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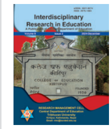

Learner's Engagement through Multi-layer Concept Map in Science Learning: A STEAM Perspective

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Concept map, STEAM literacy, multidisciplinary, collaboration, transformative learning

Abstract

This research focuses on the empirical investigation of STEAM literacy as encompassing techniques derived from implementing multi-layer concept map techniques in the science classroom. As a pedagogical tool for student learning and teacher instruction, it offers students more significant opportunities to expand their understanding of and gain engaging experiences in multidisciplinary areas like STEAM subjects. It also enhances the learner's own choice of concept and shares the designed concept map with/within the group accompanied by dialogic scenarios. Methodologically, it is based on participatory action research (PAR), and it is a qualitative-dominated mixed design, which tries to promote expanded interest and self-directed technological and artistic learning practices in science through the perspective of STEAM literacy. The meaning-making process through the genre of interpretations is directly tested in the field of action and observation and the Likert scale-based reflective statements make results more trustworthy. Embedded in the consequences of overall data is the fact that STEAM literacy practices are developed in the science classroom through this tool. Due to PAR and more engagement of learners, it enhances a variety of diverse learning opportunities and sharpens learners' independent thinking, creativity, and action.

Introduction

Concept maps are the graphic representation of concepts that make relationships between ideas (Jang, 2010), foster meaningful learning, and create a significant relationship between concepts (Novak, 1984). Novak and colleagues first developed concept mapping from their research on learners' science learning and initially utilized it to document the conceptual understanding and development of children's science concepts. In the previous time, it was used as one visual learning tool, a "reasoning tools" (Kohlberg, 1984 cited in Drake et al., 2005) which connect a pair of concepts with a one-way (unidirectional), and multiple arrows

(Bi-directional or Multidirectional), then label the arrow with a word or short phrase that describes the relationship between two or more than two concepts, ideas, related problems and many more. The learner can use these connected terms and graphics for reading sentences and creating a story and poem. Technically, these sentences and terms (concept, reason, use, etc.) are linked by an arrow and phrase and are called propositions (Vanides et al., 2005).

Currently, various software is developed to design concept maps such as Infographics, wiki, etc. Before this, the traditional concept was used only to develop the concept of learner and design, interlinking to the concept. But now I think it can be used in a different way such as design concept map activities (collaboration), open-ended activities that allow students to construct their ideas, fostering design thinking, dialogue creating, sharing (communication), writing a story and many more (Artistic literature). Ausebel (1968) meaningful verbal learning model as the theory behind their work. This theory states that when learners face unfamiliar material, a structure to help them organize the concepts may foster their learning (Jang, 2010). It is a choice between two or more courses of action when obstacles on each side hinder the decision as to which course to pursue. If we look at the maps used in teaching, we can see two main types: the first is prepared by dividing the subject matter into small sections, and the second is prepared by connecting different levels from simple to complex. In this study, the second type of map is used as a multilayer concept map. It is a hierarchically arranged set of ideas and can be developed based on scientific concepts, ideas, and reasons. It has six basic layers based on bloom taxonomy. The successful Science, Technology, Engineering, Art, and Mathematics (STEAM) pedagogical strategies (Ethical Dilemma Story Pedagogy, Art-based learning, Story-telling, etc.) are currently being implemented and some are in ongoing process but in the case of the relation between transformative learning, however, the connection of concept map with STEAM perspective is a very less researchable issue. Thus, this study focused on how to use this tool and in what ways it engages the learner in STEAM literacy. Furthermore, it tries to explore how concept maps engage the learner to enhance different classroom activities (student participation, critical reflection /critical self-awareness, and emotional and affective aspects) and develop STEAM knowledge, skills, and attitude (STEAM literacy).

From Concept Map to Multilayer Concept Map: A Multi-dimensional Learning Tool

The Concept Mapping learning tool was developed by Novak and his research team based on Ausubel's assimilation theory (Novak, 1984) and principles of schema theory, for meaningful learning. It is a graphical representation of the interconnection between prior knowledge or experience to further knowledge or present experience which leads from the known to the unknown. This process produces a two-dimensional representation of the ideas (Dansereau et al., 1995). Concept maps link new learning to previous knowledge, organize thoughts, stimulate critical thinking, and display conceptual relationships graphically (O'Brien, 2007). Concept mapping is most effective while learners create their maps throughout the learning process and connections between concepts, they get the opportunity to engage with their own real experiences.

In the process of utilization of concept mapping in the classroom, learners require the internalization of content and stimulate self-awareness, reflecting their own views. Similarly, they get an opportunity to identify and resolve the problems actively. The mapping process facilitates the fundamental constructivist requirement for learners that be allowed to manage, construct, and share their understanding of ideas and experiences (De Simone, 2007). Therefore, concept mapping is considered to be essential for a constructivist learning approach and problem-solving. A concept map may facilitate learning by enabling the learner to code a spatial frame for indexing and efficiently retrieving concepts, studying a map in which meaning is signaled.

By node proximity, shape, and color can enhance learning (Nesbit & Adesope, 2011).

Since 1970 concept mapping has been used in educational activities for various purposes as a learning tool (Chen et al., 2003), evaluation and program assessment tool (Liu, 2004), and reflective tool. Finally, the Concept map can be used as multiple learning tools such as instructional tools, assessment tools, reflective tools, and self-pacing learning tools. Furthermore, the use of this technique matches the learning style and ability of learners. The learning process with the concept maps tool indicates that students' learning role in their ability to perform engagement in active learning (BouJaoude & Attieh, 2008). Hence, a learning strategy facilitated by concept mapping may be effective for student engagement.

Moreover, a concept map perhaps useful for a meaning-making process to the learner in teaching-learning activities because it engages learners with constructive cognitive processes like integrating, elaborating, reorganizing, and reformatting the existing knowledge structures and linking knowledge elements with contexts and situations. Finally, it may facilitate learning activities in multiple ways, thus, this study uses a multi-layer concept as a multi-dimensional learner engagement tool. Because due to the different layers of Bloom's taxonomy, it focuses on engaged learning, active participation, self-reflection, critical thinking, social learning, emotional learning, and real problem-solving.

The Connection of Multi-layer Concept Map with STEAM Perspective

Different kinds of transformative learning-based approaches (EDSP, Arts-based learning, STEAM-based) are introduced into Australian schools over a decade ago (Taylor, 2016). In such conditions, the use of the concept map period focused on creating concept map activities and it can evoke lower-order to higher-order thinking of Bloom's taxonomy such as remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001 cited in Wilson, 2016) as well as critical thinking and critical reflection. In transformative science learning, Taylor and Taylor focused on the reflection process rather than on argumentation skills or moral reasoning (Taylor et al., 2019), and the side Science, Technology, Engineering, Art, and Mathematics (STEAM) pedagogy is based on the philosophy of transformative learning which can interconnect different ways of coming to know i.e. cultural-self knowing (self-realization), Relational knowing, critical knowing, visionary and ethical knowing and knowing in action (Taylor, 2015). In the above Taylors' argument, the term "interconnected' kept its significance meaning like this term in 'Concept Map', it means nodes (ideas) and internode (their relation) link the divergent ideas. If we limit the map to a certain topic like the traditional way it acts as an "informational tool". Beyond it, we change this perception and include multi-dimensional concepts, (diverse ideas and relate the several ideas, activities, actions, practical activities, etc.) therefore, it can act as a "STEAM-based tool and Holistic tool".

So, in this study, a concept map is used in a broader sense like a "Holistic Art based tool," or "Interdisciplinary interconnected tool" for learner's engagement in science rather than a narrower sense i.e. only relates to the concept of a certain topic or just "informational tool."

Many types of research show that the role of concept maps in science learning was very effective (Gardner, 2015). It is not new ideas in the lenses of the effectiveness of science learning but the relation between 21st-century knowledge and transformative science learning is relatively new. In our context, there is so much diversity in caste, religion, culture, and any other basis. Although our classroom scenario is multicultural, multilingual, and multiethnic. In this context, science-related knowledge, skill, and ability are scattered in our diverse society. Here, my concern is how the concept map engages learners in science learning to reduce disengaged learning. It is important to the requirement of successful engagement learning in science for sustainability.

The STEAM-based approach focuses on the interconnection of different ways of (coming to) knowing i.e. cultural knowing (self-realization), Relational knowing, critical knowing, visionary and ethical knowing, and knowing in action (Taylor, 2015). The analysis of the term "interconnection" kept significant meaning in the learning process which may be similar to the term "Multilayer Concept Mapping", it means nodes (ideas) and internode (their relation) link the divergent ideas and thinking level i.e. learner engage in multiple ways. Moreover, different literature claimed that concept mapping is a way to facilitate the challenging the traditional methods of rote memorization and passive learning (Grice, 2016), encouraging self-evaluation thereby facilitating self-mastery (MacNeil, 2007), self-regulation and self-efficacy (Chularut & DeBacker, 2004).

Amer (1994) claimed that concept mapping is a way to facilitate the understanding of theories and the internalization of concepts, challenging the traditional methods of rote memorization and passive learning. When we create the proper learner engagement situation in the classroom, it could develop twenty-first-century skills (4C's – collaboration, communication, critical thinking, and creativity). Moreover, in the present time, we could design some technology-based concept maps (Infographics, wiki, Microsoft, etc.) and encourage self-evaluation thereby facilitating self-mastery (MacNeil, 2007), self-regulation and self-efficacy (Chularut & DeBacker, 2004). When we integrate multi-dimensional learning efficacy of concept map it might be used as a STEAM-based learning tool. While learners engage with this means, they can open their minds to thinking and connect their experiences to solve their real-life problem.

In this study, the researcher used multi-layer concept maps in science classrooms compared with STEAM-based (Holistic, Interconnected, Creative, Design thinking promoting, and Art-based self-evaluative) tools through the lenses of transformative learning and explored the learner engagement with it. The concept maps may help learners in several ways, such as giving students insight into their thought processes, developing more productive learning strategies, and stimulating reflective thinking especially in-group/ peer learning situations ((Parajuli, 2024).

Methodology

Participatory action research (PAR) design was used in this study, which offered a radical alternative to knowledge development in its mandate to remain a collective, self-reflective inquiry to improve a situation (Koch et al., 2002). In this study, the researcher assesses the needs of the science classroom and its' main aim is to solve the classroom problem with the active participation of participants. Like other action research models, it is also conducted by a cyclical process of plan, action, and reflection, which leads to further inquiry and action for change (Minkler, 2000). This study's main data , data collection, procedure, and meaning-making process is close to qualitative.

Additionally, in this study, the meaning-making process through the genre of interpretations is directly tested in the field of action. Its main action is oriented towards the process of researcher and participant who are seeking to improve their situation and solve their existing problem in science learning. In addition, to make the results of the study more effective and reliable, the Likert's scale type statement has also been used to collect the reflections of the students after completing the PAR cycle and to support the qualitative data. Therefore, this study is dominated by the PAR design and emphasizes improving the science learning environment engaging with a concept map, and empowering balance classroom activities. The overall cycle of this study was conducted in three spirals or cycles of planning, action, observation, and reflection. It took a total of three months to complete this cycle. A single cycle lasted one month. Each cycle included training students, motivating the learner to create individual maps, collaboration, and communication: reviewing the maps in small groups, and whole class discussion concept maps and revised it. And, finally, draw the concept map using Mindomo online software. However, this time is short for the PAR, but it is important because it adds a small brick to the solution of the disengaged learning problem in the Nepalese context.

One secondary school in Kirtipur municipality was selected for study. It was selected through a purposive sampling procedure. And participants of this study were grade ten students of that school (n=19). Therefore, this inquiry is real- problem-based or field-based action. In the data collection and interpretation process, it focused on the multiple information-generating ways (tools) i.e. observation of classroom engagement, field notes, and learner reflection (Likert's scale). Likert's scale has a five-point scale and the data are analyzed interpretation by frequency and weighted mean value. And the side, the meaning-making process of qualitative data was analyzed by the process of collecting, transcribing, coding, categorizing, and reflecting. Finally, the final result of the study was generated by merging the result of qualitative data, Likert's scale response, and critical reflection of the researcher .

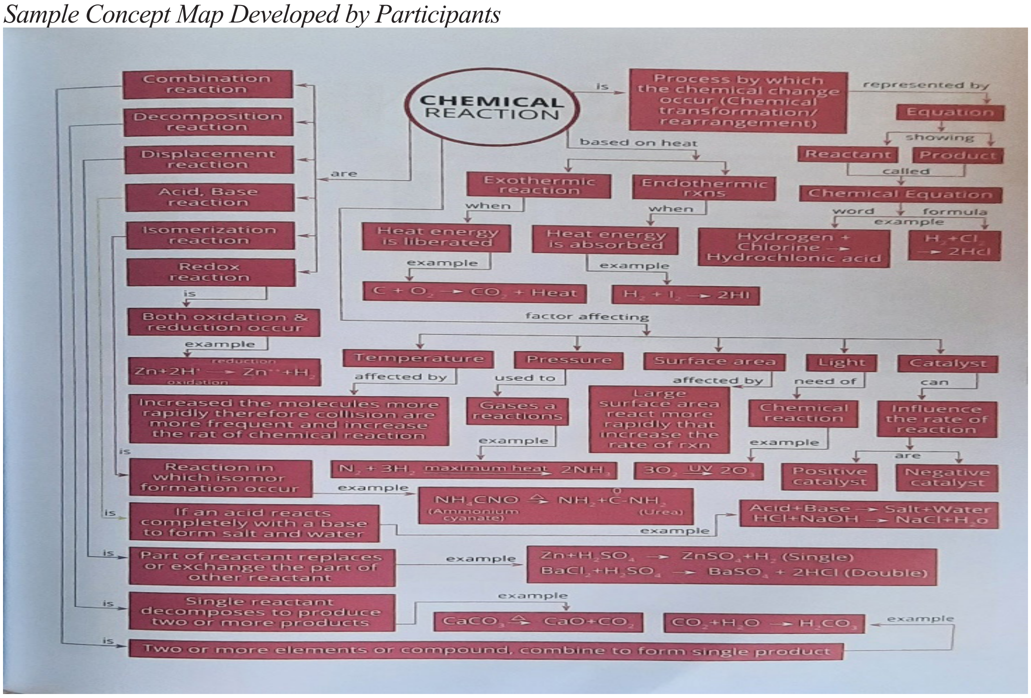
Concept Map Design and Engagement: Plan, Act, Observe, and Reflect

For this process, the researcher chose four phases (planning, acting, observing, and reflecting) of action research (Edward & Burns, 2016). In the planning phase researcher has designed an overall plan of study related to the research purpose. And, then act it, the summary of the act phase of this implemented PAR study is mentioned here " .. first of all inform and train my student for an open-ended type of concept map and quite familiarized with it. For training purposes researcher presented a sample of a multi-layer concept map (for example concept map and corresponding activity on the life cycle lesson). Then, he provided the opportunity to create individual maps. In this step, the learner elicits their own personal understanding of the related task and constructs their own maps. After they finish their (individual) concept map, the researcher organizes small group discussions among learners. Have students share their concept maps with peers. Ask them to find similarities and differences in their maps and try to reconcile them.

Furthermore, group work is shared in the whole classroom and explains their choices. Many propositions (concepts or experience) were discussed, but focus on those that are more relevant to what you want to know. Then a holistic multilayer concept map was created based on these discussions to document class progress, engage students, and provide stimuli for in-depth. Conversations about related topics/concepts/tasks. After the students had prepared their maps on drawing paper, they created a concept map using Mindomo online software. Finally, it was developed as a creative and artistic learning tool.

In the next step (observation), the researcher observed the overall action and learners' engagement to fulfill the research question with the required evidence and documented action systematically as well. In this study, every step was parallelly conducting critical reflection.

Figure 1
Sample Concept Map Developed by Participants



The researcher provides an opportunity to write students' reflections about engaging with the concept map. And suggests including their experiences before engaging with a concept map, lived experiences of the engagement period, and future talk about it (for further improvement). In the reflection, it adopted the formative approach to the emergence of finding and maintaining the openness to possible revision, redirections, new reflection of participants then finally reporting the action. However, all steps are conducted flexibly and they are changed based on learner and context demand.

Table 1
Summary of the Field Engagement Process

Plan	Act	Observe	Reflect
1. Train students	Inform and train learners /students for an open-ended type of concept map and quite familiarized with it.		
2. To motivate the learner to create individual maps.	Engage students to create concept maps based on related topics as a class activity.		
3. Collaboration and Communication: Review the maps in small groups.	After students finish their (individual) concept map, organize small group discussions, and share their concept maps with peers. Ask them to find similarities and differences in their maps and try to reconcile them.	Observation, Field notes, Conversation, Photos.	Likert's scale, Feedback, Critical reflection
4. Whole class discussion concept maps and revised it.	Group work is shared in the whole classroom and concepts or experiences would be discussed, but focus on those that are more relevant to what you want to know. Finally, they would create a concept map based on these discussions. Create a concept map using Mindomo online software.		

Result and Discussion

Participants Engagement and Reflection: The Qualitative Result

With the design and implementation of the multi-layer concept map design and implementation in learning science, the researcher became very close with his participants by observing their activities, interest, creativity, interaction, and efforts in learning. To determine the effectiveness of this tool, he tried to understand participants from different perspectives like motivation, clarity, engagement, content delivery, connection with other disciplines, etc. Based on the effort regarding the application of multi-layer concept maps in science classroom practice, it provides the real connection of learning scenarios and engages learners effectively with good motivation, a small piece of dialogue between the participants about this study supports this argument. For example, participant A said, *"I am very impressed by this new technique and tool of learning science"*. The next participant also supported Participant A's argument and said *"I also feel so excited to learn; however, it is taking a long time."* Another participant also showed her excitement in this activity and she said with her friends *"Yes, friends! Really, I am enjoying it*. The participant engagement in this action was seen as very interesting. They revealed that creating content and finding the necessary topics and words to connect the topics (internode words) felt like playing a game like *"... I feel very interesting. I search different words related to topics and their connection words and draw the concept map on drawing paper with different shapes make easy to learn science and it looks like a playing crossword game."*

Indeed, the above conversation between the participants shows that learning science through the multi-layer concept map was effective because they learned scientific concepts by connecting them with different concepts and disciplines in an artistic way. On the other hand, the concept of science (related topics) was linked with other subjects, including math, arts, technology, and engineering. Also, the other most remarkable point was, that they were highly motivated to create this tool. As a result, it seems that the use of a multi-layer concept map assisted in promoting interactions, collaboration, and critical reflection in learning science. Next, each individual was equally engaged in learning with their individual responsibility, so it reproduced their creativity, excitement, and fun in learning. They are interested in collecting the related daily used objects, and they are excited about designing different designs of concept maps in Mindomo online software. They enjoyed drawing, and they were encouraged to make their concept map much larger and more comprehensive than others, which demonstrated that learners were developing the habit of self-searching for depth in learning.

In addition, from the regular observations and understandings of participants' activities, engagement, excitement, performances, and views towards science learning using this tool; they are found to be easier than rote memorization. In the implementation of the PAR plan, the researcher regularly observed participants' activities, interactions, responses, drawing work, collaboration in empowering friends, and critical reflection on the tool. Based on the data of that observation and generating themes, it seems entertaining in concept map-based learning. Furthermore, it supported looking for inexpensive inspiration, creating a bridge between STEAM disciplines and multi-content issues, and encouraging participants to explore in depth. During the concept map construction and development period participant cooperated with their peers to make more attractive creative. Moreover, it helped to a better understanding of subject matters and provided the opportunity for deep learning. Also, it improved teamwork and interpersonal skills.

Analysis of Likert's Scale Data: The Quantitative Result

For the supportive data of qualitative inquiry 15 Likert scale-based statements [Strongly Agree (S.A), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (S.D)] are used in this study. These statements try to explore the learner's reflection over the journey of tool construction and implementation period. Such kind of data was collected after the construction and use of concept maps in science classroom. It is analyzed based on the frequency and weight mean value. To explain these data, equal to or greater than three (> 3) was accepted as a positive attitude, otherwise, it takes negative. The summary of responses' corresponding frequency and weight mean values are presented below.

Table 2
Frequency and Weighted Mean Values of the statements

S. No.	Statements	S.A.	A.	N.	D.	S.D.	Weighted mean
1	A concept map with pictures can improve my learning.	3	16	0	0	0	4.16
2	It helps to bring reality to the science classroom.	3	15	1	0	0	4.11
3	It increases the rapidity of the learning process.	3	15	1	0	0	4.11
4	Learning with a concept map is boring.	0	0	2	12	5	1.84
5	It should not be used in the learning process.	0	0	2	11	6	1.79
6	It is enjoyable and improves the result.	2	16	1	0	0	4.05
7	I/we prefer to study with traditional education methods rather than with concept map.	0	2	1	14	2	2.16
8	It allows for effective sharing and creative/ artistic work.	1	14	3	1	0	3.79
9	Learning with a concept map requires highly developed study skills and strategies.	0	1	5	11	2	2.26
10	I can connect the concept map design process with mathematics and design.	3	15	1	0	0	4.11
11	It can be used to clarify the concept of practical work and the procedure of experiments.	0	14	4	1	0	3.68
12	It plays an essential role in reducing misunderstandings in the science learning process.	0	14	4	1	0	3.68
13	Presentation through a concept map is much better than normal graphic representation or flowchart.	3	14	2	0	0	4.05
14	The dependency on a concept map is sometimes worthless.	0	1	5	10	3	2.21
15	The use of a concept map restricts the creativity of the students.	0	1	1	15	2	2.05

Table 2 data shows that most of the students are positive towards concept map with pictures as a learning tool. The mean average of the positive statement is 3.97. In another part negative and neutral statement average mean value is 1.69. The weighted mean for the positive statement is greater than three (3.97 >3) and the negative and neutral statement average mean value is less than three (1.69<3), which shows a majority of students accept the concept map with the picture more effective than normal teaching. Out of all statements, four statements (creative work/ artistic work, mathematical connection, practical procedure, and scientific fact and reduce misunderstanding) are closer to the STEAM concept which weighted mean is seen as greater than three (3.82 >3) and negative statement less than three (1.69<3). Hence the concept map with picture can work as STEAM-based learning tools. During the period of designing concept maps on a computer students highly engaged with multi-layer concept map design activity through Mindomo online software. It means that it is connected with technological skills also.

Cultivating STEAM Literacy in this Study: Triangulation and Discussion

The STEAM approach is an integrative approach that allows "science" to be studied not as a group of separate subjects, but as interconnected practices that enhance problem-solving, critical thinking, collaborative inquiry, authentic engagements, and affective aspects of learning activities (Chu et al., 2024). STEAM education has just been implemented to enhance the understanding of the structure between the fields of science, technology, engineering, arts, and mathematics in the Nepalese context. It does not connect these fields only because such kind of approach is holistically supportive of encouraging learning through community and empathetic development for all citizens (Yakman & Lee, 2012). As this paper has suggested, developing STEAM literacy through initiated self-constructed multilayer concept map during class. In the process of learning there are different ways to connect STEAM literacy to the learner, whether this study tries "learner [who] are learning how to build concept map, conduct[ing] or implement[ing] in the classroom with true scientific fact science, or design [ing] a concept map with Mindomo online software, and connecting with engineering process and attractive artistic and affective presentation (arts) (Liao, 2016).

This study initiated the design of a concept map to promote STEAM approach-based learning by establishing the relationship between science and other disciplines such as mathematics (for measurement systems, some geometrical shapes and their angle, ratio and proportion, etc), technology (for presenting concept map through Mindomo online software, searching concept map videos, figure animation, etc.), engineering (for designing different shapes, design related prototype, and templates of concept map), and arts (for drawing and sketching different color, picture). From this attempt, this study was tried to learn and generate a new idea of connecting one discipline to others. Hence this study adds brick to the STEAM literacy aspect in science learning. It seeks to integrate multi-layer concept map in the science classroom while offering opportunities for students to discuss connections between Science, Technology, Engineering, Arts, and Mathematics. Based on the abovementioned data and discussion, it tries to increase students' STEAM literacy on learners, which can improve their ability to make interdisciplinary connections as well. This connection leads to the real-world experience of learners making science classroom practices more empowering and changing classroom scenarios as the transformation (Parajuli, 2023).

Conclusion and Implication

There is great potential in purposively integrating the multi-layer concept map as a holistic learning tool corresponding with STEAM approach-based teaching and learning practices. It supports students to become interdisciplinary experts in the fields of science, technology, engineering, the arts, and math; not just for developing single disciplinary knowledge of science but connecting them globally useful skill sets like creativity, critical thinking, innovative problem solving, and collaborative works (Park, 2021). From all connections during the concept map construction and development, it established a framework to give structure to and analyze the interactive nature of both the practice and study of the formal fields of science, technology, engineering, arts, and mathematics.

Therefore, through this tool STEAM literacy practices are developed in the science classroom. Also, it enhances a variety of diverse learning opportunities and sharpens learner's independent thinking, creativity, and action. These thinking, creativity, and action are connected with STEAM-based learning which can develop STEAM literacy and transformative science learning. However further research on and application of a multi-layer concept map as a multidimensional learning tool is an important step to eliciting greater cognitive development, creativity, connection, and autonomy in STEAM-based science teaching. Finally, this study concludes the multi-layer concept map can act as a STEAM-based learning tool to increase learner engagement in science learning to open the door of transformative science learning but more engagement time and creativity are required, however, it is pedagogically beneficial for our science classroom context.

References

Amer, A. A., (1994). The effect of knowledge-map and underlining training on reading comprehension. *ESP Journal, 13*, 35-45.

Ausebel, D.P. (1968). *Educational psychology: A Cognitive View*. New York: Holt, Rinehart Winston.

BouJaoude, S., & Attieh, M. (2008). The Effect of using concept maps as study tools of achievement in chemistry. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(3), 233-246.

Chen, M., Ching, S., Chen, W., & Cho, C. (2003). Using concept mapping in accounting learning. *The Delta Pi Epsilon Journal, 45*(2), 133-143.

Chularut, P., & DeBacker, T. K. (2004). The influence of concept mapping on achievement, self-regulation, and self-efficacy in students of English as a second language. *Contemporary educational psychology*, *29*(3), 248-263. https://doi.org/10.1016/j.cedpsych.2003.09.001

Chu, I. T., Lin, H. H., & Wei, J. J. (2024). Application of multi-criteria decision-making in STEAM teaching in design innovation at the university. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(12), em2539. https://doi.org/10.29333/ejmste/15653

Dansereau, D., Dees, S.M., Greener, J.M., & Simpson, D. (1995). Node-linking mapping and the evaluation of drug abuse counseling sessions. *Psychology of Addictive Behaviors, 9*(3), 195-203.

De Simone, C. (2007). Applications of concept mapping. *College Teaching*, *55*(1), 33-36.

Drake, M. J., Griffin, P. M., Kirkman, R., & Swann, J. L. (2005). Engineering ethical curricula: Assessment and comparison of two approaches. *Journal of Engineering Education*, *94*(2), 223-231.https://doi.org/10.1002/j.2168-9830.2005.tb00843.x

Edwards, E., & Burns, A. (2016). Language teacher action research: Achieving sustainability. *ELT Journal*, *70*(1), 6-15.

Gardner, M. E. (2015). Concept mapping: Effects on content knowledge and engagement with content in elementary students' persuasive writing. ProQuest Dissertations and Thesis, 306. http://proxy.libraries.smu.edu/login?url=https://search.proquest.com/do

Grice, K. (2016). Concept mapping as a learning tool in occupational therapy education. *Occupational therapy in health care*, *30*(3), 309-318. https://doi.org/10.3109/07380577.2015.1130886

Jang, S. J. (2010). The impact on incorporating collaborative concept mapping with co teaching techniques in elementary science classes. *School Science and Mathematics*, *110*(2), 86-97.https://doi.org/10.1111/j.1949-8594.2009.00012.x

Koch, T., Selim, P. A. M., & Kralik, D. (2002). Enhancing lives through the development of a community-based participatory action research programme. *Journal of clinical nursing*, *11*(1), 109-117.

Liao, C. (2016). From interdisciplinary to transdisciplinary: An Arts – integrated approach to STEAM education. *Art Education, 69* (6), 44 – 49.

Liu, X. (2004). Using concept mapping for assessing and promoting relational conceptual change. *Science Education, 88*, 373-396.

MacNeil, M. S. (2007). Educational innovations. Concept mapping as a means of course evaluation. *Journal of Nursing Education*, *46*(5). https://doi.org/10.3928/01484834-20070501-07

Minkler, M. (2000). Using participatory action research to build healthy communities. *Public health reports*, *115*(2-3), 191-197.

Nesbit, J. C., & Adesope, O. O. (2011). Learning from animated concept maps with concurrent audio narration. *The journal of experimental education*, *79*(2), 209-230.

Novak, J.D. (1984). Application of advances in learning theory and philosophy to the improvement of chemistry teaching. *Journal of Clinical Education,67*, 606-612.

O'Brien, K. L. (2007). Learning style preference and student aptitude for concept maps. *Journal of Nursing Education*, *46*(5), 225-231.

Parajuli, D. R. (2023). *Becoming a steam-based science educator: intersecting science teacher identity and existing pedagogical practice in Nepal* (Unpublished M.Phil. dissertation). Kathmandu University. https://elibrary.ku.edu.np

Parajuli, D. R. (2024). Language analysis of science and technology textbook in Nepal: A semiotic perspective. Gipan, 6(1), 47–55. https://doi.org/10.3126/gipan.v6i1.68132

Park, J. C. (2021). Cultivating STEAM Literacy: Emphasizing the Implementation of the Arts through

Reading Practices Supporting the Asian Diaspora. *Asia-Pacific Science Education*, *7*(2), 586-614. https://doi.org/10.1163/23641177-bja10034

Taylor, P.C. (2016). Why is a STEAM Curriculum Perspective Crucial to the 21st Century? In: 14th Annual Conference of the Australian Council for Educational Research, 7-9 August 2016, Brisbane.

Taylor, P. C. (2015). Transformative science education. In R. Gunstone (Ed.), Encyclopedia of science education (pp. 1079-1082). Dordrecht, The Netherlands: Springer

Taylor, E., Taylor, P. C., & Hill, J. (2019). Ethical dilemma story pedagogy—a constructivist approach to values learning and ethical understanding. In *Empowering science and mathematics for global competitiveness* (pp. 118-124). CRC Press.

Vanides, J., Yin, Y., Tomita, M., & Ruiz-Primo, M.A. (2005). Using concept maps in the science classroom. *Science Scope, 28*(8), 27-31.

Wilson, L. O. (2016). Anderson and Krathwohl Bloom's taxonomy revised understanding the new version of Bloom's taxonomy. *The Second Principle*, *1*(1), 1-8.

Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the US as a practical educational framework for Korea. *Journal of the korean Association for Science Education*, *32*(6), 1072-1086. https://doi.org/10.14697/jkase.2012.32.6.1072