INNOVATIVE RESEARCH JOURNAL VOL:3, ISSUE:2, 12-DECEMBER, 2023

https://doi.org/10.3126/irj.v3i2.61792

A Praxis/future-driven Inclusive Science Learning Through STEAM-based Design Thinking Project

Pratima Thapaliya

pratima_phdsteam2022@kusoed.edu.np

Sanothimi Campus, Bhaktapur, Nepal

Abstract

Engaging the prospective science teacher in a praxis/future-driven orientation holding transformative STEAM-based design thinking project designing and implementing approach is new in the Nepalese science teacher education program. It could support critically reflecting on- action and in-action for reducing the gap between theory and practice for action. This paper attempted to explore the research question: How could I engage prospective science teachers in a STEAM-based design thinking project for a praxis/future-driven inclusive science learning? So, the transformative action research methodology has been launched in my workplace purposively by selecting eight research participants. I designed and implemented the STEAM-based design thinking project in my science classroom. It motivated my research participants to know this approach's conceptual, theoretical, and practical dimensions by actively participating in critical discourse. I viewed my and my participants' feelings, beliefs, and actions from the theoretical lens of critical-reflexive Bildung, which has the learners' high content and skills development orientation. It helped me to visualize the deep-rooted disempowering forces and the viable alternative ways for action. Moreover, it invited me to change my cultural reproduction-dominated science teaching. This research also envisages a curriculum as a mandala, pedagogy as/for the public good, and assessment as/for learning for praxis/future-driven science classrooms.

Keywords*: inclusive science, STEAM approach, design thinking, mandala, and praxis/future-driven*

Received: 10 october, 2023 Revision Accepted: 22 november, 2023 Published: 12 December, 2023

Introduction

As a science teacher educator and STEAM learner, I want to improve and transform my professional practice by implementing the transdisciplinary STEAM approach in my science classroom. This innovative approach could respond to discipline-based pedagogy (Nepal & Shrestha, 2023) and transform my factual, conceptual, and procedural (to some extent) knowledge and skills in delivering cultures. I agreed with Pritchard (2009), who emphasized the learners' engagement while learning. In doing so, a clear focus and goals considering the pupils' preexisting knowledge, the level of difficulty, sociocultural context, and the aim to move children's learning across the zone of proximal development are the guidelines that can be applied in planning the lessons. Preparing prospective science teachers with good competency and quality in the world of work for solving real-world problems is challenging. In this context, I realize to involve the prospective science teachers in transdisciplinary STEAM (Science, Technology, Engineering, Art, and Mathematics)-based design thinking

(DT) projects to develop their capabilities to connect science education with learners' daily lives. Mastering a set of per-specified tasks (end) requires the learners to minutely learn the detailed sequences of learning tasks to attain this end. It might need to be more for addressing the burning issue of social equity, inclusion, and sustainable development. For sustainable development to be successful, we could enrich trans-disciplinary STEAM education, which is also a worldwide need for education (Taylor, 2018). I also attempted to use the trans-disciplinary STEAM approach in science teaching for praxis/future-driven inclusive science learning. The arts in STEAM education have a crucial role in transforming our practice. It creates an opportunity for the learners to reflect on their experiences, feelings, beliefs, values, and assumptions and connect the content with their everyday lives. The role of art is required for creating interconnectedness and making the invisible visible (Ibera & Sommerstead, 2019). Furthermore, an artful teacher must prioritize in-depth thinking and reflection while designing educational projects or programs. The aesthetic learning process emphasizes these aspects. Through this aesthetic learning process, we can change our learning journey from linear to longer, more challenging, and obscure (Chemi, 2014).

In my research context, inclusive science learning represents the infusion of various compartmentalized knowledge, skills, and ideology of Western Science Worldview, and cultural and ecological knowledge of Non-western Worldviews essential for generating a holistic understanding of ourselves and our connectedness. Transdisciplinary approaches (like STEAM) assist in understanding the integrated nature of knowledge and employing critical skills by transforming the disciplinary barriers that lead to success (Kennedy & Sundberg, 2020). I want to connect the STEAM approach in higher science teacher education to developing prospective science teachers as an agency of social transformation. In this context, this paper aimed to develop STEAM-based project designing and implementing skills for prospective science teachers. So, I purposively conducted the transformative action research in my workplace by selecting eight research participants based on the research question: How could I engage the prospective science teachers in a STEAM-based design thinking project for a praxis/future-driven inclusive science learning? I also realized how to transform the hegemonic and decontextualized science teaching culture embedded in my professional practice. Therefore, I focused on viewing the trans-disciplinary STEAM approach-based designing project designing, implementing, and reflecting phases through the critical hermeneutic *Bildung* tradition that focuses on a democratic and critical approach to transformative learning. In this DT project, I also emphasized actively involving my research participant by creating a helpful science learning environment for fostering transformative science learning in general education and TVET programs for transforming the compartmentalized science knowledge and skills-delivering culture.

Theoretical Referent

Bildung's theory also emphasizes transforming the learners' personalities, feelings, relationships with others, and lifelong learning. The learners can cultivate the self by themselves. The learners engage in modifying his/ herself. *Bildung* means an individual trying to understand the cosmos and edify herself or himself (Gadamer, 1982). Critical-*hermeneutic Bildung* tradition is connected with "educational practices and a democratic and emancipatory view of society" (Sjöström & Eilks 2020, p.48). It highlights cultivating *Bildung* for all persons having vivid human capacities. There is a clear articulation of a democratic and critical approach in this tradition, which makes it an advanced concept of educational *Bildun*g (Sjöström & Eilks, 2018). According to Sjöström and Eilks (2020, pp. 65, 66), "recognizing contemporary interpretations of *Bildung* involves rethinking science education toward a more critical view to allow transformative learning of science, which promotes capabilities in the student for a self-determined life and responsible citizenry." Therefore, humanized science education (Schulz, 2009), transformative learning, and sustainability education are the fundamental ideas of critical-reflexive *Bildung* (Sjöström et al., 2017).

Methodology

Transformative Action Research (TAR) is an empowering approach that supports generating and using knowledge (Malcolm et al., 2009). Furthermore, it can generate cross-cultural collaboration (Toomy, 1997). It assists in fostering the participation, action, reflexive inquiry, achievement, and dialectical critique of community members and researchers, which are integral to social transformation (Malcolm et al., 2009). I followed Zuber-Skerritt's (1996) five steps of action research一a cyclical strategic planning process; implementing the plan (action); observation, evaluation, and self-evaluation; and critical and self-critical reflection. He argues that action research is emancipatory whenever its aims are not limited to the participants' technical and practical improvement and a better understanding of transforming the existing boundaries and conditions. To address my research agenda, I acknowledged these transformative notions of TAR while launching my research project in a real science classroom.

Discussion and Meaning-making

I discuss the STEAM-based DT project designing and implementing journey by viewing through the lens of critical-hermeneutic *Bildung*. It helped me to showcase the prospective science teachers' engagement in the STEAM-based DT project. Moreover, I also generated the meanings by being aware of the spirit of my research question and TAR methodology.

Planning the STEAM-based Design Thinking Project

As a transformative-minded STEAM learner, I realized the need for the STEAM approach to transform the chemistry teaching culture. Designing and implementing the STEAM approach-based curriculum, pedagogy, and assessment could help to understand the learners' sociocultural backgrounds, beliefs, values, assumptions, and feelings (Thapaliya, 2023). So, I designed the trans-disciplinary STEAM-based design thinking (DT) project -*"Let's Make Our Favorite Soap at Home"*- to transform my chemistry teaching culture. The project's learning outcomes were constructing a meaningful understanding of soap's conceptual, theoretical, and practical knowledge and skills to foster the learners' entrepreneurial skills. In doing so, I listed the required materials and elaborated on the learners' activities in DT's empathizing, defining, ideating, prototyping, and testing steps (Culen & Gasparini, 2019). The STEAM education can support for developing the transversal skills (Dahal, 2023) that include thinking skills (such as critical/creative thinking); multiliteracy skills (like basic/technical/visual literacy); and inter/intrapersonal and citizenship skills (like self-management, honesty, collaboration, respect, civic responsibility) for developing the etnical, moral, social, and political awareness of basic-level students [Curriculum Development Centre. (CDC, 2019)]. In this regard, I also developed the rubrics for assessing the learners' developmental aspects like knowledge, soft skills (such as collaboration, critical thinking, communication, and creativity), hard skills (handling the laboratory apparatus), and self-evaluation. It helped to assess the learners' progress in action on action and provide the ways for action.

The course facilitator of teaching and learning subjects of MPhil encouraged me to develop plans and received feedback for effectively implementing the plan in my real professional practice. Moreover, I collaborated with my trans-disciplinary STEAM colleagues and improved my project based on their feedback. They suggested rehearsing the plan before lunching in the actual classroom. Therefore, I piloted the project and recorded the session to use that video as learning material for my research participants. Furthermore, I managed all the required apparatus, chemicals, and recording systems for recording the teacher-learner collaborative project work.

Implementing the Plan

In this process, I disseminated STEAM-based DT projects to my learners. In doing so, I shared my lived experiences about soap in my teaching and learning journey. I explained some basic ideas of STEAM education and conducted the soap-making project as follows.

Empathize

At first, they conducted an in-depth interview exploring their preexisting learning experiences and feelings related to soap. Moreover, I observed their engagement in designing soap-related pictures, charts, and PowerPoint presentations. For illustration, they easily defined what is soap and the saponification process, where we can use soap, and also have the skill to test the cleaning action of soap based on their surface tension. However, they felt they were beyond the actual soap-making activity and flourishing their entrepreneurial skills. At that time, I also realized that we could have made meaningful learning if we had taught chemistry by designing the STEAM project. Furthermore, I was more interested in assessing their deep understanding of soap; therefore, I engaged them to demonstrate the cleaning action of soap by using the soap that I had made in the piloting process. I asked how, why, and related questions and critically observed their responses.

Define

After understanding their lived experience and feelings, I encouraged them to define soap-related problems. Initially, they felt it was difficult and became silent for a moment. Again, I motivated them to engage in the class discussion without feeling shy, fearful, and pressured because we all are in the process of learning to learn. Then, they felt accessible to some extent and tried to define the problems. They said, *“We memorize soap's conceptual and theoretical ideas without sense-making. Our practical work also primarily focused on 'cookbook' knowledge consumption rather than solving our real-world problems. Hence, there is a need for meaningful learning that develops our entrepreneurial skills.”* As a constructivist teacher, I supported them in defining the problems.

Ideate

Learning is an iterative and slow process (Taber, 2015). The learners' prolonged engagement can consolidate the learning and support meaningful science learning. We could introduce a new concept by understanding the learners' preexisting concept that helps to reduce the viable alternative conception in science education and support holistic learning. I invited my participants to actively participate in group work to concertize the abstract concepts they realized in the soap-making project. They deeply engaged in a group using the 'think-pair-share' method and introduced a trans-disciplinary STEAM approach for solving their real-world problem.

Prototyping

In this step, all participants engaged in a collaborative activity for designing the quality soap with attractive outlooks so the consumers could be easily attracted and become regular consumers. Hence, we can get more profit that can motivate the producer to produce the soap on a larger scale. To make their prototype more functional, I suggested observing the related video developed by myself and others as references. Furthermore, I also shared my lived experiences while designing diverse colors, sizes colors, and sizes. They carefully listened to my narratives and observed that video. Then they realized the importance of locally available medicinal plants (like *title pati*), fruits (like mulberry), and some kitchen chemicals (such as turmeric powder, tea powder, etc.) in the soap-making process. In this regard, I also felt that science teachers can acknowledge the diverse cultural contexts of students (Pokharel, 2023) for culturally sensitive science learning.

They made extract varieties using them and designed the types of soaps with various colors, shapes, and sizes. From my soap-making experience and the lab assistants' support, we engaged them to compress the semi-solid-state raw soap to set the soap molecules in a compressive manner; therefore, the remaining part of the soap can be in a solid state while being used for cleaning. Similarly, I also critically observed their activity and motivated them to participate in collaboration, individual contribution, and commitment. The student teachers in the present can become science teachers in the future. Hence, they need overwhelming support to foster their teaching skills. Therefore, I provided optimal support and feedback in their activity. In this regard, Taber (2015) argues that we need to act as optimal scaffolders to connect the cognitive and affective domains in teaching-learning as constructivist teachers.

Test

This is necessary for refining, improving, and discriminating the project work. I suggested my research participants test the cleaning action of the soap. After a few days, I did that testing activity because the saponification process can take at least one day. Then I motivated them to share their feelings. They were more excited while using that soap and positively responded to its efficiency. Due to the pandemic situation of covid-19, my participants could not test their soap. However, they observed their soap shape and color in the virtual meeting. Moreover, I shared the working efficiency of their soap by washing my hands. At the end of the project, I encouraged them to reflect on their learning outcomes by designing a concept map and presenting it in a classroom. In doing so, they can integrate the various concepts, theories, and practical skills they learned from the project, draw several concept maps and pictures, and calculate the soap price and volume. They integrated several compartmental ideas of chemistry, physics, biology, and mathematics in their concept map and presentation. Moreover, they also incorporated the engineering design idea by designing various soaps and enhancing communication skills and creativity by using simple and modern technology. Likewise, they focused on eco-spiritual concepts such as biodegradable soap formation for sustainable development.

Observation

I used videos montages, and technology to communicate the idea of homemade soap; applied engineering and mathematical ideas in the process of 3D soap designing and labeling its appropriate prices; and also incorporated the humanistic lens of arts for designing the various shapes, colors, flavors soap for attracting the public's attention as well as enhancing the learners' creativity and entrepreneurial skills. Meanwhile, I critically observed the students' engagement in the entire project. I also created a dialogic space for assessing their knowledge, skills, and outcomes. For instance, I asked them, "Why did you add lye in water rather than water in lye?" And I critically observed their facial expression and response. They looked at one another and thought sometimes. Most of the participants were unable to answer my question. After some time, one participant said it helps protect us from an accident. I elaborated on his answer and thanked him for his contribution.

Evaluation and self-evaluation

The STEAM-based DT project focused on evaluating the learners' development aspects instead of quantifying their achievement. In doing so, I developed the rubrics for evaluating my participants' learning progress. I divided the learning outcomes into several criteria, like students' active engagement, hard skills and soft skills development process, integrated knowledge construction, presentation skills, and self-evaluation. After involving my participants in the evaluating and self-evaluating criteria of rubrics, we could practice the rubrics for realizing *assessment as/ for learning* that occurs throughout the teaching and learning process to examine the student's knowledge, understanding, and skills. Students could ask questions and use a range of strategies (Harapnuik, 2020).

Critical and Self-critical Reflection

The course facilitator of teaching and learning subjects of MPhil and my trans-disciplinary STEAM colleagues supported me in the project designing phase. They gave feedback for doing things better. I addressed their comments and improved my project plan; in the implementing phase, I listened to the learners' lived experiences and preexisting knowledge and also provided enough time for their prolonged engagement to foster the learners' developmental aspects and consolidate the learning outcomes; in observing phase, I critically observed the learners' collaboration, and presentation and asked questions for assessing their deeper standing; in evaluating phase, I administrated rubrics for evaluating the learning progress. I honestly followed a trans-disciplinary STEAM approach and attempted to act as a *critically reflective practitioner* (Thapaliya, 2023) for lighting on the stronger and weaker sides, in each step of the TAR cycle by incorporating the STEAM approach. Critical reflection is the foundation for uncovering and challenging hegemonic assumptions. The critically conscious teacher neglects the naive assumption by exploring the accuracy and validity of our teaching assumption. The assumptions are the taken-for-granted beliefs that direct our teaching-learning action (Brookfield, 2017). I motivated my participants to ego turning upon the self (Grundy, 1987) by creating dialogic space.

Academic communities have continuously raised the issues of an integrated curriculum, transformative pedagogy, and assessment as/for learning (Lamichhane & Luitel, 2022). In this context**,** after deeply engaging in the research project designing, implementing, and report writing process, I would like to notice the possible implications as follows for fostering a transforming science teaching culture.

Curriculum as Mandala: The *'mandala'* represents wholeness and completion (Fremantle, 2003). "The whole sphere is expressing the vivid reality of life" (Trungpa & Rinpoche, 2010, p. 263). In Eastern traditions (Typically, Hindu and Buddhist), the complex web of human life and their activities are represented through mandala (Gautam, 2017). An inclusive mode of reasoning is beneficial for generating a holistic understanding of ourselves and our connectedness (Taylor, 2014). The present science curriculum seemed like a collection of prescribed content or s*ubject matter* (Schubert, 1986). Therefore, I realized the interconnectedness of science learning with other disciplines of STEAM and the environment. Metaphorically, I would like to envisage the science *'curriculum as mandala'* to integrate the trans-disciplinary STEAM approach for authentic, inclusive, and meaningful learning.

Pedagogy as/for Public Good: Delivering the factual knowledge and skills of science without connecting with learners' sociocultural context that might be beneficial for a few students of the class (so-called intelligent students) Such a 'banking' concept of pedagogy (Freire, 1993, 2018) is inadequate for 21st century citizens. In this context, the transformative STEAM pedagogy could contribute to developing holistic thinkers who can solve real-world problems and support them to achieve the objectives of the curriculum. According to Chemi (2014), an artful classroom helps to integrate the cognitive and emotional aspects and emphasizes mindfulness. The learners can dare to experiment, learn, and deal with complexity because arts support generates an emotionally safe environment. The teacher can act *as a* *facilitator* and successfully implement the curriculum. We could create a nexus between cognitive and affective domains and address the need for a larger mass in an artful science learning milieu. For complex role performance and life-role functioning, we need to move from the traditional and transitional zones to the transformational zone (Spady, 1994). We can apply innovative pedagogy like STEAM pedagogy, ‘3C-R’ (Connect, Concept and Context-Reflections) for actively enfolding the learners’ pre-existing knowledge; involving in hands-on and mind-on activities; and applying the constructed knowledge for addressing the emerging issues. In this learning process, reflection is the central part of knowing their perceptions, practices, and emergent learning (Dahal, 2023). They can support fostering transformative science learning, creating multiple futures, and addressing the needs of a larger mass instead of a few people.

Assessment as/for Learning: A more structured paper-pencil test needs to be revised to assess the learners' deep understanding or sense-making process.

After engaging in this research work, I experienced that we could assess the learning progress of each learner in the process of learning. The transformative assessment goes beyond the *assessment as 'of' learning* (i.e., summative process like standardized test) for making better sense of learning in their real-life world. It also focuses on *assessment as/for learning* approaches (i. e. formative processes like continuous assessment systems). It could assist in developing the knowledge, skills, dispositions, and positive behaviors of learners (Qutoshi, 2016). Thus, I also call for practicing assessment / for learning in science education to assess learners' developmental aspects.

Conclusion

We could incorporate a transformative and transdisciplinary STEAM-based design thinking approach in science classrooms. It provides quality learning opportunities to prospective science teachers for autonomously involved in transformative knowing, doing, being, and valuing cultures. I realize the need for reformation/transformation in science curriculum, pedagogy, and assessment practice to counter the domination of disciplinary egocentric content-delivering cultures fostering prospective science teachers' higher learning abilities (like entrepreneurship skills). Metaphorically, I envisage the science *curriculum as a mandala* for making a holistically meaningful understanding rather than in a small chunk; *pedagogy as/for the public good* for addressing the need of larger masses of students rather than delivering the canonical science content and skill to a few people; and *assessment as/for learning* for assessing the learner's developmental aspects rather than a more measuring the rote memorizing capacity of students through the structured paper-pencil test. In other words, the research demands high content and skill orientation in science curriculum, pedagogy, and assessment systems for individual and social transformation. *We can teach science well with or without having the students learn.* This study might be significant to other novice science teachers, prospective science teachers, science teachers, and researchers to be aware of science teaching and learning from the transformative viewpoint. Because *teaching and learning science are interconnected but not synonymous.* Furthermore, they *could counteract the domination of scientific knowledge and skills delivering and receiving cultures without connecting with learners' sociocultural context for* praxis-driven and future-driven inclusive science learning.

References

Brookfield, S. D. (2017). *Becoming a critically reflective teacher* (2nd ed.). San Francisco, CA: Jossey-Bass.

Chemi, T. (2014). The Artful Teacher: A Conceptual Model for Arts Integration in

Schools. *Studies in Art Education, 56*(1) 370-383

Culén, A. L., & Gasparini, A. (2019). *STEAM Education:* Why Learn Design Thinking?: Science, Technology, Engineering, Arts and Mathematics. *Promoting Language and STEAM as Human Rights in Education (pp.91-108).*

Curriculum Development Centre (CDC). (2019). *Curriculum of Basic Level (Grades 1-3).* CDC, Sanothimi, Bhaktapur.

Dahal, R. (2023). Autoethnographic reflections on navigating the path to empower teachers' transversal skills. *Journal of Transformative Praxis, 4*(1), 68-83.

https://doi.org/10.51474/jrtp.v4i1.670

Freire, P. (1993). *Pedagogy of the Oppressed*. Burns & Oates.

Freire, P. (2018). *Pedagogy of the Oppressed*. Bloomsbury Publishing USA.

Fremantle, F. (2003). *Luminous emptiness: A guide to the Tibetan book of the dead*.

Shambhala.

Gadamer, H.G. (1982). Truth and method (G. Barden & J. Cumming, Trans.). New York: Crossroads.

Gautam, S. (2017). Transformative Research Space Through Epistemic Indeterminacy of Mandala. *Journal of Education and Research, 7*(1), 25-35.

Grundy, S. (1987). *Curriculum: product or praxis?* Lewes: Falmer Press.

Harapnuik, D., (2020). Assessment OF/FOR/AS Learning. Creating significant earning environment. Retrieved from https://www.harapnuik.org/?p=8475

Ibarra, L., & Sommerstad, A. (2019). Notes from artists: Making the invisible visible and art as the bridge to science and interconnectedness. In Z. Babaci-Wilhite (Ed.), *Promoting language and STEAM as human rights in education* (pp. 151-159). Singapore: Springer.

Kennedy, T. J., & Sundberg, C. W. (2020). 21st-century skills. In B. Akpan & T. J. Kennedy (Eds.), *Science education in theory and practice: An introductory guide to learning theory* (pp. 479–496). Springer International.

Lamichhane, B. R., & Luitel, B. C. (2022). A critical rendition to the development of mathematics education in Nepal: an anticolonial proposal. *British Journal for the History of Mathematics, 38*(1), 3–23. https://doi.org/10.1080/26375451.2022.210983

Malcolm, C., Gopal, N., Keane, M., & Kyle, W.C., (2009). Transformative action research: Issues and dilemmas in working with two rural South African Communities. *Researching Possibilities in Mathematics, Science and Technology Education.* 193-212.

Nepal, K., & Shrestha, I. M. (2023). Rethinking Pedagogy Through Storytelling in School Mathematics. *Journal of Transformative Praxis*, *4*(1), 29–41. https://doi.org/10.51474/jrtp.v4i1.669

Pokharel, J. K. (2023, July 6). Cultural Discontinuity as a Major Problem of Rai Students' Learning of Mathematical. *Innovative Research Journal*, *2*(2), 76– 85. https://doi.org/10.3126/irj.v2i2.56160

Pritchard, A. (2009). *Ways o f l earning: Learning theories and learning styles in the classroom (2nd ed.).* New York and London: Routledge.

Qutoshi, S. B. (2016). Creating my own living-theory: An autoethnographic-soulful inquiry. *Educational Journal of Living Theories, 9*(2), 60-86. https://ejolts.net/node/287

Schubert, W. H. (1986). *The curriculum: Perspective, paradigm and possibility*. Macmillan.

Schulz, R. M. (2009). Reforming science education: Part I. The search for a philosophy of science education. *Science & Education, 18*, 225–249.

Sjöström, J., Eilks, I. (2020). The *Bildung* Theory—From von Humboldt to Klafki and Beyond. In: Akpan, B., Kennedy, T.J. (eds), *Science Education in Theory and Practice. 55 - 67*, Springer. https://doi.org/10.1007/978-3-030-43620-9_5

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of *Bildung* in the international science education literature, its potential, and implications for teaching and learning. *Studies in Science Education, 53*, 165– 192.

Spady, W. G. (1994). *Outcome-based education: Critical issues and answers*. Arlington, VA: American Association of School Administrators.

Taber, K.S. (2015). Meeting educational objectives in the affective and cognitive domains: Personal and social constructivist perspectives on enjoyment, motivation, and learning chemistry. In M. Kahveci, M. Orgill (Eds.), *Affective dimensions in chemistry education* (pp. 3-27). Verlag Berlin Heidelberg: Springer.

Taylor, P. C. (in press/ 2014). Contemporary qualitative research: Towards an integral research perspective. In S. K. Abell and N. G. Lederman (Eds.). *Handbook on research on science education*. New York, NY: Routledge.

Taylor, P.C. (2018). Enriching STEM with the arts to better prepare 21st century citizens. *Proceedings of the 5th International Conference for Science Educators and Teachers* (ISET) 20017 (pp. 020002-1-020002-5), Phuket & Melville, NY.

Thapaliya, P. (2023). Enhancing critical reflective practice in science education through a STEAM approach. *Journal of Transformative Praxis, 4*(1), 54-67. https://doi.org/10.51474/jrtp.v4i1.575

Toomey, R. (1997). Transformative action research. *Educational Action Research*, *5*(1), 105–121. https://doi.org/10.1080/09650799700200022

Trungpa, C. & Rinpoche, S.M. (2010). *Cutting through spiritual materialism*. 263, Shambhala.

Zuber-Skerritt, O. (1996) Emancipatory action research for organizational change and management development. In O. Zuber-Skerritt (ed.) New Direct-ions in Action Research. London: Falmer, 83–105.