Becoming future-proof STEM teachers for enhancing sustainable development: A proposed general framework for capacity-building programs in future studies

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Abstract  Post-normal times and post-normal science are characterized by contradictions, unknown unknowns and uncertainties, and complexity. These global grand challenges require a revolutionary shift in thinking and mindset on the part of teachers and students. Therefore, there is an urgent need to identify new roles for STEM education that will prepare students for this post-normal world and the sustainability mindset it requires. STEM education supports sustainable development by building the capacities of future generations. The integration of Future Studies (FS) into STEM education practices is therefore critical to support efforts at sustainability and to ensure that students are competent 21st century problem-solvers. Building STEM students’ competencies in this area depends on their teachers having the appropriate knowledge and skills to integrate FS within their subjects. Therefore, Futures Studies should be included in STEM education teachers’ capacity-building programs. Based on a sample of 52 Egyptian university academics, this study revealed the basic knowledge and skills that should be included in a Future-Proof STEM teachers capacity-building program.

Keywords  STEM education · Sustainable development · Future-proof · Future studies · Egypt

Global grand challenges, sustainable development, and future studies

In recent years, there has been an increasing focus on the close relationship between STEM (science, technology, engineering, and mathematics) education and sustainable development (SD) in school and university education (Bascopé & Reiss, 2021; Gough, 2021; Krug, 2012; Pahnke et al., 2019; Suh et al., 2019; Ulmeanu et al., 2021; Velázquez et al., 2020). A primary reason for this increased focus is that STEM education is
considered one of the major pillars that support SD through building the capacities of future generations (Pahnke et al., 2019).

In this era of post-normal times and post-normal science, the world is going through a period of deep transformation, with governments forced to address future challenges (Sardar, 2010a, 2010b). One objective of STEM education is to confront and solve these global grand challenges. Since post-normal times and science are characterized by contradictions, unknown unknowns and uncertainties, and complexity (Samuel and Thamburaj, 2015), these global grand challenges require a revolutionary shift in thinking on the part of teachers and students (Schratz & Symeonidis, 2018). Therefore, there is an urgent need to identify new roles for STEM education that will prepare students for the “post-normal” world and the sustainability mindset it requires (Sardar, 2010a, 2010b).

Science and technology are no longer seen by the young generation as positive means for addressing grand global challenges but rather as sources of fear (Eurobarometer, 2015). As a result, an increased interest in reforming STEM curricula to be “Future-Oriented STEM Education” has developed. As stated by Pahnke et al. (2019):

A powerful and sustained implementation of future-oriented science, technology, engineering, and math (STEM) education focused on the issues of critical importance, such as those outlined in the UN SDGs, and potential solutions to those problems, will help to inoculate young people and their teachers and parents against societal and health problems that can adversely affect their lives. (p. 3)

Furthermore, Velázquez et al. (2020) argued that anticipatory competency is a key to sustainability:

Anticipatory competency: The abilities to understand and evaluate multiple futures—possible, probable, and desirable; to create one’s own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes. (p. 9)

STEM education should enhance the capabilities of students in innovation, creativity, scientific thinking, and problem-solving skills as well as develop their sustainability mindsets; it must enable them to engage with the interdisciplinary learning methodologies that address the complex economic, social, and environmental aspects of both the formal and informal curriculum. This will empower them to become active players in their societies and contribute to improving the quality of life. Education for sustainable development (ESD) aims “to empower and equip present and future generations to meet their needs using a balanced and integrated approach to the economic, social, and environmental dimensions of sustainable development” (Leicht et al., 2018, p. 7). Put differently, ESD imparts the competencies for understanding such real-world changes and transformations as the COVID-19 pandemic, it identifies current problems and anticipates those that may occur in future societies, and collaboratively finds innovative solutions to them.

The students of today, who are the generation that will live in these future societies, must acquire the appropriate knowledge and skills to define and solve sustainability problems (Suh et al., 2019). According to the Sustainability Overview statement:

Education for sustainability develops the knowledge, skills, values and world views necessary for people to act in ways that contribute to more sustainable patterns of living. It enables individuals and communities to reflect on ways of interpreting and engaging with the world. Sustainability education is futures oriented, focusing on
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protecting environments and creating a more ecologically and socially just world through informed action. Actions that support more sustainable patterns of living require consideration of environmental, social, cultural and economic systems and their interdependence. (para. 6)

Although STEM education should have more innovative and, indeed, more anticipatory roles in identifying global grand challenges and should be future-oriented, it is difficult—and sometimes impossible—for STEM teachers to forecast global grand challenges and translate forecasting results into workable capstone projects that require Future Studies (FS) concepts, methodologies, tools, methods, and skills (Tanenbaum et al., 2016). The competencies that STEM teachers must obtain are future-scaffolding STEM competencies relevant to STEM related disciplines, which will empower students to think creatively about the future (Levrini et al., 2019). STEM teachers should be able to systematically forecast future global grand challenges, critical issues, disruptions, new smart technologies, and strategic areas of research and innovation, as well as solve complex sustainability problems in innovative ways.

Why futurize STEM education

Before exploring the proposed knowledge base and skills that should be integrated into a capacity-building program in FS for STEM teachers, we must recognize FS’s controversial nature. Although FS has recently penetrated many fields and engaged many professionals and institutes, the issue of integrating FS in education, including STEM schools, has been ignored (Bol & Staring, 2018). To this end, the European Union funded the “I SEE project”, which aims at supporting students in acquiring such future thinking skills as strategic planning, managing uncertainty, modeling, risk-taking, strategic and creative thinking and argumentation (Levrini et al., 2019).

The I SEE project developed an approach in which FS can inspire Science Education through the systematic use of forecasting methods and tools as well as by fostering the role of Science Education in addressing problems of the future (Branchetti et al., 2018; Lloyd & Paige, 2016).

In light of the above, this study explores what knowledge base and skills in-service STEM education teachers should possess and demonstrate to become Future-Proof STEM teachers who can enhance SD. To determine this, the following research questions should be answered:

- Research Question 1. Why is it so important to futurize STEM education to enhance SD efforts?
- Research Question 2. What are the basic knowledge base and skills that in-service teachers should possess and demonstrate to become Future-Proof STEM teachers for enhancing SD?
- Research Question 3. What is the general framework for a Future-Proof STEM teachers capacity-building program?
Literature review

As Schratz and Symeonidis (2018) argued, many significant issues challenge educational systems in general and teacher education in particular to review their goals and curricula. The most important of these are the complexity of rapid social change and the uncertainties and contradictions that the world is currently experiencing. To prepare coming generations of students to tackle the expected challenges of these post-normal times, in which facts are uncertain, educational systems must futurize their curricula (Lotz-Sisitka et al., 2015).

Many advocates of future-focused education (Facer, 2011, 2016; Sardar, 2010a; Slaughter, 2015) emphasize the importance of integrating FS as a response to the increased unpredictability, chaos, and complexity in our world and believe that the methods currently used to assess student progress in reading, writing, and arithmetic are not suitable for measuring the development of innovation, creativity, and complex problem-solving competences (Silva, 2009). Thus, STEM education should focus on preparing students for understanding and implementing forecasting tools and futures thinking-skills in various educational contexts.

The concept of future-proof

Although many fields of study have employed the concept of future-proof, it is rarely used in the field of education. To “proof” (as in waterproof, for example) means to provide protection against something. Future-proofing can be defined as the process of using forecasting methods to prepare for unknown future shocks and risks (Walonick, 2010) and develop suitable alleviating strategic plans (Rehman et al., 2017).

Futures thinking

Futures thinking is one of the basics of Futures Studies, an integrative, interdisciplinary group of methodologies, theories, and principles that enable individuals to think in a constructive and systematic way about the future (Miller, 2003) and to reflect on the fundamental changes that might happen over the next 10-20 years in major areas of life. Futures thinking tries to direct strategies that can foster the desirable futures and avoid the undesirable ones (OECD, 2006).

A brief recent history of future studies

Futures Studies emerged as an interdisciplinary academic field in the mid-1960s, after the World Wars. Many terms are used to refer to FS—for example, futuring, futurology, futures thinking, prospective, futuribles, prognostics, technology forecasting, futuristics, futures research, strategic foresight, and visionary management (Sardar, 2010a, 2010b). In the late 1950s, the RAND Corporation in the United States developed long-range planning and technology forecasting, using as its principal tools scenario analysis and the Delphi technique (Dalkey & Helmer, 1951).
In 1970, Japan developed “foresight” by developing its first 30-year forecast of the future of Science and Technology. The early 1980s witnessed many foresight initiatives in France, which took the lead, followed by Australia, Sweden, and Canada. Then, in 1990, an expansion of forecasting studies took place in many European countries and the United States. Hartmann (2011) observed that foresight has evolved over three generations:

First generation activity was concerned with technological forecasting by experts, second generation bringing in industry and the market, and third generation foresight adding a social and user-oriented perspective. It should be stressed that these generations are ideal types and that an individual foresight activity may exhibit elements of two or even three generations. (p. 336)

The nature of FS

Inayatullah (2013) defined FS as a systematic discipline based on worldviews to predict probable, possible, and preferable (desirable) futures. Voros (2001) similarly defined Futures Studies as an application in a strategic planning field that considers distinctive possibilities of the future. Accordingly, futures thinking and foresight are appropriate long-term planning tools for forecasting and getting ready for unknown futures. It could be argued that Futures Studies differs fundamentally from forms of research in other academic fields in three ways: (1) Futures Studies generally explore "wild card" futures as well as alternative images of the futures, (2) Futures Studies attempt to create comprehensive images of the future grounded on insights from various disciplines and fields, and (3) Futures Studies detect and reveal the presumptions behind prevailing images of the future. A person who academically studies the future is called a futurist, one who analyzes and explores future possibilities with a view to providing information that enables policy makers to choose a desired future (Glenn, 2003).

Voros (2003) introduced his futures cone to help futurists distinguish between four alternative futures. Voros (2003) defined these as “possible futures (what may be); preferable futures (what should be); … plausible futures (what could be); and probable futures (what will likely be)” (pp. 13–14). The Voros cone, shown in Figure 1, is a visualization of these four alternative futures that demonstrates their interrelationships (pp. 16–17).

Possible futures are the simplest and most straightforward type of alternative futures that can be objectively described. It is also the widest category, including every possible future that may occur.

Plausible futures are a subcategory of possible futures (Voros, 2003). Plausible futures are real and achievable because they are based on current knowledge of the real world and its social systems. They signify that a clear path exists from the present to the future. Therefore, plausible futures can be used as a basis for envisioning how institutions can reach their preferable futures (Henchey, 1978).

Preferable futures are extremely subjective and normative, as they express people’s preference for a specific phenomenon or event. Preferable futures are most closely associated with people’s principles, values, and ethics since these determine why one future would be more preferable than another (Henchey, 1978).

Probable futures are the most likely futures of an issue or phenomena projected forward over a certain period of time and under identified emergencies (Bell, 1998).
Futures studies, foresight and forecast: Similarities and differences

According to Bell (1998), Berkhout & Hertin (2002), Glenn (2003), Sardar (2010a), Kuosa (2011), Hartmann (2011), and Inayatullah (2013), individuals or groups engage in Futures Studies or foresight to explore the future from various perspectives in order to inform the current process of making decisions. The distinction between Futures Studies and foresight is subtle. While Futures Studies focuses on predicting all alternative images of the future (probable, possible, preferable, and plausible), foresight focuses on strategizing how navigation of a certain issue or a phenomenon can be carried out in a future full of uncertainties. Futures Studies is based on employing creative imagination to avoid the restrictions of the present and inspire innovation by employing futures thinking to create distinctive approaches and methods to get things done in an innovative way (Berkhout & Hertin, 2002).

Berkhout and Hertin (2002) also pointed out the subtle difference between strategic foresight and forecasting. While forecasting makes its predictions in terms of recent trends or frequencies of similar past events, foresight anticipates alternative images of the future and envisions the possible outcomes of those alternative images as well as their consequences (Fuerth, 2009). The difference between foresight and forecast can be summarized as follows:

- Foresight: To see something earlier than it happens
- Forecast: To make a prediction of a future thing.

Futures studies aims and approaches

Futures Studies as a discipline or subject of study has four general aims: (1) developing appealing future visions, images, and scenarios; (2) directing and enhancing planning and decision-making processes; (3) answering the great global questions, and (4) creating an applicable interdisciplinary methodology (Kuosa, 2011). While the first approach is concerned with describing the most probable trends, the second approach focuses on identifying selected possible trends, and the third approach aims at identifying the preferred trends. Finally, the fourth approach gives great attention to developing prospective futures (Gidley, Bateman, & Smith, 2004).

Materials and methods

This study is exploratory since the literature that has been reviewed has not established a strong connection between FS and STEM education to enhance sustainable development. This study tries to demonstrate such a connection by examining quantitative and qualitative data collected from academics who have experience and knowledge of STEM education and FS.
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Participants

The current research was based on a non-probability, purposive sample of 52 key Egyptian education experts who were selected from five top-ranked universities in Egypt on the basis of their experience and knowledge of STEM education and FS. Table 1 indicates the distribution of the participants according to gender, academic rank, teaching experience and specialty.

Instruments and procedures

The basic knowledge and skills that should be included in a Future-Proof STEM teachers capacity-building program were identified through a two-step procedure. First, we asked the 57 participants to respond to an open-ended questionnaire that contained two parts. The first part asked for participants’ demographic data, and the second part included two open-ended questions: (1) Please define the basic knowledge for enhancing SD that in-service teachers should possess and demonstrate to become Future-Proof STEM teachers; and (2) Please define the basic skills for enhancing SD that in-service teachers should possess and demonstrate to become Future-Proof STEM teachers. That was followed by another questionnaire with closed items for obtaining participants’ level of agreement on a synthesis of the participants’ responses in the first questionnaire. Participants were asked to rate their level of agreement using a 7-point Likert scale, where (1) was the lowest level of agreement and (7) was the highest. The questionnaire included space for participants to add any items they felt had been omitted.

Table 1 Demographic distribution of the sample (N = 52)

| Variables          | Categories           | Frequency (f) | Percentage (%) |
|--------------------|----------------------|---------------|----------------|
| Gender             | Female               | 31            | 60             |
|                    | Male                 | 21            | 40             |
|                    | Total                | 52            | 100            |
| Academic Rank      | Professor            | 17            | 32.69          |
|                    | Associate Professor  | 26            | 50.00          |
|                    | Lecturer             | 9             | 17.31          |
|                    | Total                | 52            | 100            |
| Teaching Experience| <5 years             | 9             | 17.31          |
|                    | 5–10 years           | 26            | 50.00          |
|                    | >10 years            | 17            | 32.69          |
|                    | Total                | 52            | 100            |
| Specialty          | Mathematics          | 11            | 21.15          |
|                    | Chemistry            | 10            | 19.23          |
|                    | Physics              | 9             | 17.30          |
|                    | Biology and Geology  | 9             | 17.30          |
|                    | Educational Sciences | 7             | 13.46          |
|                    | Management Sciences  | 6             | 11.54          |
|                    | Total                | 52            | 100            |
Data analysis

Statistical Package for Social Sciences (SPSS) version 23.0 was used for analyzing participants’ responses. Frequencies (75%, as indicated by Christie & Barela, 2005), mean, median, standard deviation and the interquartile range (IQR) were calculated. The IQR and frequency were calculated to determine the level of agreement between participants (IQR of 1.5 or less), and the median was calculated to determine the central tendency of the responses of the participants for each statement. These results are shown in Table 2.

Results and discussion

The participants’ responses to the two questions in the initial questionnaire are shown in Table 3.

As shown in Table 4, all of the 37 items reached an agreement (fulfilling agreement criteria: Mdn of 5-7, IQR≤1.5 and/or IQR of 2.0 or 2.5 and with ≥ 75% of participants’ responding 5–7).

A proposed general framework for an FS capacity-building program

Based on the literature review and the results achieved, the author proposes the following general framework for planning and implementing a Future-Proof STEM teachers capacity-building program:

1. **Build awareness of the program’s rationale.** It is very important to define the rationale of the program and the need for STEM teachers to become Future-Proof STEM teachers. The stakeholders should be aware of those needs through conducted workshops.

2. **Secure general policy, permission and stakeholder buy-in.** The support of higher education institution leaders is needed in the form of general policy and procedures and supportive financing and resources. Leaders’ support could be achieved by convincing them of the importance of the new capacity-building program. In addition, early discussions with faculty are needed to make them aware of the goals of the capacity-building program and its benefits.

| Table 2 | Statistical criteria for agreement |
|---------|----------------------------------|
| Consensus | Statistical Criteria |
|          | Median | IQR   | Frequency |
| Agree (A) | ≥ 5    | ≤1.5  | 5–7 ≥ 75% |
|          | ≥ 5    | ≤2.5  |          |
| Neutral (N) | = 4    | ≤2.5  |          |
| Disagree (D) | ≤ 3    | ≤1.5  | 1–3 ≥ 75% |
|          | ≤ 3    | ≤2.5  |          |
Table 3  Basic knowledge and skills that are essential for a Future-Proof STEM teachers

| Code | Basic Knowledge                                                                 | Code | Basic Skills                                      |
|------|---------------------------------------------------------------------------------|------|---------------------------------------------------|
| BK 1 | Problem-solving in post-normal times and science                                | BS 1 | Systemic forecasting methodologies and tools       |
| BK 2 | Theoretical and practical basics of Futures Studies in post-normal times and science | BS 2 | Technological skills                             |
| BK 3 | Systems, complexity, and chaos theories in relation to solving complex sustainability problems in the light of post-normal science | BS 3 | Scoping, surveying, and scanning skills           |
| BK 4 | Theoretical and practical basics, methodologies, and tools for forecasting future critical issues, disruptions, new smart technologies and strategic areas of research and innovation | BS 4 | Ordering and converging skills                    |
| BK 5 | Methodologies and tools of forecasting future opportunities and threats in a post-normal era | BS 5 | Interpretation skills                            |
| BK 6 | Methodologies and tools for systematically analyzing critical current societal, national, and international issues. | BS 6 | Analytical skills                               |
| BK 7 | Basics of strategic systemic innovation and entrepreneurial discovery           | BS 7 | Synthesis skills                                 |
| BK 8 | Employing the methods, approaches, and tools of FS to solve complex sustainability problems and to address national and global grand challenges in innovative ways | BS 8 | Knowledge reasoning skills                       |
|      |                                                                                  | BS 9 | Knowledge representation skills                  |
|      |                                                                                  | BS 10| Problem-solving skills                          |
|      |                                                                                  | BS 11| Recognize logical relationships skills           |
|      |                                                                                  | BS 12| Managing uncertainty skills                     |
|      |                                                                                  | BS 13| Problem-structuring skills                      |
|      |                                                                                  | BS 14| Innovative thinking skills                      |
|      |                                                                                  | BS 15| System thinking skills                          |
|      |                                                                                  | BS 16| Holistic thinking skills                        |
|      |                                                                                  | BS 17| Complexity thinking skills                      |
|      |                                                                                  | BS 18| Systemic thinking skills                        |
|      |                                                                                  | BS 19| Systematic thinking skills                      |
|      |                                                                                  | BS 20| Systemic inquiry skills                        |
|      |                                                                                  | BS 21| Designing skills                               |
|      |                                                                                  | BS 22| Scenarios thinking skills                       |
|      |                                                                                  | BS 23| Dynamic thinking skills                         |
|      |                                                                                  | BS 24| Creative thinking skills                        |
| Code | Basic Knowledge | Code | Basic Skills |
|------|----------------|------|--------------|
| BS 25 | Strategic thinking skills | BS 25 | Strategic thinking skills |
| BS 26 | Strategic planning skills | BS 26 | Strategic planning skills |
| BS 27 | Divergent and convergent thinking skills | BS 27 | Divergent and convergent thinking skills |
| BS 28 | Thinking beyond the realm of possibilities skills | BS 28 | Thinking beyond the realm of possibilities skills |
| BS 29 | Opportunity discovery skills | BS 29 | Opportunity discovery skills |
3. **Create a form-planning team.** Planning an FS capacity-building program is very complex and includes multiple skills and themes. Therefore, an important step is the selection of the most appropriate and competent individuals for these tasks, the identification and clarification of the roles each of them will play, and building a climate of trust and commitment among them.
4. **Perform a needs assessment.** One of the most important pillars of the capacity-building program planning is conducting a needs assessment of STEM teachers to become Future-Proof STEM teachers. The results of the needs analysis process will help planners in building sound foundations for the capacity-building program and guide the next steps in the program planning process.

5. **Achieve intended learning outcomes.** By the end of the program, the trainees will be able to:
   - Forecast future critical issues, disruptions, new smart technologies and, strategic areas of research and innovation.
   - Employ the methods and approaches of FS to solve sustainability problems in an innovative way.
   - Employ the scenarios as alternative solutions for grand challenges.
   - Identify the dimensions and local resources and peculiarities for integrated national development in time and space.
   - Forecast future opportunities and threats.
   - Identify the systematic integration between strategic planning and FS.
   - Implement and design foresight exercises as vision-building processes at international and local levels as well as in different societal areas.
   - Explain the process of mobilizing local resources.

6. **Include basic knowledge and skills.** The proposed basic knowledge areas and skills to be included in the program are identified in Table 3.

7. **Ensure that students gain practical experience alongside theoretical background internships (work-based learning).** This will enable students to apply the knowledge they gained during course work to professional and practical work situations.

8. **Develop the module.** In order to develop the modules, various activities should be conducted. These include workshops (face-to-face and virtual), focus groups, interviews, research, case studies, and surveys. A survey of existing FS capacity-building programs internationally and nationally should be conducted. Furthermore, a number of face-to-face and virtual workshops and webinars should be conducted to define and finalize program objectives and learning outcomes, modules and syllabi, assessment mechanisms, and delivery and implementation and to prepare modules materials according to international standards. In addition, various virtual workshops, surveys, and experiments should be used to evaluate the existing tools and decide on a collaboration model and platform suitable for the proposed program as well as the needed structure of the curricula, the necessary infrastructure, and the modes of delivery.
9. **Develop a business plan.** The strategic plan aims to determine the competitive advantages of the program and the requirements for the program implementation; define marketing strategies, return and cost analysis; and show how the higher education institution will ensure the sustainability and development of the program.

10. **Obtain the required resources.** It is essential to ensure that all program implementation requirements and their financial resources are available.

11. **Establish support systems.** Support systems are among the essential components of the program. The suggested services are:
   - Easy-to-learn materials with clear content, a dictionary of technical terms, and a list of suggested readings to enable the trainees to practice self-learning.
   - Two-way communication channels to provide appropriate feedback on trainees’ performance, and a personal communication program organized through face-to-face individual counseling.
   - Administrative services.
   - Financial support.

12. **Obtain capacity-building program approval.** Obtain capacity-building program approval through matching the mission of the program with the mission of the higher education institution.

13. **Pilot test for adjusting and fine-tuning the modules.** This step aims at testing the effectiveness of the content of modules and the methods and strategies. This activity led to revision of the new program prior to its being offered on a large scale.

14. **Implement the program.** Local publicity for the program will prepare for the first student intake and help implement the program according to the business plan.

15. **Evaluate the program.** To assess the developed professional training modules, we will conduct a pilot evaluation. Collaboration with FS international associations will take place during the course of the program to ensure that students are up to date with new advances in FS. We will also develop an evaluation and quality plan that will report on monitoring the development of capacity-building program modules.

**Conclusions**

The global grand challenges that STEM education has to address have emerged in an era characterized by ambiguity, contradictions, and uncertainties. The human-centered economy and post-normal times and science will increasingly require new innovations in the capacity building of STEM education teachers. One of these innovations is the inclusion of the discipline of Futures Studies in the content of STEM education teachers’ capacity-building programs. FS will enable teachers to optimize STEM education for all learners since it helps STEM teachers to have a better understanding of today’s and tomorrow’s complex sustainability problems and global grand challenges and hence employ the appropriate methods, approaches, and tools of FS to handle them in innovative ways. Accordingly, in this article I argued for the great importance of Futures Studies for STEM education teachers and introduced the basic knowledge and skills that should be included in a Future-Proof STEM teachers capacity-building program. Finally, I identified the major planning steps that should be undertaken to develop a Future-Proof STEM teachers capacity-building program. I believe that to support SD efforts, not only STEM teachers but all educational practitioners in all types of educational systems should prepare for post-normal times and science.
This study could contribute to the field of teacher education in two ways. First, the suggested eight areas of basic knowledge and 29 skills of FS can be adopted as a framework for integrating FS in educational actions and practices as an approach to promote SD practices. Secondly, the proposed framework could play a significant part in guiding the redesign of in-service teacher education capacity-building programs.

Although this study was conducted in an Egyptian context, the suggested basic knowledge and skills of FS could provide a useful understanding for other areas of study. This area of research is still in its infancy, and more studies with wider perspectives should be carried out on in order to learn how the proposed framework can be effectively applied in various educational contexts.

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