Analysis of Policy Recommendations in Science Education Research:

Research on Lebanon between 2010 and 2022

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Abstract

This study aimed to analyze the policy recommendations proposed for Lebanon's science education. For this purpose, the study included a collection of peer-reviewed articles in science education journals between 2010 and 2022 that proposed policy recommendations for Lebanon. Then an analysis using Merriam's framework of coding in qualitative research to distribute the recommendations into relevant categories, and then identify themes of policies for Lebanon. The recommendations are then compared to the existing literature in other national contexts.

Keywords: policy recommendations, science education, Lebanon

1. Introduction

1.1. Research Area

This study investigated policy analysis and recommendations in science education research reports. Research in this particular field has grown significantly in the past decade among governments, researchers, politicians, and funders (Levin, 2004). Educational policies aim to set guidelines for effective practices and achieve the desired outcomes (Karkouti, 2020), and policy analysis is a research field where researchers delve into the effectiveness, evidence, evaluation, and implementation frameworks of policies in educational contexts (Lingard & Gale, 2010).

Science education research is the study of science curriculum content, pedagogy, philosophy, and nature (Barnes, 1961). Several research papers tackled policies proposed for science education and provide analysis and recommendations accordingly.

Science education is fundamental for individual and social development. Consequently, the research investigated the aim and objective of science education to properly evaluate the policies related to it. In research from the National Research Council (2012), K-12 science education aims to build students' perception and knowledge of scientific topics. Students are expected to have some appreciation of the wonders of science, poses a sufficient knowledge basis of science to engage in public discussions, practice careful consumption of scientific information, be able to learn about science outside the classroom, and be able to pursue desired career choices related to science if they want to.

The analysis of key findings in research across different phases produces recommendations for policy development (Stylianidou et al., 2018). These policy recommendations aim to enhance students' learning and facilitate educational operations.

1.2. Research problem

Research on educational policy for science education, in particular, is developing significantly and studies are looking at the effectiveness of policy frameworks and providing recommendations for curriculum and instructional improvement (Schumacher & James McMillan, 2022).

According to Cooper et al. (2009), educational research is emphasizing evidence-based decision-making significantly in the past few years. Therefore, as Cooper et al. claim, this will result in leading policies that are evidence-based, taking more informed decisions, and implementing effective practices (Cooper, et. al, 2009).

I assumed that policy recommendations based on research in education are fundamental for achieving learning outcomes. As discussed, science education aims to build a learner profile where students make the best of scientific knowledge, make informed decisions, and lead responsible lifestyles. So, implementing evidence-based policy recommendations in science education is key to achieving the desired scientific learning profile (National Research Council, 2012).

Several policy recommendations have been analyzed and applied in national contexts and have shown promising results. For instance, Milford et al. (2010) analyzed the frameworks of Canadian science education in light of the recent research at the time. The researchers analyzed the implications of the Common Framework of Science Learning Outcomes (1997), the document of science education learning outcomes, on the curriculum and instruction in Canadian science classes (Milford, et al., 2010).

Also, the Singaporean math and science curriculum has been investigated several times because of the impressive successes it has shown. According to Yeo and Tan (2021), science education in Singapore is centered on science as inquiry. It encourages similar a similar learning profile to the National Research Council. The researchers analyzed the curriculum from primary to pre-university levels. The Singaporean Ministry of Education implements policies like annual work plan seminars, frequent syllabi reviews, and teacher training. As per their research, these policies have been vital to Singapore's educational success (Yeo & Tan, 2021).

In the context of Lebanon, UNESCO published a comprehensive document on "Science, Technology, and Innovation Policy in Lebanon". It proposes several reformations in the context of Lebanon (UNESCO, 2006). However, no peer-reviewed research analysis of policy recommendations for the Lebanese context has been performed.

Several peer-reviewed studies include implications of their results in research and practice. For example, Yacoubian (2021) discussed students' views of the nature of science (NOS), then suggested implications for development like research on content and methodology of teaching NOS.

1.3. Purpose

In this paper, I analyzed policy recommendations in science education research. Specifically, I investigated peer-reviewed articles from science education journals that discussed policies for the Lebanese context in the period 2010-2022. The aim was to provide insight into the key opportunities and recommendations for the development of Lebanon's science education.

1.4. Research question

To fulfill the purpose of my study, I posed the following research question:

What policy recommendations do peer-reviewed science education journal articles propose for science curriculum and instruction in Lebanon?

1.5. Rationale

Although many studies investigated science education and provided policy recommendations, and analysis of policy recommendations in Lebanon's context was not provided.

According to Ahn et al. (2012), a noticeable increase in analysis of research publications is evident in education and social studies research. This is due to the recent acts and policy-making paradigms that require research evidence. Analysis of existing literature provides a comprehensive collection of research findings for policymakers to utilize (Ahn et al., 2012). Hence, this study aimed to provide a comprehensive analysis of policy recommendations in Lebanon and provide a stepping stone for policymakers in Lebanon to develop the nation's science education program.

Also, I decided to limit the research radius to peer-reviewed journal articles in science education journals between 2010 and 2022. I assumed this is a significant era in research and provides relevant recommendations. Research has expanded considerably in these years, and a lot of arising questions are covered in up-to-date research publications (Murnane, 2012).

There was considerable research performed in various national contexts like the examples of Canada and Singapore mentioned earlier, and the upcoming literature review (see section). These studies included policy recommendations that policymakers used to develop the nation's curriculum in certain aspects (citation for this). Similarly, this study aimed to provide an analysis of the policy recommendations for Lebanon's science education to be utilized by policymakers in hope of the development of the sector.

1.6. Significance

The analysis provided a comprehensive evaluation of policies proposed by science education researchers (Ahn et al., 2012). This acts as evidence for policymakers and officials to identify the frameworks of science education in Lebanon.

This study was concerned with policy recommendations for Lebanese science education. According to the Lebanese Ministry of Education and Higher Education, there were 1508 schools across the Lebanese territories (Ministry of Education and Higher Education, 2021), and science is a fundamental aspect of the national curriculum. Therefore, providing evidence-based policies to facilitate science education is beneficial for a large population of learners and educators.

For researchers, this analysis provided a comprehensive analysis of what research in science education proposes as policy recommendations for Lebanon. Therefore, researchers can critique and evaluate policies analyzed concurrently. In research from Greenhalgh (2019), comprehensive analyses of studies provided researchers with large amounts of information gathered together, ease in comparing research findings to achieve generalizability, and the ability to point out inconsistencies. Researchers interested in science education in Lebanon find great value in this analysis.

On the other hand, practitioners find an analysis of evidence and hence be able to produce evidence-based policies and practices accordingly. Teachers and policy-makers will be able to identify and evaluate program and policy effectiveness based on the gathered findings. Instructional approaches, as well as school frameworks in science education, can be fundamentally enhanced according to the research presented (Bennett et al., 2007).

Consequently, the study is significant to both researchers and practitioners.

1.7. Operational definitions

Policy recommendations:

A particular area of study in educational research is policy analysis, where the key findings of research across different phases produce actions for learning development. Policy recommendations aim to guide leaders and policymakers to make informed evidence-based decisions to enhance the learning opportunities of students, in addition to facilitating the needs of the educational community (Stylianidou et al., 2018).

Science education research:

It is difficult to define science education comprehensively, but Barnes (1961) tried to sum up the core scope of science education. He defined it as the study of science curriculum content, pedagogy, philosophy, and nature. It aims to build students' knowledge of scientific content, enhance positive attributes toward science, develop scientific decision-making, and prepare the path for science-related career choices (Quinn et al., 2012).

2. Literature review

In this section, I discussed examples of analyses of policy recommendations in certain national contexts. The aim was to show similar examples to this study in other national science education programs and to analyze the role of research in affecting policies.

2.1. Studies on national science education programs

There have been many studies that discussed science education in several national contexts. I investigated studies that analyzed those contexts and then extracted samples of policy recommendations in those studies. The selected samples are chosen because they show how a nation's science education program was evaluated, and how policy recommendations from research had a role in that target.

Tan et al. (2021) discussed Singapore's math and science education curriculum in their book "*Singapore Math and Science Education Innovation*". They start on a premise that the new age in technology advancement radically shifted the paradigms of science and math instructional needs. They argue that Singaporean policies have equipped students with the innovative and critical thinking essential for the new age. Well-planned and resourceful syllabi that emphasize thinking processes and applied to learn, authentic learning experiences, and Singapore's teacher policy are examples of what Tan et al. argued to be the catalysts of their students' success. They contribute these policy changes to research performed from 1970 until the current day.

India's science education was analyzed by Koul et al. (2020). They looked at the historical and contemporary foundations of India's science education program, which was unique to this study. Their study includes an analysis of the historic development of India's programs and an analysis of their national policies, including pre-service science teacher training, pedagogical orientations, action research, diversity in a science classroom, and community learning. The researchers investigated the effectiveness of these policies and their effect on India’s science education programs and objectives. They also discuss talent identification and nurture and their relation to fueling the country's innovative labs, which was also unique to this study.

There is significant literature on Canada’s science education. In research by Tippett and Milford (2019), the researchers analyzed each Canadian state’s science education trends and challenges. For instance, they investigated Alberta, Manitoba, and Yukon among others. In particular, their focus was on the consistencies and variations across Canada, in addition to policy and research recommendations. For instance, Tippett and Milford discussed Ontario’s science education. They stated the jurisdiction’s educational administrative regulations and analyzed the learning expectations in science domains (physics chemistry, biology, earth and space sciences). Ontario also integrated technological knowledge and design topics into the elementary science curriculum. The jurisdiction also has several standards for accrediting teachers, including teacher training programs, ministry-supported professional development, and practicum arrangements.

As for the United Kingdom, a group of researchers analyzed the UK’s science education as a whole system. Based on the opinion that scientific understanding develops using varied community resources, the researchers used analytical tools to examine the UK science education community. They observed that the community is very collaborative between its different sectors, but schools were outliers in this pattern. Also, they concluded that the UK needs to increase its diversification of the science domains and entities studied, as well as encourage collaborative relationships between schools and other scientific personnel (FALK et al., 2014).

Several comprehensive studies discussed China’s science education. For instance, Hu and Shou (2018) analyzed China’s science education in the primary years and investigated the effectiveness of the policies associated with the country’s development in this area. They also analyzed the policies and reforms according to how much they advanced the country's program to national science goals. In addition to updated science curriculum and textbooks, China promoted using scientific experiments and skills training. Also, the country placed efforts into ameliorating the inequity between urban and rural provinces. It also implemented science learning initiatives that followed the Learning by Doing and Learn to think worldwide trends. However, Hu and Shou argue that these reforms were challenging due to the nature of pre-service teacher training programs and the lack of constant development. Moreover, Beijing shared an outline of its national plan of education reform titled "China's National plan for medium and long-term education reform and development 2010-2020". The nation's plan discusses all its plans and reformations that it planned to implement during the last decade (The central people's government of the people's republic of china, 2010)

Similar to the previous examples, the United States program is usually evaluated based on the performance of its students in international assessments, according to the National Research Council et. al. They claim that the United States education programs, especially in math and science, have been thoroughly researched by R&D agencies and journals, as US students still lag behind international counterparts and several gaps exist between groups in the US itself. Compared to the Canadian inconsistencies between states, the US's gap is much more severe and poses a real challenge to policymakers. A group of researchers argued that unevenly distributed professional development for teachers, inconsistent curriculum standards, and public attitudes among others. Also, education in the US takes place in 16,000 autonomous school districts, a point that researchers correlate with hurdles science education faces. However, the study analyzes how the reforms took place in each critical domain. For instance, national councils' role was activated and enlarged to ensure consistency across the nation, and curriculum standards have been constantly revised. Teacher licensing and accreditation includes more holistic professional development and training (National Research Council et al., 2009).

In research from Singer-Brodowski et al. (2018), the study analyzed Germany's science education policies and their effect on education and sustainable development in the country. The claim is that the science-policy interfaces (SPIs) in Germany are under-researched. They research the gap between Germany's success criteria and student achievement, similar to the work of the National Research Council in the United States. They also compare with UNESCO's Global Action Program for Education for Sustainable Development (ESD). Their key findings include modifying expectations and standards to fit the desired achievement level, and critical analysis of the diverse way evidence-based strategies are used. In addition, another study investigated German policy effectiveness concerning the students' performance in PISA assessments compared to their neighboring countries. These core policies include implementing the National Education Standards which are heavily influenced by the PISA results and frameworks, and emphasis on scientific literacy and competency models as the basis of research to benchmark the standards. Also, their paper discusses the effectiveness of the measures implemented to reach those benchmarks (Neumann et al., 2010).

There have been studies that looked into Saudi Arabia's science education frameworks. Alhammad (2015) studied the reforms Saudi Arabia proposed for their science education. The research compares mainstream western approaches, which are mostly constructivist and based on communication with the students to build on their prior knowledge, and the traditional approach widely used in the kingdom. According to his research, Saudi Arabia is very dependent on teacher-based education and textbook knowledge. However, Alarfaj (2015) disagrees as his research shows the national movement and reformations done by Riyadh to enhance science education to meet

21st century needs. His study analyzes the national reform of science curriculum across K-12 grade levels in 2008, as well as Tatweer and Qiyas initiatives. It seems that reforms were shaped as governmental initiatives awaiting further research. Also, compared to trials in Singapore and Canada, it could be a safe assumption to consider Saudi Arabia's reform very young and will be investigated thoroughly.

A study by a group of researchers analyzed and compared science education across the countries along the Belt and Road. These countries include Algeria, Egypt, Jordan, Oman, Kenya, Sudan, South Africa, and China among others (Huang et al., 2022). For instance, a study in the book by Hosny et al. (2022) analyzed science education in Egypt, building an intelligent environment in particular. Their study focused on sustainable changes for the educational system in Egypt and emphasizes focus on artificial intelligence and technology. Their research proposes providing cohesive decision-making for students and opportunities to explore the knowledge and values of science. They were the only investigated study that proposed this particular recommendation. Consequently, scientific thinking strategies are a solid foundation for the recommendations they put forward.

Park et al. (2021) formulated a cross-disciplinary analysis of studies that investigated research trends in South Korea's science and math education. Although their paper focuses on a comparative analysis of science and math education in South Korea, a lot of their findings are fundamental to the progression of science education in the country. Their analysis revealed the significance of self-reflection and facilitating communication between different disciplines, and their effect on enhancing scientific knowledge and concepts.

In conclusion, there is a visible pattern of policies recommended by those researchers. Policies like interaction in science inquiry, scaffolding over students' knowledge, consistent standards and learning objectives, skills training, and talent identification. Each country identified certain policy recommendations related to its national context and implemented initiatives to develop its programs. Those studies also identified several hurdles that decrease the effectiveness of science education like teacher-based instruction and textbook learning. That being said, those studies could be considered examples of national analysis of policies in science education. The findings of this study were discussed according to the relevant findings in this section.

3. Methodology

3.1. Data sources

For this study, I collected peer-reviewed studies proposing policy recommendations and implications on science education development in the Lebanese context.

The journals I scanned were science education journals ranked Q1 on Schimago in 2020. Examples of these journals included *the Journal of Research in Science Teaching, International Journal of Science Education, Eurasia Journal of Mathematics, Science, & Technology Education*, and *Science Education International*. I investigated the volumes published between 2010 and 2020 and extracted the studies related to the Lebanese context. The names of the investigated journals are in table 1.

Then, I read and reviewed the studies, and extracted those that proposed policy recommendations for the development of science education in Lebanon across K-12 schooling. I omitted any study that did not discuss the Lebanese context in its analysis, or do not propose policy recommendations for the Lebanese context. From the papers I had, I derived the policy recommendations related to the research question. Based on the discussed criteria, I collected 19 articles in total. This number is used as the total in the percentages calculated later in the study.

Table 1: Names of science education journals ranked Q1 and Q2 in Schimago

1. **Q1:**
- Journal of research in science teaching
- Studies in science education
- Research in science education
- International journal of science education
- International journal of science and mathematics education
- Science and education
- Journal of science education and technology
- Journal of science teacher education
- Chemistry education research and practice

2. **Q2:**
- Canadian journal of science, mathematics, and technology
- Journal of chemical education
- International journal of mathematical education in science and technology
- International journal of education in mathematics, science, and technology
- Eurasia journal of math, science, and technology education

Several studies investigated aspects of science education in Lebanon. Many were comprehensive and discussed science education as a whole, and others were aspect-specific and discussed an aspect of Lebanese science education like textbooks, teacher preparation programs, and nature of science in the curriculum, or grade level samples like middle school. For this study, I deducted the policy recommendations from the studies found in both categories.

3.2. Data analysis

I used a synthesis of inductive and deductive coding strategies to form categories and themes of policy recommendations. Following Merriam's framework of coding in qualitative research, I started with open coding and added any segment of data in policy recommendations found in the literature. Then, I moved to analytical coding where I grouped codes into relative and related groups. Then, I created categories of conceptual elements including many codes. Finally, I described recurring patterns and themes in the literature to formulate the study's results (Merriam & Tisdell, 2015).

The categories found in each section of policies were named by the researcher to cover the common areas of recommendations. For example, policies like including non-western representations in textbooks and intertextuality are both under the category “textbook reform (TBR)”. A category of policy recommendations was considered a theme when it was mentioned in at least 10% of the articles covered.

4. Results

In this section, I explained the policies discussed in the Lebanese context in peer-reviewed studies. The studies I analyzed are peer-reviewed studies published in science education journals between 2010 and 2022. As I synthesized the studies, I used Merriam’s framework of analyzing codes in qualitative studies to identify themes of policies proposed for Lebanese science education. The detailed extraction and codes of the policy recommendations are in table 2.

The frequency of recurrence of the codes along with the derived patterns were presented in table 2. Only the codes recurring at least 4 times in the literature were considered. The complete list of codes across the references is in appendix 1.

After a review of the frequency of the codes, I identified 2 main patterns of codes: inclusion of nature of science (NOS) elements and targeting students’ misconceptions. There were several other possible categories of policy recommendations, but were not recurrent enough to identify patterns. For example, textbook reform was mentioned in 3 articles. But no pattern could be identified.

Table 2: The frequency of recurrence of policy recommendations across the analyzed literature

Policy recommendations (Codes)	**Citations**	**Freq.**	**Patterns**
NOS needs to be explicitly integrated in the curriculum (3) NOS requires clear standards of knowledge and attitudes Reflective discussions foster NOS understanding (2) Norms of discussion foster NOS understanding NOS requires several opportunities for learning across the year Further research required on content and methodology of NOS instruction	(BouJaoude et al., 2010) (Khishfe, 2013) (el Takach & Yacoubian, 2020) (Olson, 2018) (Yacoubian & BouJaoude,2010) (el Takach & Yacoubian, 2020) (Khishfe, 2012) (Khishfe, 2015) (Yacoubian, 2021)	9	**Inclusion of nature of science (NOS) elements in curriculum and instruction**
Utilize NOS teaching Build on students' prior knowledge Opportunities for logical analysis NOD target misconceptions Counter balancing stereotypes Inquiry-based learning	(BouJaoude et al., 2011) (Osman et al., 2016) (Osman et al., 2016) (Khishfe, 2012) (Yacoubian et al., 2017) (Areepattamannil et al., 2020)	5	**Target student misconceptions (TSM)**

4.1. Inclusion of NOS elements

A lot of studies investigated areas related to NOS in Lebanon. It was the most frequently addressed code in the study. For example, BouJaoude et al. (2010) analyzed biology teachers' views on evolution. He proposed that NOS needs to be **explicitly** addressed in the curriculum and throughout instruction. He argues that this addition promotes scientific thinking and literacy. Another study recommended that "science as a way of thinking" should be **explicitly** addressed in the curriculum to highlight the process related to producing scientific knowledge. They suggested that "science as a way of thinking becomes part of the explicit curriculum of school science and university science education courses" (el Takach & Yacoubian, p.10, 2020). Khisfe (2013) also agreed the teaching of NOS needs to be explicit and clear.

Building on the premise BouJaoude, el Takach & Yacoubian claimed, Olson's study in 2018 discussed that Lebanon's science curriculum does not state standards explicitly including **NOS aspects** in the curriculum. She looked into official documents of 9 states, particularly Lebanon's science curriculum developed by the CRDP, and investigated the presence of NOS elements. Olson concluded that the national curriculum did not describe learning expectations on NOS as well as methodologies and pedagogical approaches to teaching them. NOS was scarcely mentioned in the general objectives of the curriculum. Consequently, Olson recommended that the curriculum includes clear standards of NOS knowledge and attitudes (Olson, 2018).

Several other studies discussed certain policies that promoted NOS elements in science education. For instance, Khishfe (2012) argued in her study that creating norms of discussion in the classroom is a remarkable factor in developing students' argumentation skills and understanding of NOS. This included listening to each other, creating arguments, and the ability to research information correctly. Moreover, she recommended in her 2015 study that the opportunities for NOS learning are spread throughout the year and are allocated significant learning time (Khishfe, 2015).

el Takach and Yacoubian (2020) discussed the effect of implementing reflective discussions in developing students' understanding of NOS elements and perceptions of science and scientists. Learners would be encouraged to reflect on their beliefs and observations and target their misconceptions on the topic. Another study by Yacoubian and BouJaoude (2010) emphasized the role of reflective discussions following inquiry-based lab activities in developing students' understanding of NOS elements. The researchers recommended including reflective discussions in instruction because it is effective in promoting NOS elements as per their findings.

Yacoubian (2021) recommended that research sheds light on *what* (content) and *how* (teaching strategies) the curriculum needs to address NOS to promote its values. He explained that to develop sustaining beliefs on NOS for future citizens, the curriculum should include guidelines based on research on the content and practices of teaching NOS. Khishfe (2012) agreed with Yacoubian on the importance of explicitly defining the NOS units in the curriculum.

4.2. Targeting students' misconceptions

This pattern was evident in 4 analyzed studies. Most of the topics covered were controversial socioscientific issues like evolution, and researchers would recommend targeting students' misconceptions in their respective field of study, whether on the content or process of thinking of the topic.

BouJaoude et al., for example, investigated views on evolution and suggested that NOS teaching in the curriculum may tackle students' misconceptions or naïve understanding of how science and scientists operate (BouJaoude et al., 2011). This shows a relation between both patterns, where teaching NOS elements could tackle students' misconceptions in controversial issues.

Osman et al. (2016) discuss rampant misconceptions of G7-12 students on scientific issues. They propose that the science curriculum should target students' misconceptions on the related topics, as well as include frameworks for teachers to build on students' prior knowledge. They also claim that the curriculum must include opportunities for logical analysis of content, follow development theories, and consider teachers' expertise in the area. The policy recommendations in this study were mentioned as discussions in some other studies as well (BouJaoude et al., 2011) (Yacoubian & BouJaoude, 2010).

Moreover, Khishfe's (2012) argument on creating norms of discussion was also applicable in the context of targeting students' misconceptions. She claimed that open discussion along with teaching argumentation and research skills can target students' misconceptions similar to the way scientists work on scientific topics. However, Khishfe and BouJaoude suggested that further research would provide educators insight into students' thinking regarding controversial issues and consequently help them address the misconceptions related to the topic (Khishfe & BouJaoude, 2014).

Furthermore, a study compared inquiry-based learning and teacher-directed learning on criteria of developing students' positive perception of science and scientific skills. Areepattamannil et al. (2020) claimed that a blend of both strategies, inquiry-based learning and teacher-directed learning, was the most effective in acquiring the desired outcomes. However, they also claimed that inquiry-based learning was a more effective strategy to target students' misconceptions about the discussed topic because it provides more discussion opportunities.

A comprehensive analysis of textbooks was Yacoubian et al.'s study in 2017. They analyzed the national textbooks of basic education and identified several stereotypical images. They claim that the stereotypes do not foster social justice nor do they encourage dialogue between cultures. Hence, they recommended that textbooks counter balance stereotypes related to NOS elements and cultural representations.

5. Discussion and Conclusions

The collection of the policy recommendations showed 2 important themes: 1) content and instruction model; 2) recommendation triad.

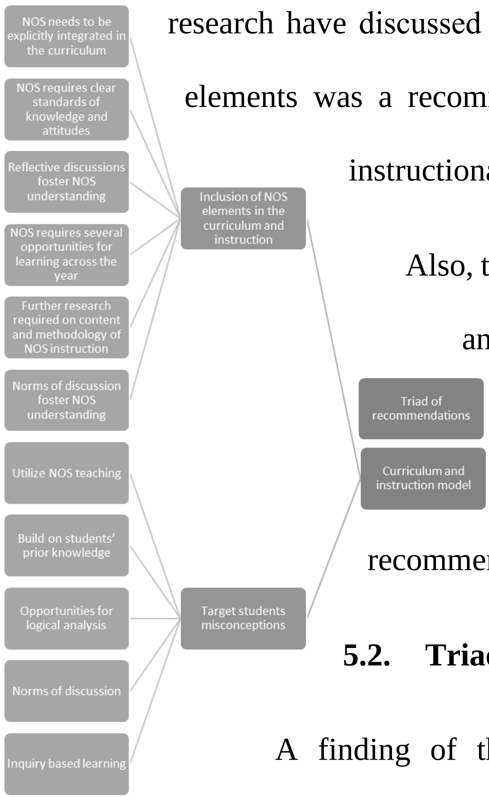
5.1. Content and instruction model

The 2 patterns of policy recommendations (including NOS elements and targeting students' misconceptions) were inter-related. The 2 patterns formed a model for science education content and instruction. The model would include explicitly stated NOS standards explaining the expectations of students' knowledge and attitudes, as well as instructional methods that support deep NOS understanding like norms of discussion and IBL.

Research showed that Lebanon is falling behind regarding NOS elements when compared to other national contexts. Olson (2018) claimed that some countries already developed a more advanced curriculum compared to countries like Lebanon. As an example, Australia had 20 NOS standards written as statements, 55 NOS statements written as headers, and 13 NOS statements written as front/back matters. Lebanon scored 0 in all 3 criteria. Hence, including NOS elements would increase Lebanon's status in comparison to other nations.

Moreover, this addition to the curriculum would target students' misconceptions around several socioscientific issues like evolution, as research states. Several policies found in the

Figure 1: Development of patterns and themes from codes



research have discussed students' misconceptions. The majority agreed that including NOS elements was a recommendation to target misconceptions, in addition to supplementary instructional methods.

Also, the model consisted of the ground framework for Lebanese curriculum and textbook development, as it targeted both areas where Lebanon is lagging behind compared to other nations. Figure 1 showed the development of the patterns and themes from the policy recommendations (codes).

5.2. Triad of policy recommendations

A finding of this study was that a significant number (11/19) of the policy recommendations from the peer-reviewed articles investigated followed a triad of components (figure 2).

This theme was evident in many recommendations. The researchers would propose a recommendation and suggest more in-depth research on its generalizability in a different context as well teacher training programs related to it. For example, Khishfe (2015) called for in-depth research on the relationship between NOS elements, argumentation skills, and students' ability to transfer this knowledge to other socioscientific issues.

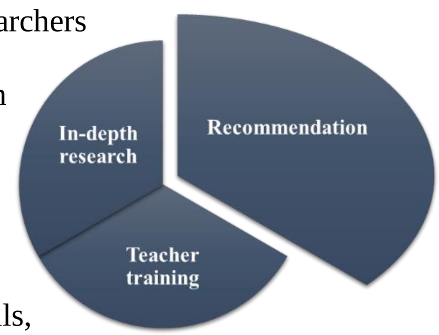


Figure 2: Triad of recommendations

It was a common feature in most of the policy recommendations found in the whole group of articles, not only the ones discussed in both patterns above. Those included policy recommendations on research ideas, instructional methods, and textbooks.

Consequently, this triad can be used as a tool or framework for understanding and implementing many of the instructional methods discussed in this study. It would provide a theoretical base of evidence of the effectiveness of the recommendation, as well as practical teacher training aspects for implementation.

5.3. Implications

There were several implications to this study. These implications included:

- Adopting and implementing the evidence-based policies discussed in the study.
- Utilizing the triad to create a database of recommendations alongside the research supporting it and the training it requires.
- Researching the generalizability of the instructional strategies suggested.
- Conducting comparative research on Lebanon and other national contexts.
- Funding a reform of national textbooks and curricula of science following the recommended model.

Appendices

Appendix 1: The distribution of the all the codes over the articles

Policy recommendations (Codes)	**Citations**
Target student misconceptions (TSM)	(BouJaoude et al., 2011)
Inclusion of NOS elements	(Olson, 2018)
NOS standards on content and methodology	(Olson, 2018)
Reflective discussions (RD)	(el Takach & Yacoubian, 2020), (Yacoubian & BouJaoude, 2010)
Triadic dialogue (TD)	(Salloum & BouJaoude, 2017)
Norms of discussions (NOD)	(Khishfe, 2012)
Teaching of argumentation skills (TAS)	(Khishfe, 2013)
Foster student retention (FSR)	(Khishfe, 2015)
Teacher-directed learning (TDL)	(Areepattamannil et al., 2020)
Inquiry-based learning (IBL)	(Areepattamannil et al., 2020)
Diverse participation modes (DPM)	(Salloum & BouJaoude, 2020)
Research-related policy (RRP)	(Dagher & BouJaoude, 2011) (Khishfe & BouJaoude, 2014).

Research on students' interaction with controversial topics	(Khishfe, 2012)
Research on relationship btw. NOS understanding and argumentation skills	(Khishfe, 2013)
Research on transferring NOS and AS	(Khishfe, 2015)
Research on fostering student retention (FSR)	(Yacoubian, 2021)
Research on content and methodology of teaching NOS	(BouJaoude et al., 2010)
Training on teaching NOS concepts and TSM	(Areepattamannil et al., 2020)
Training on IBL and TDL	(Salloum & BouJaoude, 2020)
Training on TD	(Salloum & BouJaoude, 2017)
Teacher inquiry and reflection (TER)	(Shehab & BouJaoude, 2016)
Explicit captions and labels (ECL)	(Yacoubian et al., 2017)
Authentic representations of NOS elements	(Yacoubian et al., 2017)
Inclusive cultural representations (ICR)	(Yacoubian et al., 2017)
Images counter-balancing existing stereotypes	(Yacoubian et al., 2017)
Opportunities for critical exploration.	(el Takach & Yacoubian, 2020)
Highlight contributions of minorities and multicultural scientists	

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