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Physics Problem-Solving: Teachers' Views on the Impact of Mathematics on Secondary Students' Interest

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Abstract

Through this study, we are going to explore the importance of mathematization in physics problem-solving according to teachers' views and observations in the region of Fez-Meknes Morocco. Data collection was based on a questionnaire for 141 teachers. The results obtained have shown. Firstly, physics mathematization problem-solving is important, but the implementation of this situation remains difficult to apply by Moroccan teachers in their classroom practices. Second, professional interaction and pedagogical collaboration among Moroccan teachers on ways to integrate mathematics into physics problem-solving are sorely lacking. Third, the mathematization of problems can influence students' interest in physics.

Keywords: *Interest, Physics Mathematization, Secondary students, Teachers' views, Morocco*

1. Introduction

Research on problem-solving has long been an ongoing, sustained and continuous activity in all the fields of science education and training (Soh et al., 2010). First, (Huffman, 1997) pointed out that problem-solving is the teaching of students to use more advanced techniques to solve a specific problem situation. In this context, various researchers justify this by the fact that problem-solving is not only about finding the right answer but also about taking steps that cover the mental abilities to be mobilized to find a solution to an everyday problem (Altun, 2002). Second, (Wolff, 2020) has shown that a good understanding of a scientific domain generally depends on the application of this knowledge in solving real and practical problems. So, the scientific literature has identified several disciplinary fields that emphasize problem-solving.

Problem-solving in physics has therefore proved to be an interesting research topic to be studied. On the one hand, physics education generally involves rigorous problem-solving (Pal & Rinki, 2022). On the other hand, physics is a context where students are allowed to demonstrate their cognitive and intellectual abilities to solve a physics problem situation (Gräber, 2011; Naki ERDEMİR, 2009).

One of the most fundamental characteristics of physics is its relationship with mathematics because physics is full of abstraction and mathematical representations (Kabil, 2015; Pal & Rinki, 2022). Indeed, physics and mathematics are two disciplines deeply linked in the long history of science (Meli et al., 2016; Vinitsky-Pinsky & Galili, 2014) and often physics phenomena are explained via mathematical models (Bain et al., 2019; Hu et al., 2019; Kim et al., 2018; Zeidmane, 2013).

Physics mathematization can have an impact on students in several ways. Firstly, cognitive structures can be modified by finding solutions for practical issues (Haeruddin et al., 2020) and the general learning environment can enrich education around mathematics (Capone, 2022). That is to say, each physics' situation can be learnt in the suitable mathematical context. Secondly, students' interest can be oriented by developing knowledge, skills, and positive attitudes toward students' physics problem-solving in secondary school (Balta et al., 2016; Hasni & Patrice Potvin, 2015; Naki ERDEMİR, 2009).

That's why, students should take part in the development and construction of their knowledge and adapt to an interest towards physics mathematization problem-solving because, in Morocco, we are lacking the physics mathematical practical integration. To clarify, Moroccan physics teaching instructions focus only on the informative and injunctive styles and neglecting its practical side (El Moussaouy et al., 2014). Therefore, teachers are still facing the problem of implementing interdisciplinary education (Reverdy, 2016) in their classroom practices (Başkan et al., 2010). For this reason, the interaction between mathematics and physics is difficult for problem-solving.

This research aims to analyze the views, opinions, and observations of Moroccan secondary school teachers on the effect of mathematics in physics. The specific issue is not only about physics problem-solving but also on Moroccan secondary school students' interest. To achieve the objectives of this work, we have tried to provide elements of an answer to our general question of this research: is the interdisciplinarity of mathematics and physics taken into consideration in the Moroccan educational system?

This question drives other research questions as follows:

- What is the effect of mathematics on the difficulty of physics problem-solving?
- How can mathematics in problem-solving influence the physics interest of Moroccan students?

In this paper, we have conducted an empirical study through a questionnaire administered to physics teachers in the region of Fez-Meknes, Morocco. This investigation has been done. Firstly, to analyze the teachers' views on physics mathematization problem-solving. Secondly, to highlight the teachers' views on the student's interest and attitudes in physics mathematization problem-solving.

2. Conceptual Framework

Conceptual frameworks and scientific models in terms of problem-solving are very diverse, depending on the context of the research carried out. On the one hand, Docktor et al., (2016) have developed a well-known framework for problem-solving. It consists of five steps focusing on science in general and physics in particular: (1) a useful description of the problem; (2) an appropriate principled physics approach; (3) a specific application of the physics concept adaptable to the conditions of the situation; (4) an application of the particular mathematical procedure; and (5) an organized, goal-oriented logical progression that guides the solution process.

So, the model of (Docktor et al., 2016) left the mathematization stage as the penultimate stage of problem-solving. This situation leads us to the fact that the interpretation and application of physics concepts, laws, and/or notions are the crucial steps of physics problem-solving and mathematization is only a tool to help in problem-solving and is not the final goal.

Indeed, regarding the relationship between mathematics and physics problem-solving, (Jensen et al., 2017) have shown that problem-solving is a skill that needs to be developed and trained around two important phases: the first is physicalization and the second is the practice of mathematics. So, for (Jensen et al., 2017) mathematization is a real goal in physics problem-solving.

The model of (Jensen et al., 2017) starts with the student having a special mental capacity to solve non-formalized problems. After that, students need to focus on the formalization skill that transforms the problem from non-formal to formal. Moreover, the experience of (Jensen et al., 2017) shows that the problem formalization stage requires students to have some mathematics knowledge no matter what type of formalization it is.

It should be noted that affective qualities such as students' interests and attitudes toward physics, which are not generally evident in these two selected models. This is the importance of the present research about the mathematization of physics problem-solving.

3. Methodology

3.1 Data collection

To reach our research objective, the present study is based on a paper-pencil questionnaire consisting of 12 questions (12 items). Indeed, we have built essentially multiple-choice questions oriented to determine the teachers' point of views on the difficulty of physics mathematization problem-solving as well as identify the impact of mathematization on students' interest and teaching pedagogy.

In our questionnaire, we have adopted a four-point Likert scale for majority of questions: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA). The remaining questions are multiple choice items.

Afterwards, the questionnaire has been distributed to a group of 141 teachers of high school in the region of Fez-Meknes, Morocco. This population represents more than 17% of physics teachers in the whole region. When answering the questionnaire, the teachers took between 10 to 20 minutes to fill in the entire questionnaire. The teachers were told that the questionnaire was anonymous.

3.2 Questionnaire validation

The validation of the items consists of a test to ensure the reliability of our questionnaire. To test the internal consistency and reliability of the questions, we have calculated Cronbach's Alpha values. The Cronbach's alpha score of our questionnaire is higher than 0.85, confirming the good reliability of the constructs in previous studies (Bagozzi & Yi, 1988; Manis & Choi, 2019; Peterson, 1994; Schweizer, 2011), which indicates the validity of our questionnaire.

Before its release to our sample, the questionnaire was validated with 50 teachers who were not participating in the survey. During this validation, teachers were asked to provide any comments they might have regarding the comprehensibility of the questions and to indicate the time required to complete the questionnaire.

3.3 Treatment of results

The data collected from the questionnaire is presented in the form of percentage figures by Microsoft Excel software.

4. Results

4.1 Teachers' views on physics mathematization problems

Question 1: Mathematization is an attempt to reconstruct physics knowledge.

The results obtained highlight the relationship between physics and mathematics. The majority of the physics teachers questioned (63%) agreed (32%) or strongly agreed (31%) that mathematization is an attempt to reconstruct physics knowledge (Fig.1). This is in contrast to 37% of the teachers who disagree (24%) and strongly disagree (13%) (Fig.1).

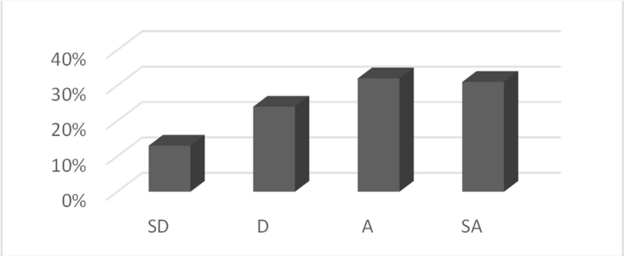

Figure 1: Percentages of teachers' responses regarding physics mathematization.

Question 2: Physics mathematization generally depends on the problem studied.

For the data of this question, we found that 51% of the teachers agree and they state that the mathematization of physics generally depends on the problem studied. Also, 24% of the teachers strongly agreed with this view (Fig.2). On the other hand, 25% disagreed with this view (20% disagreed and 5% strongly disagreed (Fig.2)).

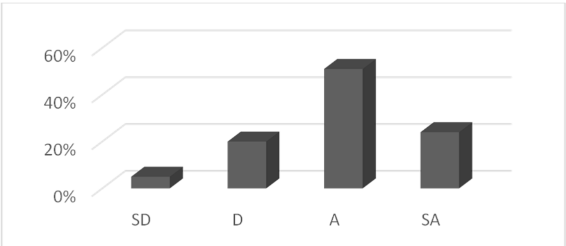

Figure 2: Percentages of teachers' responses regarding the relationship between mathematics and physics problems-solving.

Question 3: Physics mathematization is an important part of problem-solving.

The results obtained showed us that 27% of the teachers questioned strongly disagreed that physics mathematization is an important part of problem-solving (Fig.3). In the same context, 35% of the teachers disagree (Fig.3). However, 38% of the teachers disagreed with this statement (28% agreed and 10% strongly agreed (Fig.3)).

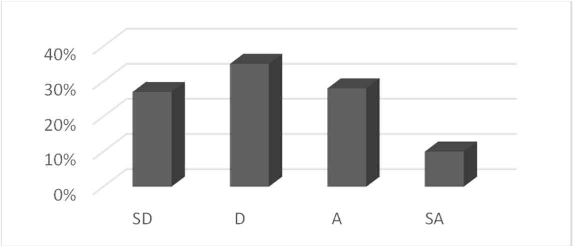

Figure 3: Percentages of teachers' responses regarding the importance of mathematization in physics problem-solving.

Question 4: Mathematization is only a method of physics problem-solving.

The results obtained show that 42% of the teachers agree that mathematization is only a method of physics problem-solving (Fig.4). Similarly, 11% of the teachers strongly agreed that mathematization is not the major part of problem-solving (Fig.4). However, 47% of the teachers disagreed with this statement (33% disagreed and 14% strongly disagreed (Fig.4)).

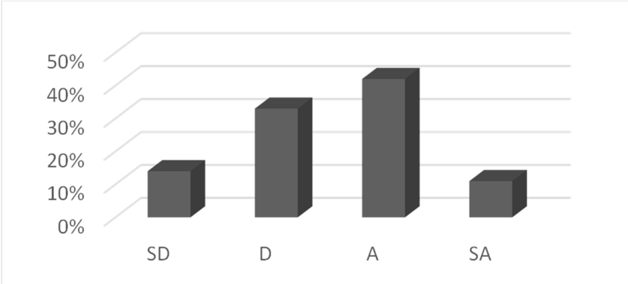

Figure 4: Percentages of teachers' responses regarding the implementation of physics mathematization in problem-solving.

4.2 *Teachers' views on mathematization problem-solving difficulty*

Question 5: Mathematization is a real difficulty in physics problem-solving.

For this question, 75% of the teachers surveyed agreed (19%) or strongly agreed (56%) that mathematization is a real difficulty in physics problem-solving. On the other hand, 25% of these teachers disagreed (18%) or strongly disagreed (7%) (Fig.5).

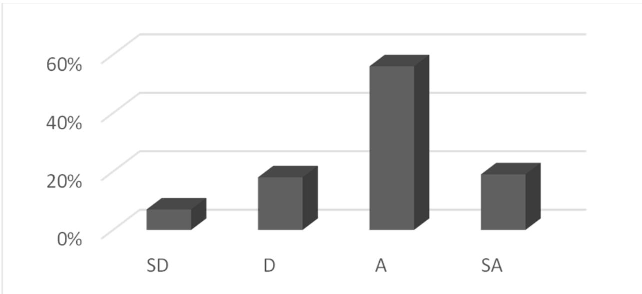

Figure 5: Percentages of teachers' responses regarding the difficulty of mathematization in physics problem-solving.

Question 6: Do your students find physics mathematization problems difficult (yes or no)?

This question was asked in a way that teachers were allowed to answer with *Yes* or *No*. The results of this question (Q6) showed us that almost all teachers said that their students find physics mathematization problems difficult. 92% of the teachers answered *Yes* and only 8% answered *No*. The question is followed by a clarification for those teachers who answered *Yes*:

The response data showed that 29% of the teachers are lying for *(1): The symbols used in physics, unlike in mathematics, are not chosen arbitrarily, but they represent certain physics quantities (Fig.7), 32% for *(2): Students fail to attach physics meanings to mathematical symbols, equations, and formulae (Fig.6). 34% for *(3): Symbols, equations, and mathematical formulas are meaningless to students (Fig.6). 5% for *(4): Teachers are lying to others (Fig.6) and they specified their choices which we are going to discuss in the following part of this article.

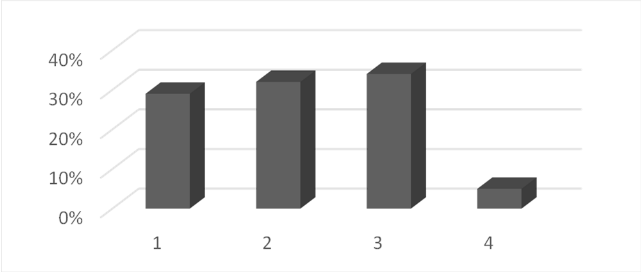

Figure 6: Percentages of responses given by teachers concerning the types of difficulties found in physics mathematization problem-solving.

*(1): The symbols used in physics, unlike in mathematics, are not chosen arbitrarily, but they represent certain physics quantities.

*(2): Students fail to attach physics meanings to mathematical symbols, equations, and formulae

*(3): Symbols, equations, and mathematical formulas are meaningless to students

*(4): Teachers are lying to others and they specified their choices which we discuss in the following part of this article.

4.3 Teachers' views on students' problem-solving interests

Question 7: Students' interest develops during mathematization problem-solving.

According to the results obtained, 51% of the teachers agreed (7%) or strongly agreed (44%) that Students' interest develops during mathematization problem-solving (Fig.7). On the other hand, 49% disagreed with this view, since (28%) disagreed and (21%) strongly disagreed (Fig.7).

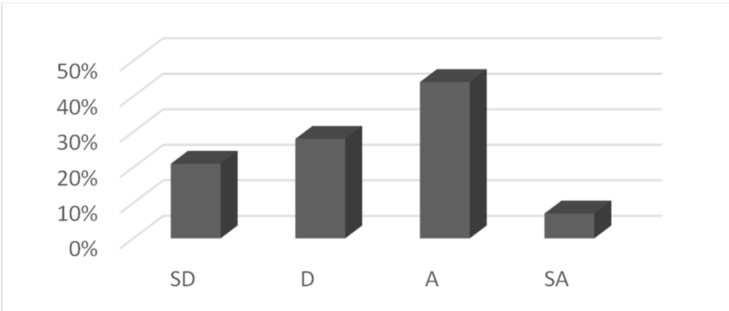

Figure 7: Percentages of teachers' responses regarding the relationship between students' interest and physics mathematization problem-solving.

Question 8: Mathematization problem-solving can influence students' attitudes.

For this question (Q8), the majority of the teachers surveyed ((84%) agreed (59%) or strongly agreed (25%)) that the change in the teaching practice of physics mathematization can influence students' interests and attitudes (Fig.8). On the other hand, 16% of these teachers disagreed (11%) or strongly disagreed (5%) (Fig.8).

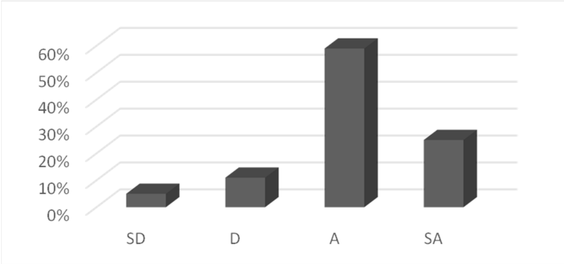

Figure 8: Percentages of teachers' responses regarding the influence of problem-solving mathematization on students' attitudes.

Question 9: In your experience, a mathematical reminder is mandatory for physics problem-solving.

The results obtained showed that 79% of the teachers questioned affirmed that a mathematical reminder is compulsory for physics problem-solving (Q9) since 47% of the teachers agreed or strongly agreed (32%) (Fig.9). This is in contrast to 21% of teachers who disagreed (13%) or strongly disagreed (8%) (Fig.9).

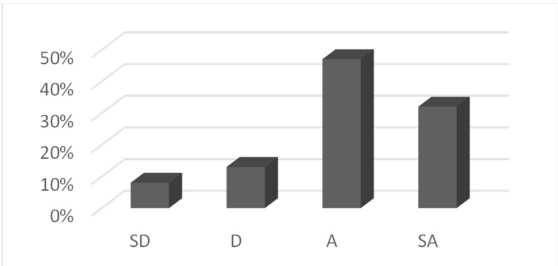

Figure 9: Percentages of teachers' responses regarding mathematical reminder in physics problem-solving.

Question 10: Mathematical reminders can influence students' interest and attitudes towards physics problem-solving.

The data obtained highlights the impact of mathematical reminders on students' interests and attitudes towards physics problem-solving. Moreover, 87% of the physics teachers surveyed agreed (62%) or strongly agreed (25%) that physics problem-solving requires mathematical reminders (Fig.10). In contrast, 13% of the teachers disagreed (9%) and strongly disagreed (4%) (Fig.10).

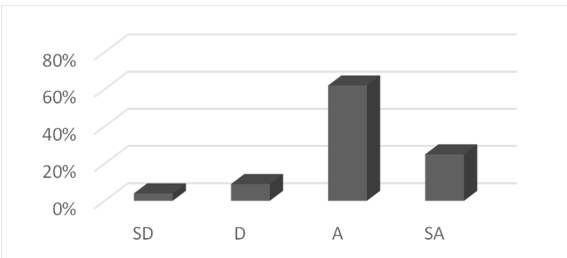

Figure 10: Percentages of teachers' responses regarding the impact of mathematical reminders on students' interest and attitudes towards physics problem-solving.

4.4 Teachers' views on physics problems mathematization processes

Question 11: Success in physics teaching requires a unified teaching pedagogy for physics mathematization.

The results obtained for this question (Q11) showed us that 54% of the teachers agreed and 26% strongly agreed (Fig.11) that success in physics teaching requires a unified teaching pedagogy for physics mathematization. On the other hand, 20% disagreed (14% disagreed and 6% strongly disagreed (Fig.11));

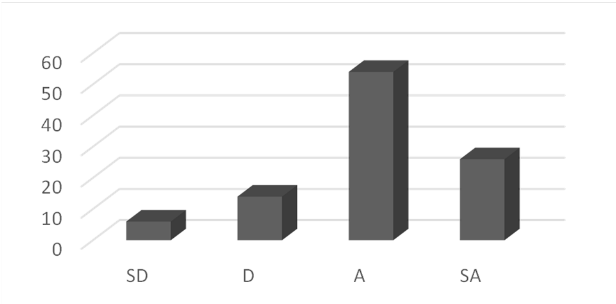

Figure 11: Percentages of teachers' responses regarding the unified teaching pedagogy for physics mathematization.

Question 12: Physics mathematization becomes essentially a project of teaching and learning the subject.

The results obtained showed us that 17% of the teachers questioned strongly disagreed that physics mathematization is essentially becoming a project for teaching and learning the discipline. In the same direction, 27% of the teachers disagreed with the project of physics mathematization (Fig.12). However, 56% of the teachers disagreed with this statement (38% agreed and 18% strongly agreed (Fig.12)).

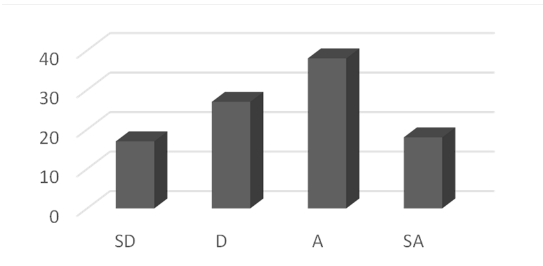

Figure 12: Percentages of teachers' responses regarding the project of physics mathematization in the teaching and the learning of the subject.

5. Discussion

The analysis of the questions (Q1, Q2, Q3, Q4) allowed us to see that physics teaching is a field for practicing mathematization (Balta et al., 2016; Bing & Redish, 2009; De Cock, 2012; J. Tuminaro & E. F. Redish, 2007; Kim et al., 2018), i.e. to consider mathematization as an attempt to reconstruct physics knowledge, especially in problem-solving (Q1). But, in another context, physics teachers should focus on physics concepts and notions but not on mathematical calculations (J. Tuminaro & E. F. Redish, 2007). This is seen in the teachers questioned in this research. 62% (Fig.3) of the teachers are sure that mathematization is not an important part of physics problem-solving (Q3) and 53% (Fig.4) of them assert that mathematization is only a process of physics problem-solving (Q4) or (Reverdy, 2016) concluded in her research that mathematics is a "*tool-matter*" at the service of physics i.e., physics mathematization always requires adaptation to the problem-situation (Q2) (Gustafsson et al., 2015; Huffman, 1997). Because problem-solving is a grouping of all the mental capacities that must be mastered and mobilized to find the right solution to a problem (Abdullah et al., 2009; Altun, 2002; Han & Gezer, 2006) or the right formalization to a problematic situation (Jensen et al., 2017).

Although the relationship between the physics and mathematics in problem-solving was the objective of many scientific research (Bain et al., 2019; Ceuppens et al., 2019; Haeruddin et al., 2020; Hu et al., 2019; Lucas & Lewis, 2019; Meli et al., 2016; Rodriguez et al., 2018), little research has defined where the difficulty of physics mathematization problem-solving lies. Indeed, the scientific literature has shown that many teachers of physics in secondary education take into account the difficulty of mathematization in their classroom practices (Meli et al., 2016). In this sense, the analysis of the teachers' views highlighted the obstacle of mathematization in problem solving (Q5), and they have divided this obstacle into three major difficulties in problem solving (Q6) as follows: Firstly, the symbols used in physics, unlike in mathematics, are not chosen arbitrarily, but they represent certain physics quantities (Q6), Secondly, students fail to attach physics meanings to symbols, equations and mathematical formulas (Q6) (Zeidmane, 2013). So, the analysis of these results has shown us that Moroccan students have difficulty in problem-solving, especially if the situation requires mathematics (Q5). This confirms the findings of Redish, (2005) and Tuminaro, (2004) who demonstrated that many secondary school physics teachers emphasize the difficulties of students to a lack of mathematical knowledge in their daily practice (Q5).

Now that we have portrayed and weighed the importance of mathematization in the physics curriculum according to the views of Moroccan secondary school teachers, let us now examine the views of these teachers on students' interests and attitudes toward physics problem-solving ((Q7) and (Q8)), as they are the key players who will put the programs to the test. Thus, their opinions on students' interests and attitudes during their classroom practices will be an opportunity to enhance the value of the discipline in the Moroccan secondary science curriculum. Indeed, the present work allowed us to conclude that physics problem-solving has a deep relationship with students' affective qualities such as interest, attitudes, and motivation, which are generally not evident in the scientific literature, as they are not assessed by the models chosen in this work.

However, teachers are still appreciative of the problem of the relationship between physics and mathematics due to the lack of possibilities for a unified pedagogy between teachers in this area (Q11), which is an obstacle to problem-solving in classroom practices (Başkan et al., 2010). Furthermore, the teachers questioned in the present work state that they are always obliged to go through mathematical reminders to physics problem-solving(Q9). However, interdisciplinary education (Reverdy, 2016) is insufficient for the interaction between mathematics and physics problem-solving. For this reason, 87% (Fig.10) of the surveyed physics teachers agree (62%) (Fig.10) or strongly agree (25%) (Fig.10) that good science education in physics problem-solving requires mathematical reminders (Q10).

We can conclude at the end of this discussion that the informative and injunctive style is dominant in physics problems. Thus, Moroccan secondary school students often need mathematical reminders to exploit problem-solving successfully ((Q9) and (Q10)). Therefore, success in physics teaching requires innovation in the physics mathematization curriculum (Q12) by applying for example information and communication technologies (ICT) (Drigas & Kontopoulou, 2016; El Azzouzi et al., 2022) or a STEM-based methodology (Zaher & Damaj, 2018).

In the same way, the views of several Moroccan teachers, the dominant form of thinking among Moroccan secondary school students towards physics problem-solving is an analogy with similar problems, where students try to remember whether they have seen this type of problem before or not. Indeed, Moroccan students believe that the general rule of problem-solving is to memorize as many problems and situations as possible to develop a sense of autonomy and self-reflection for their learning throughout the teaching and learning of the discipline (Hammoumi et al., 2020). However, the problem-solving approach is the complete opposite: On the one hand, according to Capone, (2022) problem-solving is a student-centered conceptual approach to the discipline and is often associated with mathematics. On the other hand, the approach used is then compatible with the fact that science teaching is based on both practice and interpretation. It is therefore connected to real life and requires cooperation, which should facilitate problem-solving practices. In addition, several researchers have focused on problem-solving methods, which is a difficulty in most science disciplines. This research indicates that teacher-directed and self-directed problem-solving strategies have significantly impacted the development of secondary students' physics interests and positive attitudes (Gustafsson et al., 2015; Naki ERDEMİR, 2009).

6. Conclusion

Our results are discussed in four main areas. The first axis undertakes an analysis of teachers' views on the physics mathematization problems. The second axis is a study that continues the analysis of teachers' opinions, but the study is dedicated to showing the difficulty of physics mathematization problem-solving. The third axis is devoted to the teachers' views on students' interests during problem-solving. Thus, an innovation in the physics mathematization curriculum can influence students' physics interest on the one hand, and the teaching and learning of the subject on the other.
Several findings related to our empirical study follow from this investigation. Firstly, physics mathematization problem-solving is important, but the implementation of this situation remains difficult to apply by Moroccan teachers in their classroom practices. Second, professional interaction and pedagogical collaboration among Moroccan teachers on ways to integrate mathematics into physics problem-solving are sorely lacking. Third, the mathematization of problems can influence students' physics interests and attitudes. Hence, physics mathematization becomes essentially a project for teaching and learning the subject.

7. Recommendation

The present research is not a study on pedagogies or working methodologies in physics teaching and learning but just a summary of Moroccan physics teachers' opinions, views, and observations. Indeed, this study emphasized the difficulty of physics mathematization in the Moroccan curriculum of the discipline by trying to overcome it with future physics teachers.

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