Discover Education

Review

A model for utilising crises-related issues to facilitate transdisciplinary outdoor STEAM education for sustainability in integrated mathematics, language arts and technology classrooms

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Received: 9 January 2024 / Accepted: 15 January 2025

Abstract

STEAM (Science, Technology, Engineering, Arts and Mathematics) Education is one of the approaches that teachers adopt as they shift from content delivery focused teaching to skills development teaching. Also, effective STEAMING requires connection to issues outside the classroom (outdoor STEAM) and hence the coinage of the term Transdisciplinary Outdoor STEAM. However, research shows that teachers fail to design problems that match the framework of Transdisciplinary outdoor STEAM. In this study, we propose a model for using real-life crises such as Covid-19 or heatwaves or famine to support teachers in their effort to improve teaching practices in the 21st Century. The development of our model was informed by the theoretical framework for Transdisciplinary STEAM proposed by Quigley and colleagues (Sch Sci Math 117:1–12, 2017; J Sci Educ Technol 29:499–518, 2020) and the model for problem mathematical modelling cycle proposed by Blum and Leiß (Mathematical Modelling, pp. 222–231, 2007. https://doi.org/10.1533/9780857099419.5.221). We have also illustrated teaching–learning activities for this model to develop learners' expected skills in STEAM education. We argue that using this model may cater to the lack of educational technologies in low-resource countries and that it will promote an action-oriented spirit among students to deal with crises emerging in their contexts.

Keywords Language education · Mathematics education · Outdoor STEAM · Sustainability · Transdisciplinary teaching

Abbreviations

STEAM	Science, Technology, Engineering, Arts, Mathematics
SDGs	Sustainable development goals
EfS	Education for sustainability

1 Introduction

Learners of the 21st Century need to know how to develop and apply new skills rather than memorizing knowledge. This need is rooted in the nature of the increasing uncertainties in their changing everyday lives and future career [1, 2]. As Eaton ([1], p. 7) posits,

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> Today's job market requires more than a knowledge of another language. In the twenty-first century, a comprehensive essential skill set is needed for employment. This includes competence in areas beyond languages such as numeracy, thinking skills, computer use (and) the ability to work well with others.

Consequently, teachers' focus is changing from delivering content to facilitating the learning process of students. Quigley and colleagues ([3], p. 499) underscore, "Educators are now moving classroom instructional objectives away from what content do we need to know towards how can we support learners in the process of inquiry." Therefore, this attracts research attention to how to support teachers to meet current teaching demands.

STEAM (Science, Technology, Engineering, Arts and Mathematics) education represents reforms in education to enhance learners to develop skills for dealing with real-life problems [2, 4–6]. This approach requires the teachers to create a learning environment in a way that students learn to develop and apply skills from these disciplines simultaneously as integrated ones rather than isolated [2, 4]. In the efforts to implement STEAM, it has been noted that some teachers have been integrating in a multidisciplinary, interdisciplinary and/or transdisciplinary way [3, 7]. Multidisciplinary involves students understanding various perspectives of approaching a problem [3, 7] such as asking students to comment on the use of condoms based on religious and political perspectives. In this scenario, students will be using two perspectives in discussing content from science disciplines. Interdisciplinary involves using the knowledge and skills of one discipline in the context of another discipline [3, 7]. For example, teachers might ask students to give their views on the project of giving loans to small-scale traders as a way to support entrepreneurial activities. In this scenario, the students will need to have the knowledge and skills about financial issues on how a loan can benefit someone and then use these skills to decide on the discipline of economics. Therefore, the students will be applying financial skills in the context of economics.

Transdisciplinary involves connecting skills from various disciplines with a focus on solving the problem. In this way, students interweave skills and knowledge from many disciplines [3, 7–11]. Quigley and colleagues [3] argue that the transdisciplinary approach does not focus on the contents from a specific discipline, but rather on problems that require students to keep on raising and answering many questions as they move towards the solution to the problem, for instance, if you ask students to consider the possibilities of lowering mortality rates in their community. This will force students to consider the causes of mortality rates, the economic aspects, the culture of the people in that community, the health infrastructure and political aspects among others. If the students think building hospitals or raising health literacy can be a solution, they will examine the economic, political, and cultural implications of their solution. Quigley and colleagues [3] perceive transdisciplinary as the most challenging but the best for true STEAM for the students of the 21st Century and this study focuses on supporting teachers to develop skills to facilitate transdisciplinary STEAM integration in the classroom.

Development of models for STEAM learning has been one of the approaches to support teachers. Anggraeni [12] proposed 5E-STEAM model for guiding teachers how to facilitate STEAM learning activities. The 5Es of this model are engagement, exploration, explanation, elaboration and evaluation, The engagement stage involves the teacher giving student contextual problems that requires them to develop a solution. During exploration students conduct a research activity such as observation to understand the problem. In the explanation stage, teachers encourage to clarify the problem using their own language. During elaboration, students apply the concepts from the explanation stage. And the last stage is evaluation, teacher provides feedback and confirm students' level of skills and knowledge development. This implies increasing contribution among researchers to support teachers to facilitate STEAM learning succesfully in their classrooms.

Another aspect considered in the literature to make STEAM authentic is to connect classroom learning with learners' real environment or objects (Outdoor STEAM) [13–15]. This is intended to help learners realize how connected classroom learning is to real-life problem-solving and internalize the need for long-life learning [13–15]. As Lavicza and colleagues ([14], p. 24) posit "Skills and knowledge, they [students] learned in classrooms could be applied beyond school, but most often these connections are not recognised and mathematics considered out of reach from real life." Therefore, this prompts initiatives among educators to facilitate outdoor STEAM.

In countries with advanced technology, Outdoor STEAM is developing as teachers are able to use various educational technologies to connect students to their real-life or real objects. For example, MathCityMap is a technology that teachers and students use with the support of mobile technology to simulate real-life situations [14, 16]. Students based on their physical location can be given relevant mathematics tasks to accomplish while having the option to see various alternatives/answers from the mathematics trail that is linked to MathCityMap [14, 16]. Many researchers support the implementation of Outdoor STEAM through educational technology [13, 16, 17]. However, this study is on the teachers and students from educational contexts with less or no access to educational technologies to support Outdoor STEAM. Consequently, we propose an alternative approach that accommodates educational contexts with low or no access to educational technology.

Our thinking about STEAM education integration in the classroom is connected to the transdisciplinary and Outdoor and hence transdisciplinary Outdoor STEAM education approach. We consider crises such as COVID, famine, pollution, climate change and many others, as real-life problems that require complex skills in the mitigation or prevention processes. This makes it one of the teaching resources that fit in the transdisciplinary STEAM where students need to navigate through various disciplines' frameworks before reaching the solution to the problem. Also, students having experienced crises in their homes, bring a better connection between home and school if its discussion is brought into the classroom, which is the Outdoor STEAM requirement. Based on this, using crises as teaching resources in the classroom can enhance the implementation of Transdisciplinary Outdoor STEAM integration. Therefore, as a way to support teachers in using crises to implement transdisciplinary outdoor STEAM education, we propose a model for using crises to facilitate transdisciplinary outdoor STEAM education for sustainability in an integrated mathematics, language, arts, and technology classroom.

We have organized this article as follows. We presented the theoretical framework in Sect. 2. We have presented the review of the framework for the integration of transdisciplinary STEAM education in Sect. 3. We have also presented a review of the assessment framework in STEAM education in Sect. 4. In Sect. 5, we have presented an overview of the essence of teaching mathematics, language, arts and technology to students of the 21st Century. In Sect. 6, we have presented the relevance of crises as teaching resources in contemporary education. In Sect. 7, we have presented our proposed model and illustrations on its applications and implications. Section 8 covers the discussion of the proposed model and Sect. 9 covers the conclusions and recommendations.

2 Theoretical framework

The present study is informed by the principle of equity in education as one of the concepts of inclusive education. Equity means creating learning environment that consider fairness among the learner in a way that all learners are given necessary support to achieve their learning potentials [18, 19]. Equitable teaching practices involves adapting teaching and learning resources to accommodate learners' diversities [18, 19]. Graham and colleagues ([18], p. 61) argue "And educators will not do it if they believe that equity means that everyone should be taught the same way, get the same resources, or do the same assessment." This implies the urgent need to provide teachers with various ways to promote equity in their classroom.

This concept is relevant to the present study as the study aims at proposing the model to facilitate Outdoor Transdisciplinary learning in context where students have no access to technologies for interacting with environment outside the classroom. Since studies on Outdoor Transdisciplinary STEAM learning are linked with the use of technologies such as MathCityMap [14, 16], its implementation can be limited in contexts without such technologies. Therefore, to avoid this risk, the present study proposes a model for using Crises related issues for Outdoor STEAM learning as an alternative teaching and learning resource to promote equity in the contexts with low access to technology.

3 Transdisciplinary outdoor STEAM integration framework

As we have alluded to in the introductory part of this article, our operational definition of the transdisciplinary outdoor STEAM education approach is the integration of STEAM education in the classroom to enhance learners' development and application of integrated skills from various disciplines when solving problems encountered outside the classroom. In this section, we review the conceptual model of STEAM teaching practices proposed by Quigley and colleagues [3]. The model was developed as part of the initiatives to empower teachers to integrate STEAM education effectively. The model consists of two domains (instructional content and learning contexts) that are classified further into various dimensions each with criteria for teacher's self-assessment as shown in Table 1. The instructional content domain involves ways in which the teacher organizes his/her teaching to support learners' process of developing and applying skills in the STEAM-integrated classroom [3]. On the other hand, the learning context domain entails the state of the learning environment as created by the teacher to support the development and application of the desirable skills among students [3].

Although the domains and dimensions are presented as separate aspects, it should be noted that they should be applied in an interactive manner as presented in Fig. 1.

Figure 1 shows that instructional content and learning contexts are interconnected in a way that each forms a part of another. This implies that the teacher is thinking of the instructional content and the learning context simultaneously to see how each fit into one other. For example, when the teacher is planning to meet the requirement of problem delivery-based as the dimension of instructional contents, he/she needs also to consider the teaching methods and other aspects of learning contexts to see how they can accommodate the content delivery. This goes further to all dimensions of the two domains (instructional content and learning context). We argue that the connection of all aspects considered in this model makes it a comprehensive one. We also perceive the model as useful for teachers who are entering the field of STEAM education because of the presence of assessment criteria for each dimension. Through these criteria, the teacher will be able to assess his/her teaching practices. It should be noted that there are other frameworks for transdisciplinary approach such as those proposed for research training by Herweg and colleagues [11] and for higher education by Budwig [10]. These frameworks are similar to Transdisciplinary STEAM framework proposed by Quigley and collegues [3] in a sense that they all recognize students as active inquirers who create knowledge using content from various disciplines. However, unlike Transdisciplinary STEAM framework, these frameworks are less comprehensive and precise enough to cater to teachers' demand in the classroom. As a result, Transdisciplinary STEAM framework was perceived as the most relevant to inform the model for supporting teachers to implement Transdisciplinary Outdoor STEAM education.

Despite the model being focused on transdisciplinary STEAM, we find it aligns with the requirements of outdoor practices. One of the criteria for outdoor learning is to ensure that the learning provides students with an authentic experience [13]. Similarly, this model emphasizes the authentic experience of learners as illustrated in the criteria under the problem-delivery and assessment practice dimensions. Therefore, we argue that the model can guide teachers in outdoor teaching practices and hence consider it as a framework for transdisciplinary outdoor STEAM integration.

However, the model has failed to explicitly guide teachers on how to systematically assess learners. The inclusion of standard alignment and problem skills (Table 1) is crucial to facilitating the assessment of learners because these remind the teacher to be consistent and focused on specific skills (i.e., problem solving skills). Furthermore, Quigley and colleagues [3] define what each category of the skills entails (See Table 2), which helps the teacher to assess learners. Nevertheless, the model has not explicitly guided the teacher on how to approach the whole process of assessment. Therefore, the need to complement this model with an explicit assessment model cannot be overemphasized.

4 Students' assessment framework in transdisciplinary outdoor STEAM

Since the Transdisciplinary STEAM education approach focuses on students' process of developing and applying skills from various disciplines [3, 7, 8], the assessment should focus on the process rather than a product. Therefore, we consider the best assessment framework in this teaching practice to be the one that tells the teachers what to focus on at various stages of students' process of engaging with the learning task(problem). Blum and Leiß [20] proposed an assessment framework for modelling in mathematics that teachers can use to scaffold students throughout the modelling process. The model consists of four phases namely understanding, simplifying, mathematising and working mathematically as illustrated in Fig. 2. The understanding phase involves learners' construction of a situation model as a result of reading and understanding the problem. The simplifying phase involves the students' creating a structure of the situation into a real model. In the mathematics phase, the students transform the real model into a mathematical model. The working mathematically phase involves students' use of mathematical tools such as formulas to solve the problem. Blum and Leiß [20] caution that these phases should be considered interactive rather than linear in the sense that sometimes the students may be working on the first phase while at the same time involved in activating mathematical tools which is the last phase. Blum and Leiß ([20], p. 2) posit,

> Of course, actual individual problem-solving processes are usually not as linear as it is suggested by this model. For instance, the second step, simplifying and structuring, is already influenced by the mathematical tools available to the problem solver, and often the process goes several times back and forth between the real world and mathematics.

Therefore, this indicates that teachers should not be following the model rigidly in such a way that they limit students to moving back and forth as they solve the problem. What is important is that they ensure that skills needed at least for

Table 1 A conceptual model for transdisciplinary STEAM integration

Domain	Dimension	Description	Criteria
Instructional content	Problem-based delivery	This dimension captures the ways in which teachers deliver materials from multiple disciplines in real-world problem-based ways—including concepts, methods, and approaches—and how they support the learning objectives	- Problem-focused instruction - Content purpose - Standards alignment - Discipline consideration
	Discipline integration	This dimension captures the ways in which teacher present material from multiple disciplines or content areas (science, technology, engineering, arts, and math) in clear and connected ways	- Content connection - Instructional strategies - Synthesis across the disciplines
	Problem solving skills	This dimension captures the ways in which teachers foster developing the underlying skills that are needed for effective problem solving	- Cognitive skills - Interactional skills - Creative skills
Learning context	Instructional approaches	This dimension captures the ways in which teachers structure the classroom environment, tasks, and resources to facilitate deep learning	- Inquiry rich - Multiple domains - Technology integration
	Assessment practices	This dimension captures the iterative process of refining instruction and evaluating learning in a real-world context using multiple forms of data	- Authentic alignment - Regular feedback - Data driven adjustments - Student reflection
	Equitable participation	This dimension captures the ways in which the classroom facilitates access and engagement in learning for all students, with specific attention to abilities and resources	- Task relevance - Diversity appreciation - Responsiveness - Student choice

Source: adopted from ([7], p. 5)

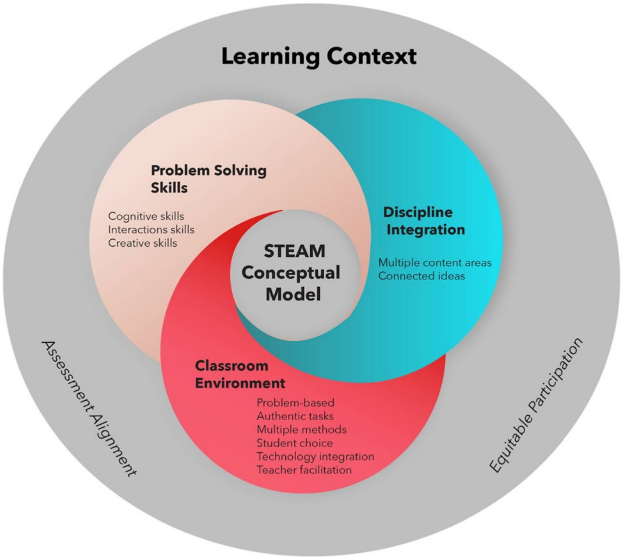


Fig. 1 The conceptual model for transdisciplinary STEAM integration. Source: adopted from ([3], p. 502)

Table 2 Classification of problem-solving skills

Cognitive skills	Abstracting, analyzing, applying, classifying, formulating, interpreting, perceiving, modeling, synthesizing, and questioning.. communication and collaboration
Interactional skills	Communication and collaboration
Collaboration skills	Ways in which students collaborate in investigations, design, creation, inquiry, and the ways in which students collaborate to connect knowledge evidence and experience
Creative skills	Designing, patterning, play, performing, modeling, and connecting ideas

Source: [7]

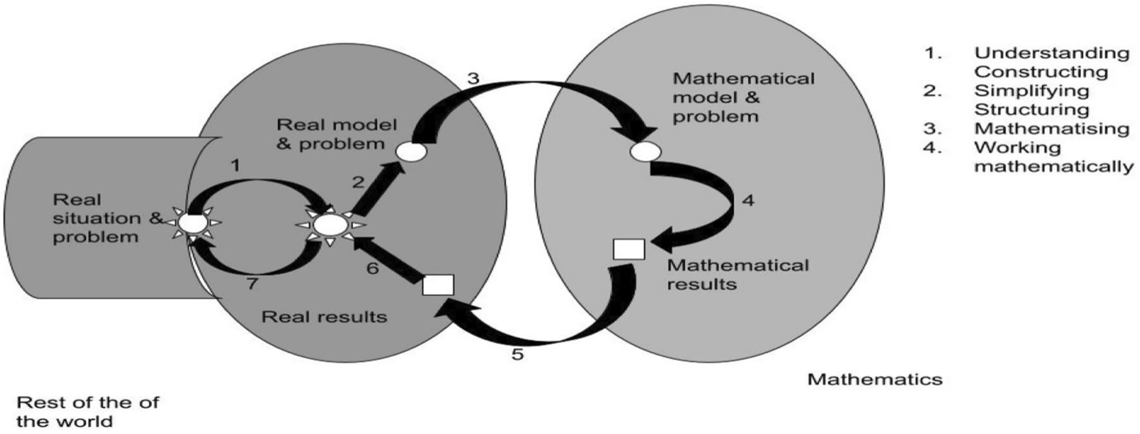


Fig. 2 Assessment framework modelling cycle. Source: adopted from ([20], p. 225)

each phase are reflected in students' learning process. Although the model was intended for modelling processes in mathematics, we propose it can be customized to accommodate the assessment of students' process of engagement in problem solving using skills from disciplines other than mathematics.

5 Mathematics, language, arts and technology for education for sustainability

Education for Sustainability (EfS) requires teachers to integrate sustainability concepts in their teaching by connecting their teaching subjects to how they can enhance the balance among society, economy and environment [21–24]. EfS calls for teachers to employ a transdisciplinary, action-oriented and learner-centred approach while focusing on developing sustainability competencies such as problem solving and normative competency [24–26]. We propose that teachers could implement EfS effectively if they are trained on the basis of the EfS framework that is different from their traditional teaching practices. The STEAM education approach is a way to implement EfS and we propose the model in this study that will facilitate teachers in the implementation of EfS.

Mathematics, language, arts and technology represent subjects that create the foundation for basic skills for students' future learning and problem solving [21]. Mathematics and language provide the language for students to understand the world. Through language and mathematics literacy, learners can understand and express the relationship between various world aspects [27, 28]. Arts, on the other hand, cultivate creativity among learners. The skills that learners acquire from arts such as painting, drawing, and dramatizing among others help them to realize that there are multiple ways of understanding and presenting the world [4, 29]. This, in the long run, enhances students' ability to develop various possibilities for solving problems [2]. Also, technology acts as a tool for learners to understand and express their world [2, 4]. Students can experience or express the world beyond their reach of common sense if they use technologies such as mobile applications. Based on this, we consider mathematics, language, arts and technology as core subjects in the implementation of EfS. However, to adhere to the framework of EfS, they should be taught as integrated and hence adopting the STEAM education approach.

6 The relevance of crises as teaching resources

Since they represent problems that human beings encounter in real-life situations, they are rich teaching resources for students to develop skills for problem solving. Research shows that students get motivated to participate in learning if what they learn is relevant to their future professionals or lives [30]. Thus, we believe that students will be convinced of the value of education only if they are involved in dealing with threats around their communities.

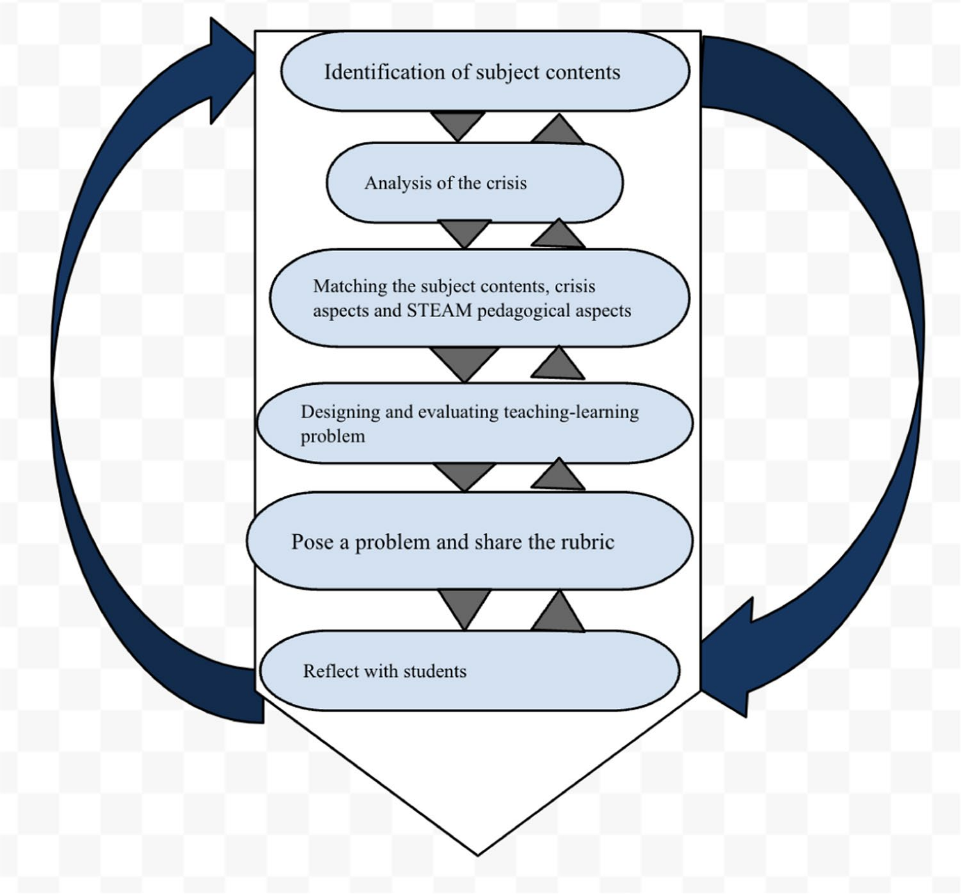
Since mitigation of crises requires integrated skills and direct involvement of students, it aligns with the framework of EfS as the learning becomes transdisciplinary, student-centered and action-oriented. Also, given that crises are something that students find outside the classroom yet support their learning, it falls into the framework of outdoor teaching practices. Overall, since the students' learning is through problem solving to develop skills from various disciplines, it aligns with transdisciplinary STEAM. Therefore, based on this, we conceive crises as relevant teaching resources for the transdisciplinary outdoor STEAM education approach for EfS.

7 The model for using crises in transdisciplinary outdoor STEAM education approach

Our proposed model is based on the conceptual mapping and reflections from the reviewed conceptual models for STEAM integration [3, 7] and problem solving through mathematical modelling [20]. The proposed model consists of six phases namely (a) identification of subject content areas (b) analysis of the crisis, (c) matching the subject areas, the crisis aspect and pedagogical aspects of transdisciplinary STEAM, (d) designing teaching–learning activities (problem) and evaluating teaching–learning activities (problem), (e) pose a problem and share the assessment rubric and (f) reflect with students.

Identification of the subject content areas requires the teacher to determine the content areas that he/she wants students to link with the problem. Quigley and colleagues [3] argue that subject contents are very important because they help learners to link what they learn in the classroom and the problem they engage in with. The phase of analysis of the problem requires the teachers to study all aspects and features of the crisis such as its scope, linked disciplines and trends among others. This will help him/her to determine ways in which the crisis can be linked to the content areas and other disciplines. The phase of matching subject content areas, crises and pedagogical aspects of transdisciplinary STEAM involves the teacher finding aspects of the crisis that can be linked with subject content areas and pedagogical framework either directly or indirectly. For example, if the teacher focuses on mathematics content such as statistics and realizes that the crisis has affected various contexts differently, he/she may consider such distribution of effects of the crisis as linked to statistics. Designing and evaluating teaching–learning activities (problem) requires the teacher to develop classroom activities that will facilitate students' development of the target skills in the process of solving the problem. In this phase the teacher identifies his/her role as the facilitators and students' role as discoverers/problem solver. The teacher can consult other teachers or students if he/she feels less confident in capturing some aspects of effective teaching–learning activities [7, 9]. In addition to evaluating the teaching–learning activities, the teacher should ask questions to see if the designed problem accommodates (a) learners' development of integrated skills from various disciplines (b) learners' individual needs (c) multiple teaching methods and (d) explicit assessment framework. The teacher can pilot the learning activities before the actual implementation to learn possible concerns of the designed problems. Pose problem and share rubric phase requires the teacher to assign the task to students and communicate explicitly his/her expectations. It is important that the teacher asseses the level of knowledge of learners on aspects that he or she expect learners to engage in. This will help the teacher to identify teaching and learning activities that should take place as a way to provide students with strong foundation for dealing with the assignment. For example, the teachers may be interested to know if students are conversant with some concepts and principles related to the problem they are dealing with. These principles maybe from the target subject or other disciplines. Based on what the teacher observed, he or she may lead the discussion of some concepts or provides hands-on activities to improve learners' skills and knowledge related to what they are working on. Also, the teacher should ensure presence to students through various communication channels to ensure students' access to personalized feedback. Reflection with students requires the teacher and students to assess the overall teaching–learning process to find what should be maintained and what should be rectified. However, it should be noted that the phases of this model are interactive rather than linear. It is possible for the teacher to go back to crisis analysis while working on the phase of posing a problem and sharing the assessment rubric. This aspect is tailored into the model to accommodate the dynamic nature of the classroom that requires teachers to continuously adapt to the emerging diverse classroom needs. This iterative aspect of the proposed model is illustrated in Fig. 3.

Fig. 3 The model for using crises in transdisciplinary outdoor STEAM education approach. Source (Author 2023)



The arrows in opposite direction between phases indicates that the interactivity between one phase to the next one. However, the two arrows in opposite direction from the beginning of the phase to the end, indicates that the iterative nature of the model is not limited to the adjacent phases but also distant phases.

7.1 Illustration of the application of the proposed model

Our focus was to apply the model for teaching four integrated subjects namely mathematics, language, arts and technology. Although these subjects can be taught in different levels of education, we assume one develops the teaching–learning activities with college students in his/her mind. Therefore, our consideration of each phase of the model was as follows.

7.1.1 Identifying subject contents

One can identify the contents of his/her interest from each of the subjects as presented in Table 3.

7.1.2 Analyzing the crisis

The teacher can choose COVID-19 as the target crisis because it is current and interesting globally based on its scope and impact. Although COVID-19 has many dimensions such as causes, effects and mitigation among others, the teacher may choose the dimension of mitigation, especially through vaccines, particularly because people are still vaccinated worldwide. One may consider the vaccination as rich in aspects that he/she can relate to the pedagogical framework (transdisciplinary STEAM integration) and subject contents from mathematics, language, arts and technology.

7.1.3 Matching the subject contents, crisis and the pedagogical framework

Pedagogically, one may view vaccines as resonating with transdisciplinary outdoor STEAM in various ways. The COVID-19 vaccine is a real phenomenon, which makes it authentic. It is also associated with various disciplines such as cultural, political, economic and scientific. Subject content-wise, the COVID-19 vaccine can be associated with contents from all four subjects in terms of understanding or presenting information related to its trend.

7.1.4 Designing and evaluating the teaching–learning activities

Here the teacher may ask students to work in groups to create a short video clip of not more than 4 min to present their views about the vaccine's trend in the community of their interest. The teacher can use self-reflection, peer review, and piloting with a few students to see if the problem has the potential to yield desired outcomes. The teacher may develop a rubric that focuses on aspects of subjects' contents and transdisciplinary outdoor STEAM. For instance, he/she may ask students to write a report about the whole process they went through. Showing them specific themes to include such as the knowledge that students used from different disciplines, the subject contents that were relevant in dealing with the problem and the technology they used among others.

7.1.5 Assigning or problem posing

Here the teacher can present the assignment to his/her students and make a follow-up as they perform the task. It is important that the teacher offer his presence throughout students' engagement with the learning activity to offer

Table 3 Contents identified from the four subjects

Subject	Contents
Mathematics	Probability, proportions, statistics relation and sets
Language	Reading, writing, speaking, listening
Arts	Drawing, dramatizing, painting
Technology	Digital literacy

learning support whenever needed. Depending on the students' level of knowledge, the teacher maybe required to do various activities such as introducing some concepts from the target discipline or other disciplines as a way to contextualize the problem posed to learners. Apart from classroom meetings, the teacher can determine other possible ways to interact with students such as emails to ensure students have access to personalized feedback.

7.1.6 Reflection with students

The teacher may use a reflection journal or small conference to reflect with students on their learning experience. Based on the reflection the teacher may go back to redo some of the previous stages. However, it should be noted that reflection is done throughout the process. The only difference is that reflection in the last phase is done by the whole class at once for the overall teaching-learning process.

From the sample of the proposed problem, students will need to understand various issues associated with the COVID-19 vaccine to be in a position to give their views. For instance, students will need to consider the influence of the political will, the economic power of the country, the supply of vaccines, the media and people's attitudes among others, on the existing trend. This implies that the students will be developing and using knowledge from various disciplines to solve the problem at hand. However, students will need to apply contents from mathematics such as statistics, proportion and relations to understand the relationship among these factors and how they altogether relate to the trend of COVID-19 vaccines. Figure 4 is an example of possible mathematical contents that students may find relevant in understanding how the COVID-19 vaccine trend is associated with various disciplines. Therefore, based on this, students will find the connection between the problem they are solving and mathematics.

On the other hand, language contents such as listening and/or reading, and speaking and/or writing will be used in collecting and sharing information. The use of technology will help the students in searching and disseminating information. For example, students can collect information from various websites or social media about what is going on in the community of their choice in relation to the COVID-19 vaccine. Likewise, they can use mobile applications to create video clips for sharing their views and posts on various digital platforms. Students will employ content from arts through various creativity that they will use in understanding and creating video clips. Thus, they will see the connection between arts and problem solving.

Moreover, the fact that students will share their views on the COVID-19 vaccine trend on COVID-19 after being informed about what is happening in the community, means they apply scientific principles. This entails the integration of science as

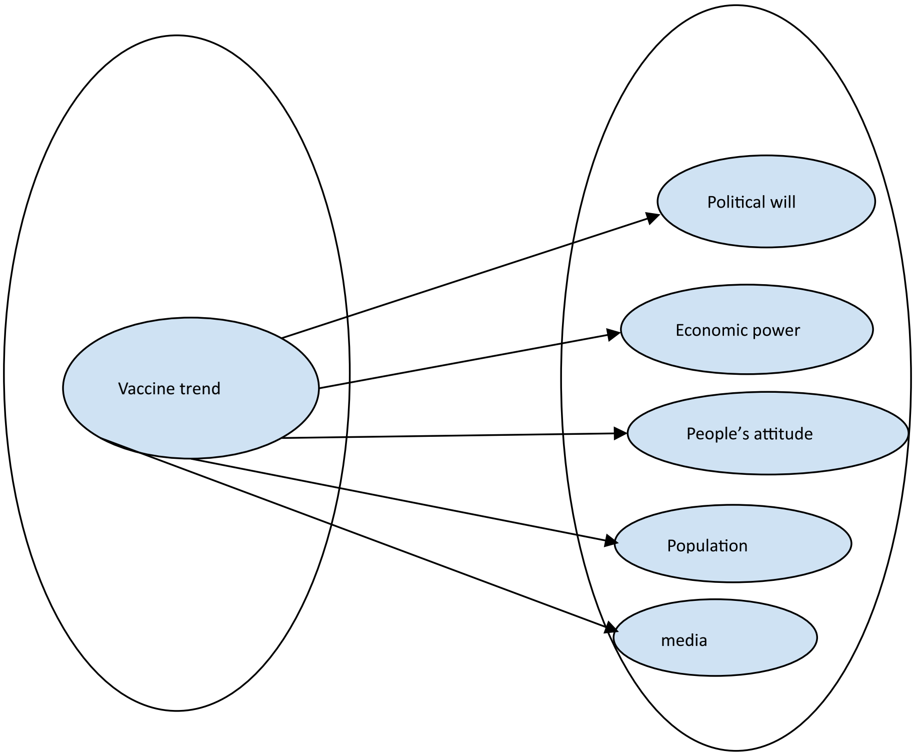


Fig. 4 Mathematical representation of issues to consider for Covid-19 vaccine trend. Source (Author 2023)

an element of STEAM. In addition, creating video clips is an element of using technology in fulfilling Engineering tasks. In this manner, two elements of STEAM (Technology and Engineering) will be integrated. The use of various design aspects such as colors and images in their video will capture the STEAM aspect of Arts. The STEAM aspect of Mathematics can be integrated into their work as they will apply it when connecting various aspects of the videos such as the relationship between time and contents, presentation styles and the audience.

We argue that the proposed teaching–learning problem to illustrate the application of the proposed model can facilitate teachers' implementation of transdisciplinary outdoor STEAM integration in their classes to promote EfS. This is because the nature of the problem from the crisis allows students to connect subject contents and the problem; various disciplinary knowledge and the problem; and aspects of STEAM and problem-solving process. Given the integration of STEAM aspects in the proposed problem, it is apparent that students will develop STEAM skills (cognitive, creative and interactional skills) However, the teacher can help students realize the link among the contents, multiple disciplinary knowledge and aspects of STEAM if the assessment rubric prompts students to identify and find the connection of these aspects. This is because not all the time students can see, for instance, the link between problem solving and mathematical skills or contents. To help them see these clearly, the teacher needs to guide them to realize this.

8 Discussion

Our proposed model indicates the possibility of using crises in facilitating transdisciplinary outdoor STEAM education approaches in teaching EfS. This implies that the model can promote equity in contexts with low access to technologies. We believe that by following this model teachers can easily employ crises in their classroom. Research shows that teachers' confidence in adopting a certain teaching approach is determined by the presence of teaching models that act as their guidelines for best practices [3, 7]. Therefore, we encourage teachers who wish to take advantage of crises in their classrooms to consider employing the proposed model.

The illustration on how one can apply the model makes the model more concrete because it clears misconceptions that may arise when the teacher is trying to understand the proposed model. Illustrations for how models can be employed give a clear picture to those who wish to employ the models in their teaching practices [3]. Nevertheless, teachers will need support from peers who are knowledgeable of other disciplines or they will need to be trained to be knowledgeable in other areas other than their teaching subject areas. As Quigley and colleagues ([7], p. 6) posit,

> Effective teaching requires high-level content expertise so teachers can highlight the connections between disciplines. However, teachers are not expected to be experts in all disciplines. Instead, teachers should be able to identify and locate gaps in their content knowledge and fill in the gaps with content area experts or resources. In this way, teachers may possess expert knowledge in some aspects of the content, but need to collaborate with others for areas of content for which they do not have a solid level of expertise.

Therefore, effective adoption of this model can be supported by initiatives to develop teachers' knowledge in various disciplines. We acknowledge that the consideration of using crises in teaching transdisciplinary skills is not new. Quigley and colleagues [3] used fishing malpractices to illustrate the conceptual model for transdisciplinary STEAM integration in teaching. To put in it in other words, this model shares common aspects with both models for general STEAM and Outdoor STEAM. For example, the emphasis on reflection and skills development among learners is also alluded to in 5E STEAM and Outdoor STEAM models. Consideration of learners' cultural contexts have been pointed out in the Outdoor STEAM model proposed by Quigley and colleagues [3]. However, the crisis-based models offer more insights on facilitating Outdoor STEAM using crisis as a vehicle to experience learning outside the classroom in the context with low-tech, which promote learners' participation in scientific inquiry. As mentioned earlier, the previous outdoor STEAM models are relying on the use of technologies such as a MathcityMap to contextualize learning activities [14, 16]. This makes the crisis model more inclusive than the previous models. In addition, the model could result into more meaningful learning outcome if the solution proposed by students mitigate the impact of the crisis, which can be instantly felt by the whole community.

9 Conclusions and recommendations

In this study we proposed the model for using crises in facilitating the transdisciplinary outdoor STEAM education approach. Based on the illustrations of the application of the model, we argue that the model has the potential to facilitate the transdisciplinary outdoor STEAM education approach for sustainability in integrated mathematics, language, arts and technology. However, the previous researchers considered crises of small scale within the teaching of a single subject [3, 7] while we have proposed the model for integrated four subjects (mathematics, language, arts and technology). Also, our model is illustrated through global crises (COVID-19) that students have actual experience rather than constructed classroom situations. Moreover, our model is accompanied by the assessment rubric to see if the integrated problems meet students' needs in transdisciplinary STEAM integration. We suggest that teachers should develop collaborative teaching as a way to cope with the need for teachers to be knowledgeable of content from multiple disciplines. We also urge educational stakeholders to facilitate training for teachers to understand transdisciplinary outdoor STEAM integration and to develop skills for its implementation.

Acknowledgements Authors would like to acknowledge everyone who provided us with constructive feedback during the development of the idea for this paper.

Author contributions MS is the primary author of this study, he was involved in conceptualization, writing data analysis and editing. ZL was involved in conceptualizing, data analysis, and proofreading. TH was involved in designing the research method, data analysis, and reviewing the abstract section. PC was involved in conceptualization of the idea and proofreading. FM was involved in conceptualization of the idea. To this effect, all authors hereby declare that they have read and approved the submission of this article for publication.

Data availability The authors declare that the data supporting the findings of this study are available within the paper.

Declarations

Competing interests The authors declare no competing interests.

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