	Ramallah	24
10	Female	Sciences	Nablus	16
11	Female	Sciences	Nablus	23
12	Female	Mathematics	Bethlehem	18
13	Male	Science	Nablus	12

Note. YE: Years of experience

Researchers have been interested in the social aspect of students' learning when studying mathematics and science (Daher, 2017). Students' engagement in specific educational contexts. For example, Daher et al. (2022b) and Salhab and Daher (2023) studied the affective engagement of students who learned a mathematics course in online setting.

The current research aims to find out what are the cognitive, behavioral and emotional engagement processes of students in the upper basic stage in the Palestinian schools that adopted PIQMAS. This is the first study of its kind that investigates the impact of using PIQMAS on students' engagement in the Palestine Region, as it was recently implemented in some schools, providing an opportunity for researchers to conduct additional research on the subject by identifying different variables or conducting comparative research.

Research Question

What are the cognitive, behavioral, and emotional engagement processes of students during their learning under the application of PIQMAS teaching strategy?

METHODOLOGY

Research Context & Participants

This research investigated the impact of using JICA (2016) project teaching strategy on the engagement of upper basic stage students from the perspective of their teachers and their cognitive, behavioral, and emotional engagement processes. The sample, as shown in **Table 1**, was homogeneous, as all participants used PIQMAS teaching strategy with its main tools, the blackboard and notebook, and worked in public schools in different governorates. The study attempted to cover both the homogeneity and differences among study participants (Burmeister, 2012).

Data Collection

Data were gathered by conducting semi-structured interviews, which are the best method for gathering qualitative data in educational research due to their flexibility (Flick, 2022). Before starting the interviews, researchers created an interview guide to focus on the issues raised without being constrained to a specific topic (Lindlof & Taylor, 2017). There are 14 different types of emotional, behavioral, and cognitive involvements that are covered in detail. **Table 2** shows a summary of these questions. The researchers observed two science and mathematics classes, where the project strategy was being used. Observation is one of the primary tools for data collection in qualitative research, and is often accompanied by recording tools, videotaping, transcription, and analysis. The researcher was a non-participating observer, so he observed and took field observations from a distance (Creswell & Poth, 2018). Videotaping, transcription, and analysis were used to document observations.

Analysis of Data

The deductive and inductive content analysis was used. The deductive thinking was based on the theory of students' classroom engagement in its three categories: cognitive engagement, behavioral engagement, and emotional engagement. Based on the following indicators of engagement (Cevikbas & Kaiser, 2022):

- Indicators of the cognitive domain, such as realizing learning objectives, recalling previous experiences, solving problems in different ways, and evaluation and judgment;
- Behavioral domain indicators such as interaction and increased achievement; and
- Indicators of the emotional domain such as taking responsibility, enhancing self-confidence, enthusiasm, pleasure and attraction.

Inductive content analysis was used to understand the cognitive, behavioral and emotional engagement processes during the implementation of the project. Classes were divided into events and described and analyzed. **Table 3** shows an example of coding during data analysis.

Validity & Trustworthiness of Analysis Method

The saturation point of the final sample size was determined through purposeful sampling in three levels. The first level was achieved by choosing teachers of the same profession and educational background and receiving the same training courses. The second level was achieved by adjusting the samples on the basis of gender differences, years of experience, and the governorate in whose schools they work.

Table 2. Types of questions in interview

Type of question	Example
Introduction question	Can you tell me about JICA project teaching strategy (PIQMAS) that you apply in education process?
Structuring questions	What are the steps you take during the implementation of this strategy that lead to the student's understanding of the new subject presented in the class?
Probing questions	How does the student act if he or she has difficulty understanding a particular point during the required activity or task in the learning environment (PIQMAS)? Explain that with an example.
Interpreting questions	You mean that the dialogue that takes place between the teacher and the student is the biggest motivation, that the child is preparing for the next lesson?
Direct questions	"I mean, as if you are helping him link the new topic to the other topics?"
Specifying questions	Creative! What do you mean by creative?
Follow up questions	"Okay, what do you think is the solution to this problem that you talked about?"

Table 3. A coding example

Line number	Participant	Text	Code
89	9	They work on this thing, & they discuss with each other.	They discuss with each other.
61	6	Recall past experiences, remember the law and solve it.	Call up previous experiences.
163	10	Many are enjoying the work inside (inside) the groups.	Enjoying the job.

The third level was achieved by conducting two additional interviews and analyzing them, which showed a repetition of the same categories (Ailincai & Gabillon, 2018; Daher, 2023).

Trustworthiness

The criteria outlined in Lincoln and Guba (1985) are used, which are summarized as trustworthiness, dependability, verifiability, and transferability, in addition to recently introduced component of realism. Which was achieved in the current research, as follows:

Credibility & conformability

Credibility is the degree of trust that can be put in the veracity of research findings. To achieve this, research participants must be precisely identified and described (Lincoln & Guba, 1985). According to Polit and Beck (2012), conformability refers to the extent to which a research study's findings can be independently verified by other researchers, clearly deduced from the data, and logically dependent on participant data.

This was achieved in this research by mentioning how we selected the participants, in addition to clarifying their characteristics mentioned in **Table 1**, describing data collection tools, and justifying their suitability for this research, as well as through a description of interview questions. This has also been verified by clarifying the analysis method such as Invivo coding and descriptive coding.

Dependability

Dependability is the stability of data over time and under different conditions. It determines if the research results represent reasonable information and are a correct interpretation of the original opinions of the participants (Chilsa & Preece, 2005). This was achieved in the current research by collecting data from several different regions.

Transferability

Transferability is the degree to which qualitative research findings can be transferred to other contexts or settings with other participants (Daher et al., 2021). This was achieved in this research by describing the preparation of the research and providing clear descriptions of the context, selection, and characteristics of the participants. An accurate description of how to analyze the collected data is given in **Table 3**.

Authenticity

Authenticity refers to the extent to which researchers fairly and honestly show a set of facts (Elo et al., 2014). Authenticity was achieved by presenting the results to three participants in the research to ensure that they match the data they provided during the interviews; the compatibility ratio between the analysts that was calculated using the Holsty formulae, and the ratio was (0.954), as the accepted agreement ratio is (0.850) (Holsti, 1969).

Triangulation

Triangulation was achieved in this research by using more than one data collection tool (Daher, 2023), as two tools were used: Semi-structured interviews and observations. The researchers also employed more than one method to encode the participants' data such as Invivo coding and descriptive coding.

RESULTS

To answer the research question, engagement processes were found in the three domains (cognitive, behavioral, and emotional).

The categories of each type include mostly categories suggested in theoretical literature, as well as some that were not mentioned there. Below is a description of each of the engagement categories as well as the main categories and sub-categories they contain the followings.

Cognitive Engagement

Cognitive engagement included five categories described below.

Realizing learning objectives

The science teacher (No. 11) explained the importance of writing the learning objectives on the board in order not to distract the students' thinking, as she said:

> "Their thinking focuses in one particular direction, they do not get distracted, they know what we are doing today in order to answer the main question."

According to the previous teacher, writing the objectives of the lesson is a strategic step of PIQMAS to help students realize them.

Retrieving previous experiences

The science teacher (No. 10) referred to students' participation in the new topic by collecting their previous experiences and employing them for the new topic in PIQMAS environment:

> "I recall their previous information, and in the same process they begin to link it with the new topic".

The step of preparing for the new topic is another important step of PIQMAS strategy by retrieving all previous experiences.

Information organization

Organizing information on a board enabled students to relate topics to each other, facilitating the long-term retrieval process. The science teacher (No. 10) who said:

> "When s/he comes to study, it means that the student's work on the notebook is the same as the teacher's work on the board. This is how information becomes linked and integrated and easy to memorize for the long term".

The teacher suggests that students follow the teacher by writing down the teacher's explanation on the board. This helps to organize the information to convert it into knowledge.

Solving problems in different ways

Solving problems in different ways motivated the students and stimulated their thinking to assume new data and find their solutions. Teacher (No. 1) said:

> "If we let the students have the freedom to solve problems, following PIQMAS teaching strategy, some students will be encouraged to reach results in different and new ways".

Thus, PIQMAS teaching strategy encourages the creative doing of the students.

Evaluation & judgment

The process of the student's self-evaluation of his work and his answers became clear after reaching the correct answer and comparing it with his/ her initial expectations as said by teacher (No. 11):

> "The students correct and evaluate themselves".

Or through the effective dialogue that takes place with their teacher or colleagues:

> "Dialogue enables the students to prove information or eliminate wrong information".

Thus, the process of self-assessment and information assessment were prevalent among students during the application of PIQMAS strategy.

In the observations, the cognitive involvement emerged clearly in PIQMAS teaching classroom. Excerpt 1 shows this involvement.

Excerpt 1: Recognizing learning objectives & recalling past experiences

The teacher started the new lesson by writing objectives on the board. She then asked questions to retrieve students' previous experiences and link them to the new lesson objectives. The learning actions are denoted by […].

> 5. The teacher: So, we will start our lesson today titled 'The elements' symbols'. The objectives of the lesson [the teacher points to the first column on the board, which is titled as objectives] are: the student writes the symbols for the different elements, the student knows the method of deriving the symbols of the elements, the student knows the two methods that scientists adopted to write the symbols of the elements in the periodic table [the teacher asks the students ... the students seem focused].
>
> 6. The students: In nature [they answer together].

7. The teacher: Let us recall the previous lesson [she discusses the previous science topic with the students].

8. Tasneem: Elements, compounds and mixtures [students from each group raise their hands to participate].

9. The teacher: So, we have elements, compounds and mixtures [she points to the word elements written on the board and asks the students]: What kind of elements do we have?

10. Reham: Sodium.

11. Mays: Copper.

12. Asma': Carbon.

13. The teacher: Compounds. Who can give us examples of compounds? [she points to the word compounds written on the board].

14. Roa'a: Water.

15. Tasnim: Carbon dioxide.

16. Reham: Sugar.

17. Amani: Table salt.

18. The teacher: Mixtures. Which two substances can we mix together? [she points at the word Mixtures written on the board].

19. Lama: Oil and water.

20. The teacher: Oil and water, uh, do you still remember if they are homogeneous or?

21. The students: Heterogeneous [the students answered together].

22. The teacher: Sugar and water, salt and water, oil and water.

In the previous excerpt, we notice the students' cognitive engagement clearly through the teacher's presentation of the lesson's objectives at the beginning of the lesson (line 5). This in turn led to the students' awareness of the learning objectives of this lesson in addition to the part of the lesson that the teacher allocated to retrieve the students' previous experiences about the subject and employing it to serve the new subject according to PIQMAS teaching strategy (line 7-line 22). Cognitive engagement prevails in this excerpt. As for the other areas of engagement, we notice that the students' answer with the teacher with one voice indicates their interaction with the subject and the teacher; this is one of the indicators of behavioral engagement. Emotional engagement also appeared through the students' attraction to the teacher during her explanation on the board.

Behavioral Engagement

Behavioral engagement included two categories that are described below.

Interaction

The interaction, according to the results of the interviews, includes three sub-classifications: Interaction with the tool, interaction with the teacher, and interaction with peers. Each of them will be dealt with separately, as follows:

Interact with project tools

The interaction of the students with the board occurred while writing the answers on it and explaining them to their classmates. The mathematics teacher (No. 9):

> "The students started presenting their results on the board and explaining them to whole class".

The students' interaction with the notebook was evident through their interest in recording information in an orderly manner on the notebook. The science teacher (No. 10) said:

> "… In order for them to organize their information, they began to record. I tell you, it is good that the children began to hold pens and write. Even the weak students began to take care and arrange their notebooks".

However, some parameters indicated the difficulty of arranging the information in the notebook as the science teacher (No. 1) said:

> "The girl students claimed that the notebook is not as spacious as a board, miss".

Thus, the students' interaction with PIQMAS tools was clear and positive, with some difficulties during their interaction with the notebook due to the small writing area compared to the board.

Interaction with teacher

The participating teachers explained that there is an effective dialogue taking place between the student and the teacher during the group activity after placing the main question on the board. Teacher (No. 7) said:

> "The question on the board encouraged an effective dialogue between me and the students".

We see that one of the components of PIQMAS project affected positively students' interaction with the teacher.

Interaction with peers

Here, this interaction came in two aspects: a bilateral interaction (pairs) between the student and his colleague in the form of an effective dialogue between them, as this was demonstrated in the words of the science teacher (No. 1):

> "The weak student is forced to ask her friend who is smarter than her in order to help her understand. Glory be to God, she will accept peer's help".

Based on the teachers' statements, we notice that learning in PIQMAS environment significantly increased the interaction between peers, which had a positive impact on the student's behavioral engagement.

Increased attainment

The mathematics teacher (No. 10) indicated that the students' achievement improved in the standardized exams for schools, saying:

> "In the standardized exam, males scored higher marks than their previous scores and more than students at other schools who did not apply the project".

This indicates that PIQMAS strategy has contributed to a positive impact on student achievement.

With regard to the results of the observations, the behavioral involvement appeared clearly in all steps of PIQMAS teaching strategy in the science class.

Excerpt 2: Working in groups–Interaction between group members

The teacher distributes the activity questions in the book to the five groups so that each group gets a question. The teacher asks each group to work collectively and write the final answer on a shared sheet from each group. While working in groups, the teamwork was uneven between the groups, while the cooperative work was clear among the members of one group, and the work was individually within other groups.

> 149. The teacher: Give me the Latin 37 elements that you need? Each group has a question. Let us answer the questions. Which element did the first letter of its name come from? write it to me okay? The third question, which elements were named based on the first and second letters? Any items named based on the first and third letters? Which items are named based on the first and fourth letters? In addition, which elements are named based on the first and fifth letters?
>
> 150. First group (five students): [Each student searches for the answer on her own in the book, the students show anxiety and tension as one of them puts her hands on her head and the other wears a jacket at so that her face can barely be seen and brings her head close to the book on the table, while another student turns to the right and to the left, another student is writing on the book and the last one is waiting].
>
> 151. Second group (six students): [Two students discuss the task enthusiastically, and a third student listens to the rest of the students. The third student searches for the answer in the book and another searches once in the book and once in the notebook and looks confused, and another student paints in the notebook and does not raise her head from it, putting on her blouse hat and she can barely see her face and her expressions].
>
> 152. Third group (six students): [All students discuss collectively. One of them writes the answer on a piece of paper, and the rest of the students concentrate with her to prepare for her presentation].
>
> 153. Fourth group (six students): [They discuss collectively, one of them searches for the answer in the book, the colleagues observe her, and another writes the answer on the group paper with the focus of the rest of the group. The two students show confidence in what they write, while the rest of the students seem more like spectators than interacting].
>
> 154. Fifth group (six students): [They discuss and one of the students looks perplexed and looks left and right].

Working in groups is a skill that students and the teacher need to be trained on. Therefore, it is expected that there will be a difference in cooperative work between group members. Nevertheless, we note that three groups out of five (the majority) in which the students showed interaction with their peers, which came through collaborative work, effective dialogue management, and discussion during the performance of the task, which expresses behavioral engagement processes (151-153). While the remaining groups showed feelings of negativity and signs of confusion, anxiety and stress. And these feelings fall within the scope of emotional involvement (150 & 151), just starting to work in groups. These negative feelings hindered the students' emotional involvement at the beginning, but they diminished as soon as the task became clear to them.

Emotional Engagement

Emotional engagement includes four main categories: Taking responsibility, boosting self-confidence, enthusiasm, pleasure, and attraction. It is consistent with the indicators that the researchers relied on in the theoretical literature. Below we describe each category and sub-category supported by a number of quotes from participants.

Taking responsibility

Taking responsibility appears clearly through the distribution of roles among students within the same group, so that each student is responsible for carrying out the role entrusted to him. The science teacher (No. 1) indicated:

> "In the group, when they are sitting, each one knows what his role is, and they discuss the solution of the task, and even the weak student participates in it and gives her a role so that the whole group will win".

The responsibility of the students who are the leaders in each group increases:

> "The group leader must be attentive and listen to everyone so that they do not get lost and lose the mark".

Thus, working in groups according to PIQMAS distribution of roles among them.

Enhancing self-confidence

The participants pointed out that working with PIQMAS strengthened the students' self-confidence. Teacher (No. 6) explained:

> "They have a presence, they have confidence, they have become aware of what is in their shame, we broke the barrier".

Here, the application of the teaching strategy PIQMAS has had a positive impact on the students' self-confidence.

Enthusiasm

The participants mentioned that the enthusiasm of the students during PIQMAS's lesson prompted them to help others, as the mathematics teacher (No. 2) said:

> "Because he was very excited, after he finished his group's work, he started helping another group".

Thus, learning using PIQMAS raised students' enthusiasm during the education process.

Pleasure & attraction

Participants indicated that the students enjoyed working in groups, and this was evident in the math teacher's statement (No. 6):

> "… No, they enjoyed working in groups so much that you feel that he encourages you to tell you a smile on his face, which is evidence that he is happy …"

Hence, learning using PIQMAS method has become a source of enjoyment for students, whether through working in groups or interacting with the notebook.

The emotional involvement appeared clearly in all the steps of PIQMAS strategy in the science class, as shown in the following excerpt from the observation.

Excerpt 3: Students' enthusiasm & motivation

> 250. Reham: I prepared an activity for this lesson that I want to pass to my classmates [she asks the teacher and holds prizes to distribute to those who can answer the questions correctly].
>
> 251. The teacher: Come on, Reham [the teacher seems surprised]. Oh, Reham has prepared prizes for you [the students look excited].
>
> 252. Reham: Roa'a, what is the symbol of copper element? [Reham goes to the board with her cards and stands in front of the students]. The activity is a set of cards that bear the names of the elements. You need to know the symbol of the element on the card].
>
> 253. Roa'a: Cu [Riham gives Roa'a the gift, a smile appears on her face, full of signs of satisfaction and pride].
>
> 254. Reham: Rahaf, lithium? [Reham points to her classmate].
>
> 255. Rahaf: L. [Reham moves her head left and right, meaning that the answer is incorrect, and a smile interspersed with her colleague].

The current excerpt is dominated by emotional engagement, which emerged from the moment Reham stood in front of her classmates holding awards during the final evaluation process for the new lesson (250). This is considered one of the manifestations of emotional engagement because of the feelings of contentment, enthusiasm and happiness, self-confidence and concern for female colleagues (251 & 253). Behavioral engagement was evident in this event, and it appeared through the interaction between the students with their peers to participate and answer questions.

From the foregoing, we note the agreement and consistency between the results of the interviews and the results of the observations, as the results of the observational events were supported by the teachers' statements that were mentioned in the results of the interviews.

DISCUSSION

The present research intended to examine students' engagement in learning during PIQMAS program. PIQMAS program represents here new trends in mathematics education, so it continues the attempts to experiment with new methods of teaching and learning mathematics (Bwalya & Rutegwa, 2023; Klemer et al., 2023; Owan et al., 2023; Tang et al., 2023). Below, we discuss each type of engagement in the context of PIQMAS program.

Cognitive Engagement

The study results indicated that PIQMAS affects students' cognitive engagement in different ways, such as realizing class objectives, recalling previous experiences, organizing information, and evaluating. PIQMAS is represented in sequential steps, starting with placing the objectives of the new lesson on the board in front of the student in preparation for the new topic. Writing clear and meaningful educational objectives is a necessary skill for teachers. Thus, any educational activity must begin with presenting the topic of the lesson and the learning objectives to students (Sewagegn, 2020). At this stage, the student begins to retrieve previous experiences related to the subject of the question and discusses with peers to answer the main question.

As Humaidan (2021) argued, effective dialogue involves the exchange of knowledge and experiences between individuals to achieve understanding and generate new ideas. Collaborative groups help learners retain information longer and develop critical thinking and communication skills (Malone & Lepper, 2021). Group and peer learning also affect positively the creative thinking of students, which promotes the students to find unique solutions to the main problem and achieve learning objectives (Rouibeh et al., 2021).

Behavioral Engagement

Students' interaction could be classified as: interaction with the teacher, interaction with peers, and interaction with tools. Interaction with the teacher occurs when students expect to answer the teacher's questions, or when students need to inquire about the activity. Interaction with tools occurs through the board, or the laboratory in the science class. Interaction with peers occurs during the group activity, whether the student asks for the help of his peer or helps his peer. PIQMAS project created a suitable environment for interaction. It is a flexible learning environment that uses student-centered teaching methods and facilitates interaction and cooperation, which achieves engagement with the content of the lesson (Kariippanon et al., 2019). This interaction constitutes positive engagement. Havik and Westergård (2020) indicated that students who had a high level of interaction in the classroom were also most engaged.

PIQMAS project resulted in an increase in achievement for most of the students. The achievement of students who implemented the project in mathematics classes was higher in the standardized exam compared to those who did not. This was supported by Jawad et al. (2021) who found that the educational pillars strategy based on Vygotsky's (1978) theory was effective in raising achievement in mathematics.

Emotional Engagement

PIQMAS project led to enhancing confidence, enthusiasm, and responsibility. Researchers link this to teamwork, as working in groups creates a comfortable environment, where participatory learning and teamwork work to enhance self-confidence and get rid of shyness and fear. Group discussion helps to encourage students to share their answers and express their opinions without hesitation (Rouibeh et al., 2021).

The use of cooperative teaching creates cooperation between members of the group, allowing students to perform the tasks assigned to them and facilitate the learning process (Alazzam, 2020; Bada & Jita, 2022). Additionally, the technique of formulating the goal of the new lesson in the form of a question/problem increases the students' enthusiasm and motivates them to search for the problem's solution.

Cairns and Areepattamannil (2019) found that inquiry-based science teaching was positively associated with an orientation towards science. Linking the answer to a group activity or practical experiment creates an enjoyable atmosphere, while assigning learners to conduct experiments on their own provides pleasure during the learning process. The previous explains the positive influence of PIQMAS project on students' emotional engagement.

CONCLUSIONS

Researchers and educators are interested in experimenting with new methods of teaching mathematics and science (Daher, 2010; Daher et al., 2020; Furinghetti et al., 2012; Kim et al., 2015; Lunde & Wilhite, 1996). The present research examined the effect of PIQMAS on students' engagement. Through analyzing the data collected from interviews with science and mathematics teachers and observations, the research findings shed light on the influence of PIQMAS on students' cognitive, behavioral, and emotional engagement.

The utilization of PIQMAS exhibited a positive impact on students' cognitive engagement, specifically their ability to attain the lesson objectives, as well as enhance their critical thinking skills. This was evident also through the encouragement of students to recall and incorporate past experiences. Moreover, the incorporation of peer learning and group discussions contributed to this enhancement.

The application of PIQMAS also amplified behavioral engagement among students. This was illustrated by their interaction with the project tools: board and notebook. These tools effectively organized information in a clear manner, which promoted favorable engagement. Despite encountering certain challenges when using the notebook due to its restricted writing space compared to the board, students still displayed an overall positive interaction with the tools.

By fostering a sense of shared responsibility through cooperative learning, enhancing self-confidence among students, and generating enthusiasm, PIQMAS managed to cultivate emotional engagement in the classroom setting. The inclusive and encouraging atmosphere provided a platform for students to express their ideas freely, leading to a greater sense of pleasure and attraction towards the learning experience.

In conclusion, the findings of this study indicate that PIQMAS has a positive impact on the engagement processes of upper basic stage students. The project promotes cognitive engagement by emphasizing clear objectives and encouraging peer learning. It enhances behavioral engagement through interactive learning methods and collaboration. Additionally, PIQMAS fosters emotional engagement by creating a supportive and inclusive environment for students to express themselves.

Recommendations

PIQMAS project has had a positive impact on the cognitive, behavioral and emotional engagement of students, so the researchers recommend expanding its application to include the rest of upper elementary schools in the various Palestinian governorates. They also recommend working on qualifying students of faculties of education in universities by developing courses dealing with modern teaching methods and strategies, including PIQMAS project for teaching science and mathematics.

The role of the ministry of education is critical in encouraging teaching strategies (AlFahel et al., 2016; Daher & Salameh, 2022; Masaiti & Naluyele, 2011; Sakarneh, 2014). It is suggested that the Ministry of Education prepares, draws lines, unifies and attaches notebooks for students to fill out during classes. Future research should study the reality of implementing the project from the point of view of teachers, the difficulties they face in applying it, and the factors that have the potential to increase students' involvement. This will help to eliminate some difficulties among some students.

Limitations

Even though this study was successful, there were some limitations, including the difficulty in finding a sufficient number of teachers who had received PIQMAS training and actually implemented it. A higher percentage of teachers who received training were found not to have applied the project in real classroom settings, compared to those who did. In light of this limitation, collecting a larger sample of teachers who received both training and actively implemented the project may have been difficult. In this context, the researchers were challenged to identify and include a sufficient number of teachers who had successfully implemented PIQMAS after undergoing training. Due to the limited availability of such teachers, it may have been impossible to assess the full impact of PIQMAS on student engagement. Future studies should consider strategies to overcome this limitation, such as ensuring a larger pool of trained teachers who actively implement the project and investigating the reasons behind the discrepancy between training participation and project implementation.

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