Analysis of Declared Pedagogical Practices in STEM Education in Morocco

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Abstract

Internationally, we observe that the results of Moroccan students in mathematics are significantly lower than the average results of students from other countries. This observation, could in part, be explained by maintaining an approach based on the transmission of knowledge which does not promote the development of student skills. Since STEM (Science, Technology, Engineering and Mathematics) based instruction has been shown to have a positive impact on student achievement in mathematics, we explored the teaching and assessment practices reported by five Moroccan teachers in order to identify practices that would be compatible with teaching based on STEM. Although only one participant said they knew this approach, our results indicate that all participants have practices compatible with an integrated approach to STEM. These results outline a future where teachers and researchers will work together to implement STEM-based education and explore, in the Moroccan context, the scope and limits of such education.

Keywords

Mathematic education in Morocco – STEM (Science, Technology, Engineering and Mathematics) – Reported teaching practices – Reported assessment practices

1. Introduction

Comparative data on students' mathematics proficiency levels (TIMSS, 2007, 2011, 2015; PISA 2018) have shown that, on an international scale, Moroccan students' mathematics performance is significantly below the international average rates, which are approximately 90% and 67%, respectively (Ourahay & al., 2015). For example, the majority (57%) of Moroccan 4th-grade primary school students who participated in TIMSS 2015 do not reach the lowest competence level in mathematics thus indicating that they do not possess basic skills expected of primary school students, such as addition and subtraction of whole numbers (Mullis & al., 2016). In the case of secondary education, over 40% of students fall below the low-level threshold. This result remains below international average scores (Ourahay & al., 2015). There are numerous factors that may explain these learning difficulties. The Higher Council for Education, Training, and Scientific Research (2007) associates learning difficulties with underdeveloped competencies. Indeed, the

practical implementation of this approach within the school environment remains challenging. The Council indicates that this difficulty manifests, in terms of pedagogical planning, especially in the design of activities and the assessment of learning. Furthermore, the Higher Council for Education, Training, and Scientific Research (2007) specifies that the lack of teacher training has not been conductive to the effectiveness of the competency-based approach, and, consequently, it has not been leveraged to develop students' skills. Faced with this assessment, it is essential to reflect on current teaching practices and explore certain avenues that can help students increase their proficiency levels in mathematics. This reflection guided the writing of this article.

In the problem statement, we first highlight some observations regarding education in Morocco, address the challenge of implementing STEM-based education (Science, Technology, Engineering, and Mathematics), and before emphasizing the need to identify practices compatible with such education. In the conceptual framework, we present the specificities of STEM-based education. This framework will enable us to specify our research objectives. In the methodology, we describe considerations related to the constitution of our sample, data collection, and research analysis. We present our results in the following section, discuss them, and conclude by revisiting our research objectives. Finally, we stress the importance of collaborating with teachers to establish STEM-based education and explore the scope and limitations of such education within the Moroccan context.

2. Problem statement

No one can deny the importance of quality education. It is crucial for societal advancement and, consequently, social, economic, and cultural development. However, according to the Report of the Higher Council for Education, Training, and Scientific Research 2015-2030 (CSEFRS), the quality of education in Morocco is compromised by chronic issues in schools resulting from a pedagogical approach based on knowledge transmission. The primary dysfunction of the school system, within its various components, is apparent in the quality of its services and performance. The Moroccan mathematics curriculum in effect since the adoption of the 2000 reform is not exempt from this reality. Indeed, the CSEFRS synthesis report on the evaluative study of the primary and secondary school curricula (2007) highlighted deficiencies and shortcomings in the mathematics curriculum. These shortcomings are evident in teachers' adoption of a competence-based approach with an unclear status, a situation attributed to inadequate training that does not align with teachers' needs and the requirements of the new curriculum. In summary, this phenomenon negatively affects teaching practices which remain focused on the old program but incorporate the new content, specifically the terminology associated with the competence-based

approach integrated into the new curriculum. These dysfunctions impact teaching and learning and may result in learning difficulties for students, posing genuine challenges for teachers.

Today, schools aim to develop competencies (Perrenoud, 2000). This evolution challenges traditional methods of knowledge transmission, acquisition and retrieval. It involves not only changes in the selection and integration of learning objectives and content but also influences the design and implementation of teaching/learning situations and assessment methods. A competence can be understood as "know-how based on the effective mobilization and use of a diversified set of resources" (translated freely from MEQ, 2001, p. 4). Jonnaert and colleagues (2005) propose a definition of competence that underscores its situational nature:

> *"Competence is the implementation by an individual, in a given situation and within a specific context, of a diverse yet coordinated set of resources. This implementation relies on the selection, mobilization, and organization of these resources as well as the relevant actions they enable for the successful handling of the situation"* (translated freely from Jonnaert & al., 2005, p. 6).

This definition alludes to the operational form of knowledge which is the cornerstone of this concept and enables action in various contexts. In this regard, competence requires the mobilization of a variety of resources; knowledge, experiential knowledge, schemas, automatisms, capacities, various types of skills, and more. The student mobilizes these resources to produce, act or solve a problem that holds significance for them within a well-defined set of situations in which they will apply their competence. Given that competence is exercised in a specific context, it is crucial to carefully select the situations presented to students to make mathematical knowledge meaningful.

For a comprehensive understanding of mathematical knowledge, interdisciplinary approaches could be an interesting avenue to explore. Several studies have focused on interdisciplinary practices (D'Hainaut, 1986; Y Lenoir, 1991; Yves Lenoir, Larose, Grenon, & Hasni, 2000; Y. Lenoir & Sauvé, 1998; Maingain & Dufour, 2002). According to these researchers, interdisciplinary education can contribute to making what students learn in class more meaningful as they anchor their learning in situations related to concrete and varied contexts. Unlike a compartmentalized approach to school subjects, an interdisciplinary approach can enhance students' competence in applying what they have learned to face unfamiliar situations and find solutions to problems they have not encountered before. Teaching practices compatible with a competence-based approach and emphasizing interdisciplinary education could promote the development of students' mathematical skills: STEM subjects precisely advocate such practices.

STEM subjects have generated substantial interest since the early 21st century (Thomas, 2000). It has been demonstrated that effective implementation of STEM has a positive effect on student performance (Han & al., 2015; Siregar & al., 2020). STEM can be seen as an interdisciplinary teaching and learning approach (Sanders, 2009). This approach is typically employed to:

> *(1) furthering students understanding of each discipline by building on students' prior knowledge; (2) broadening students' understanding of STEM disciplines through exposure to socially relevant STEM context and (3) making STEM disciplines and career more accessible and intriguing for students (Wang et al., 2011)* (Hasanah, 2020, p. 3).

Given the potential of STEM for mathematics education, this approach would benefit Moroccan teachers. Is this the case? If not, what aspects of their teaching practices are compatible with a STEM-based approach? This research, which falls within the field of mathematics and science education aims to answer these questions.

3. Conceptual Framework

STEM-based education emphasizes activities involving the design and creation of new products and systems as well as inquiry and exploration. Through this approach, STEM education helps students develop and apply knowledge and skills related to STEM fields and address problem-solving situations.

The literature contains various interpretations of STEM education (Breiner & al., 2012; Ritz & Fan, 2015). In fact, these interpretations refer to a wide range of interdisciplinary integration models, from teaching one of the STEM disciplines to considering it as a distinct discipline in itself (Martín-Páez & al., 2019). While Gresnigt and colleagues (2014) noted a lack of research reports and surveys on the theoretical foundations of integrated programs, interdisciplinary integration and the nature of the STEM approach are increasingly gaining attention within the scientific community.

STEM education has six distinctive characteristics that set it apart from other approaches: 1. STEM-based teaching practices focus on real-world problems and seek to find solutions. 2. They are guided by the engineering design process where design stems from students' own reflection in developing solutions to overcome problems. 3. They involve students in collaborative team work. 4. STEM subjects lead students to direct inquiry and open exploration of the meaning and concepts being studied. 5. STEM-based teaching practices integrate mathematical and scientific content to help students realize that these subjects are not isolated but complement each other to solve problems. 6. They allow for multiple correct answers and reframe failure as a necessary part of learning (Fajrina & al.., 2020).

STEM-based teaching practices can also prioritize project-based learning and problem-based learning. We briefly describe them in the following paragraphs and conclude this section by addressing assessment in STEM-based education.

Project-Based Learning

STEM project-based learning is an approach that encourages students to explore problems integrating STEM in a constrained environment. Student-centered, hands-on activities, promotion of collaboration, team communication, knowledge construction, and formative assessment have been identified as key components of STEM project-based learning. By involving students in solving real-world projects, working in collaborative groups, applying scientific reasoning and developing authentic solutions, current research in project-based learning suggests that learning activities can enhance student outcomes in STEM fields (Samsudin & al., 2020).

Problem-Based Learning

Problem-based learning is often associated with project-based learning as both are collaborative requiring students to work in groups and involving active learning. Student thinking abilities are enhanced through a systematic group or teamwork process allowing them to continually strengthen, refine, test and develop their thinking abilities (Widowati *et al*., 2021). Problem-based learning is a learner-centered learning process that enables students to conduct research simulations, integrate theory and practice and develop skills and knowledge connecting solutions to problems (Brown & al., 2013). Several studies have shown that STEM learning can be achieved through problem-based learning (Afriana & al., 2016).

Assessment of Learning

Regarding the assessment of learning, research in STEM education suggests that student competencies should include: the ability to represent physical processes in multiple ways; the ability to plan, test, or modify a qualitative explanation or quantitative relationship; the ability to design an experimental research; the ability to collect and analyze data, evaluate predictions, and experimental results, and the ability to reflect on the cognitive strategies used for problem-solving (Psycharis, 2016). To help learners develop these abilities, teaching should engage learners in appropriate activities and assess learner performance in these tasks by providing appropriate feedback, both during learning (formative assessment) and at the end of a teaching sequence (summative assessment). Formative assessment can help learners self-correct and reflect on their

learning. Furthermore, teachers can use the results of formative assessments to identify challenges that students face and adapt their teaching accordingly.

4. Research Objectives

In this study, we highlighted the potential of STEM-based teaching and now we aim to determine if certain practices can serve as a foundation for implementing this approach. Therefore, we posed the following question: Among the teaching and assessment practices reported by Moroccan teachers, which ones are compatible with STEM-based instruction? This question led us to formulate two research objectives:

1. Identify teaching practices reported by Moroccan teachers that are compatible with STEM-based instruction.

2. Identify assessment practices reported by Moroccan teachers that are compatible with STEM-based instruction.

In the following section, we provide some insights into the methodology used to achieve these objectives.

5. Methodology

Our research is situated within a qualitative interpretive paradigm with the primary objective of providing a description of teaching and assessment practices reported by Moroccan teachers that align with STEM-based instruction.

The questionnaire serves as our primary data collection tool. It is a method of gathering information that allows us to understand and explain the facts (Vilatte, 2007). It involves extracting information that describes the practices reported by Moroccan teachers and explaining how these practices could be compatible with STEM-based instruction. The choice of a questionnaire was strategic because its administration and processing are fast and cost-effective (Charron, 2004). Additionally, the fact that teachers can respond to it independently and anonymously tends to encourage them to provide authentic responses (Allaire, 1988). The pilot study was conducted with five mathematics and science teachers from the Marrakech and Rabat regions who willingly consented to participate in our study. The questionnaire was designed to capture the teaching and assessment practices of these participants and includes questions related to teaching planning, teaching management, and assessment of learning.

In terms of analysis, we first identify the teaching and assessment practices used by Moroccan teachers in their professional roles. Then, we identify practices that are compatible with STEM-based instruction, a necessary step to facilitate a transition to this form of teaching.

6-Results

The results related to our two research objectives are presented in the following paragraphs.

6.1 Results Related to Teaching Practices

The analysis of teaching practices reported by the participants allowed us to identify four teaching practices that could be compatible with a STEM-based teaching approach. Here is a brief description of these practices.

6.1.1 Working on Problem-Solving

When questioned about the goals and aims of their teaching, one participant mentioned that they aimed to develop students' capacity to independently solve problems. The development of problem-solving skills aligns with a STEM-based teaching approach although this approach emphasizes collaborative problem-solving. Additionally, two participants mentioned that problem-solving played an essential role in their teaching without specifying the nature of this role. One participant highlighted that the role of problem-solving was to develop students' scientific thinking which is in line with an interdisciplinary STEM-based approach. One of the characteristics of this approach is to encourage students to develop new perspectives, new questions, and critical thinking particularly through problem-based learning.

6.1.2 Planning Teaching While Considering Students' Relationship with Knowledge

While two participants mentioned that they plan their lessons based on its description (pedagogical guidelines or course objectives), three participants appear to consider elements related to students' relationship with knowledge in their planning ("their thinking", "their abilities", "their learning pace", and "their level"). When questioned about the choice of situations presented to their students, two participants also reiterated the need to respect students' levels. This concern for the students' current or projected relationship with knowledge is compatible with a STEM-based teaching approach as it relies on students' prior knowledge. Finally, when discussing actions to promote learning progress, one participant mentioned the importance of adapting their teaching to students' thinking and aspirations. Considering students' knowledge in the development of situations is crucial as it serves as a springboard to new knowledge and helps establish connections between knowledge developed in each of the disciplines in the field and newly constructed knowledge.

6.1.3 Choosing Situations from Everyday Life

When questioned about the choice of situations presented to their students, one participant emphasized the importance of selecting situations from their everyday life. This element could be compatible with a STEM-based approach as long as the situations created consist of problems that are meaningful to students. These situations provide a suitable ground to consider the essential properties of concepts and encourage the mobilization of resources needed to solve problems. Selecting situations from everyday life means searching for a contextual problem that leads learners to reflect, challenge their current knowledge and seek new ways to act. Students can only make sense of knowledge if it appears as an essential tool to solve a problem they have appropriated. Moreover, the use of meaningful situations is beneficial in increasing students' motivation (Senécal & Desjardins, 2018).

6.1.4 Promoting Teamwork

The participants were not very vocal about managing teaching situations. However, one participant highlighted the importance of forming groups within their class. The formation of groups usually implies teamwork which is particularly compatible with project-based and problem-based learning. Nonetheless, it should involve collaborative work under the supervision of the teacher.

6.2 Results Related to Assessment Practices

The analysis of assessment practices reported by the participants allowed us to identify two assessment practices that could be compatible with a STEM-based teaching approach. Here is a brief description of these practices.

6.2.1 Using Various Forms of Assessment

One of the participants emphasized various forms of assessment ("diagnostic, summative, self-assessment, and peer assessment") which can contribute to the further development of students' skills. Self-assessment could be associated with formative assessment and be used by students to regulate their learning in STEM-based teaching. The active involvement of learners in the assessment process through self-assessment and peer assessment can also promote the development of metacognitive components of a competence and highlight its socio-affective and motivational components (Allal, 2002). Finally, diagnostic assessment could be used in the context of a STEM-based approach as it allows for an overview of students' prior knowledge.

6.2.2 Assessing at Different Moments

Two out of five participants mentioned conducting only summative assessments ("at the end of the course" or "after completing a module"), one participant mentioned conducting both summative and formative assessments ("during the lesson"), one participant stated that they conduct assessments at every session, and finally, another mentioned assessing at any time. This means that two participants assess students at different moments incorporating feedback during the learning process (formative assessment) and at the end of learning (summative assessment). All these practices could fit within a STEM-based teaching approach, although summative assessment should be conducted upon project or problem completion.

7. Discussion of Results

In this section, we briefly discuss the results related to our two research objectives.

7.1 Discussion of the Results Regarding Teaching Practices

Four teaching practices compatible with a STEM-based approach emerged from our analyses:
- Working on problem-solving
- Planning teaching while considering students' relationship with knowledge
- Choosing situations from everyday life
- Promoting teamwork

These practices are not shared by all participants, and furthermore, even though one participant claimed to adopt a STEM-based teaching approach, his responses, like those of other participants, do not highlight adherence to all the characteristics of such an approach (Fajrina et al., 2020). In fact, two characteristics of STEM-based teaching were not raised by the participants, namely the integration of mathematical and scientific content into an interdisciplinary context and the role played by failure which is an integral part of the learning process.

While participants claim to emphasize problem-solving-based practices, their responses do not allow us to determine if they employ problem-solving in a manner compatible with a STEM-based teaching approach. Regarding the planning of teaching while considering students' relationship with knowledge, we are unsure if the participants consider all three dimensions of the relationship with knowledge: the identity dimension, the epistemic dimension and the social dimension (Charlot, 1999). Concerning the choice of situations from everyday life, even though this intention is commendable, we do not know if the chosen situations are complex enough to lead themselves to a STEM-based teaching approach. Finally, regarding teamwork, is it a collaborative effort supervised by the teacher? Our data does not allow us to answer this question.

7.2 Discussion of the results regarding assessment practices

Two assessment practices compatible with a STEM-based approach emerged from our analyses:

1. Using various forms of assessment.
2. Assessing at different moments.

The first assessment practice was mentioned by only one participant with the others mentioning the use of a more limited range of assessment forms. However, regarding assessment tools, the participants mentioned using very traditional tools (exercises, assignments, questions, exams, etc.), which make it more challenging to assess skills. While these tools are not incompatible with a STEM-based approach, it would be necessary to explore the adaptations required for them to truly align with this approach and enable students to effectively mobilize and use resources from different disciplines to face a new and complex situation. As Leroux (2007) points out, the assessment of skills differs from traditional assessment because it involves making a comprehensive judgment about the student's actions using assessment tools such as portfolios, descriptive scales and problem-solving (Leroux & Bigras, 2003). Except for problem-solving, none of the participants mentioned these tools.

The second assessment practice we identified was mentioned by only two participants. Indeed, only these two participants reported assessing students both during the learning process and at the end of a teaching sequence. This result suggests that the assessment practices reported by the other teachers in this study generally do not emphasize formative assessment. This raises questions about the role assessment plays in regulating their teaching as the participants did not report assessing students during the learning process.

8 Conclusion

In this article, we explored the teaching and assessment practices reported by five Moroccan teachers with the aim of identifying practices that might be compatible with a STEM-based teaching approach. We identified four teaching practices and two assessment practices that could potentially align with this approach. However, these practices could also be compatible with a more traditional knowledge transmission-based teaching. This highlights the necessity of working collaboratively with teachers to establish a STEM-based teaching approach and to determine the scope and limitations of such teaching within the Moroccan context. In this regard, we believe, as in the case of Mustafa and his colleagues (2016), that further research is needed to identify appropriate strategies for integrating STEM in education.

Given the size of our sample, we do not claim to generalize our results to all Moroccan teachers. Furthermore, the responses provided by the participants were at times underdeveloped which occasionally limited our analysis of certain aspects of their practices. For instance, when asked about the actions they take to promote student engagement, three out of five participants emphasized the importance of student participation. However, since they did not specify the nature of this participation, we were unable to determine whether these practices were compatible with a STEM-based teaching. Nevertheless, the study we conducted makes it possible to identify practices that could serve as a foundation for initiating a transition to STEM-based teaching. In our view, this is a promising avenue for improving the academic performance of Moroccan students in each of the STEM disciplines.

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