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Concept map-based Alternative Instructional Resource (AIR) in science

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ABSTRACT

This study explores the cognitive benefits of using concept maps in Science education for Grade 4 students. With 266 Grade 4 teachers in Ilocos Norte participating, the research employs a Research and Development (R&D) approach. The self-perception survey aligns with Most Essential Learning Competencies (MELCs), focusing on Matter, Living Things, Force, Energy, Motion, and Space. Statistical analysis indicates the high effectiveness of concept maps in teaching these topics. Validity and acceptability assessments show concept maps as Very Highly Valid (VHV) and Very Highly Acceptable (VHA). The study recommends integrating concept maps into teaching strategies across subjects to enhance critical thinking skills.

Introduction

The significance of Science education as a catalyst for modernization and national development is emphasized, recognizing the need for impactful teaching strategies (Recent Trends and Issues, 2017). Conventional direct instruction methods are acknowledged for fostering passive learning and providing limited feedback to teachers (National Science Education Standards, 2010), prompting a quest for more engaging and efficient approaches. Recent trends in Southeast Asian science education advocate for a process-oriented and locally relevant curriculum, emphasizing logical thinking and problem-solving skills. This study underscores the importance of hands-on and minds-on interactions in science education, prioritizing comprehension and reasoning over rote learning. Concept mapping is suggested as a potent method to enhance academic performance, fostering critical thinking skills and improving information retention (Vanides et al., 2010).

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Literature review

The NGSS and its implications for science education

The Next Generation Science Standard (NGSS) represents a significant shift in K-12 science education. It necessitates changes not only in the curriculum but also in the entire education system, school structure, teacher preparation, and resource availability (Trygstad et al., 2013). This transformative standard marks a pivotal moment in reshaping science education for students in the United States.

Challenges faced by elementary school teachers

Elementary school teachers, who often have minimal scientific experience, face challenges in preparing to teach a broad range of science subjects, with a preference for math and reading/language over science (Trygstad et al., 2013). The demands placed on these educators require a delicate balance between diverse subjects and the need to develop their scientific knowledge and pedagogical skills.

Early years of elementary school and scientific development

The early elementary school years play a critical role in shaping scientific knowledge. The impact of early general knowledge tests on later science performance underscores the significance of laying a strong foundation in these formative years (Curran and Kitchin, 2019). Early exposure to science concepts can set the stage for future academic success.

Science education and the development of skills

Science education transcends mere knowledge transfer; its essence lies in cultivating problem-solving skills and critical thinking. These skills not only contribute to academic excellence but also empower students to navigate diverse life situations (Importance of Science Education, 2017). Science education stands as a cornerstone in the development of these crucial life skills.

Fundamental principles for effective elementary science education

The National Science Teaching Association (NSTA) outlines four crucial principles for successful elementary science education. These principles highlight the significance of the elementary learning environment, active engagement in scientific practices, participation in the broader scientific community, and the necessity of allocating sufficient time for high-quality science instruction (NSTA, 2018). These principles stand as guiding beacons for educators dedicated to crafting a rewarding and enriching science education experience.

Aligning science education with 21st-century skills

Science education strives to empower students with 21st-century skills, including critical thinking and problem-solving, aligning with the imperative of preparing a workforce for the demands of the modern economy (Windschitl, 2009). It is essential that high-quality science education not only fosters these contemporary skills but also upholds the fundamental integrity of scientific education (NSTA, 2018).

Content coverage in elementary science education

The ongoing debate centers on the extent and depth of science content covered in elementary education. Advocates for a more targeted approach emphasize core concepts (NGSS), while others support a broader array of topics. International comparisons highlight differences in content coverage, with American standards often encompassing a wider scope than those of high-performing countries (Curran and Kitchin, 2019). Striking a balance between the depth and breadth of content continues to pose a challenge.

Challenges faced by teachers in managing curriculum content

Teachers grapple with challenges arising from time constraints and the demands of curriculum content. Initiatives to improve both in-service and pre-service teacher training are underway to tackle these issues (Recent Trends and Issues, 2017). The pursuit of effective solutions to these challenges remains a paramount concern for science educators.

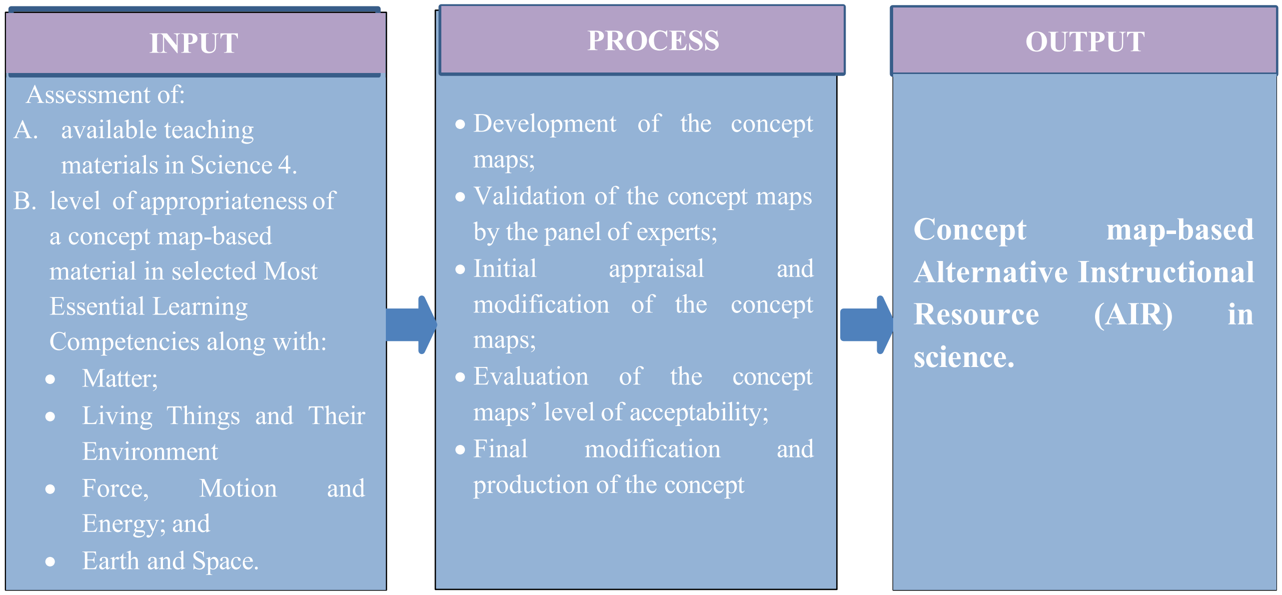
Concept mapping as an instructional tool

Concept mapping emerges as a promising instructional tool for fostering meaningful learning in science education. It offers a visual representation of concepts and their interconnections, aiding students in comprehending and retaining scientific knowledge (Novak, 2010). Utilizing concept mapping encourages students to participate in higher-level thinking, synthesize information, and engage in creative problem- solving (Elshaer, 2020).

Science education in the Philippines

The Philippines faces challenges in science education, reflected in students' below-average performance in international mathematics and science assessments (Magsambol, 2019). Evidence suggests that the incorporation of concept mapping in science classrooms enhances the comprehension and retention of scientific concepts (Barett, 2016). Moreover, when paired with diverse teaching methodologies, concept mapping proves effective in engaging students and positively impacting their learning outcomes (National Academy of Science, 2020). This innovative approach holds promise as a potential solution to the challenges prevalent in the Filipino educational context.

Conceptual framework



Source: Most Essential Learning Competencies (MELCs) in science

Figure 1: The conceptual framework employs an Input-Process-Output (IPO) model. It begins with identifying teaching materials and Science 4 topics aligned with MELCS for concept map creation. The outcomes guide the development of concept map-based Alternative Instructional Resources (AIR) for Science 4. The procedural steps involve data analysis, concept map development, validation by an expert panel, initial assessment and refinement, evaluation of acceptability, and final revisions leading to concept map production.

Statement of the problems

This study aimed to develop concept maps for selected topics in science 4 as an Alternative Instructional Resource (AIR).

Specifically, the study sought answers to the following questions:

1. **What teaching materials are available in teaching Science 4?**
2. **What is the level of appropriateness of using concept maps along with:**
   - **2.1 matter;**
   - **2.2 living Things and their Environment;**
   - **2.3 force, motion, and energy; and**
   - **2.4 earth and space?**

3. **What supplementary material can be developed to enhance the teaching-learning process in science 4?**

4. **What is the validity of the Concept Map-Based Alternative Instructional Resource (AIR) in science in terms of:**

4.1 layout;
4.2 organization;
4.3 links; and
4.4 visual appeal?

5. What is the level of acceptability of the Concept Map-Based Alternative Instructional Resource (AIR) in science in terms of:
5.1 usefulness;
5.2 suitability;
5.3 style and format; and
5.4 illustrations and presentations?

Research methodology

The methodology section outlines the research design and stages employed to develop a validated Concept Map-Based Alternative Instructional Resource (AIR) in Science, including data sources, population and sampling, data collection procedures, and tools for data analysis, while presenting a detailed breakdown of each stage in the research and development (R&D) process.

Research design

The study utilized a Research and Development (R&D) approach to craft a validated Concept Map-Based Alternative Instructional Resource (AIR) in Science. This design was selected to fulfill the goal of enhancing learners' comprehension of Science 4 concepts through concept maps. The R&D model comprised three pivotal stages: planning, development, and validation.

Locale of the study

The study was conducted across various school districts within the Schools Division of Ilocos Norte, which consists of four zones: North, Central, East, and South. These zones encompass a total of 254 schools.

Population and sampling

The study included 348 Grade 4 teachers of the Schools Division of Ilocos Norte (SDOIN) (North, Central, East, and South). Total enumeration was employed; however, representation was maintained in terms of characteristics such as educational background and length of service.

Research instrument

This study utilized three instruments, namely: a survey rating scale on the science topics for the teacher respondents, a validation rating scale for content specialists, and an acceptability survey rating scale for randomly selected Grade 4 teachers in Science.

Statistical treatment of data

Mean was employed to analyze and interpret data from the survey suitable for concept map creation, validity, and level of acceptability.

The following range of means and their descriptive interpretation below was used:

Range of Means	***Descriptive Interpretation***
4.51- 5.00	*Very Much Appropriate (VMA)*
3.51- 4.50	*Much Appropriate (MA)*
2.50- 3.00	*Moderately Appropriate (DA)*
1.50- 2.49	*Slightly Appropriate (SA)*
1.00- 1.49	*Not Appropriate (NA)*

The validation of the concept maps involved a 5-point rating scale with the following range of values and their equivalent descriptive interpretations.

Range of Means	***Descriptive Interpretation***
4.51- 5.00	*Very Highly Valid (VHV)*
3.51- 4.50	*Highly Valid (HV)*
2.51- 3.50	*Valid (V)*
1.51- 2.50	*Slightly Valid (SV)*
1.00- 1.50	*Not Valid (NV)*

The level of acceptability of the concept maps was analyzed using mean and was interpreted through a five-point scale with the following range of values and their descriptive interpretations:

Range of Means	***Descriptive Interpretation***
4.51- 5.00	*Very Much Acceptable (VMA)*
3.51- 4.50	*Much Acceptable (MA)*
2.51- 3.50	*Acceptable (A)*
1.51- 2.50	*Slightly Acceptable (SA)*
1.00- 1.50	*Not Acceptable (NA)*

Data presentation and analysis

The presentation of the findings followed the arrangement of the statement of the problem. It specifically answered the following questions:

Specifically, the study sought answers to the following questions:

1. What teaching materials are available in teaching Science 4?

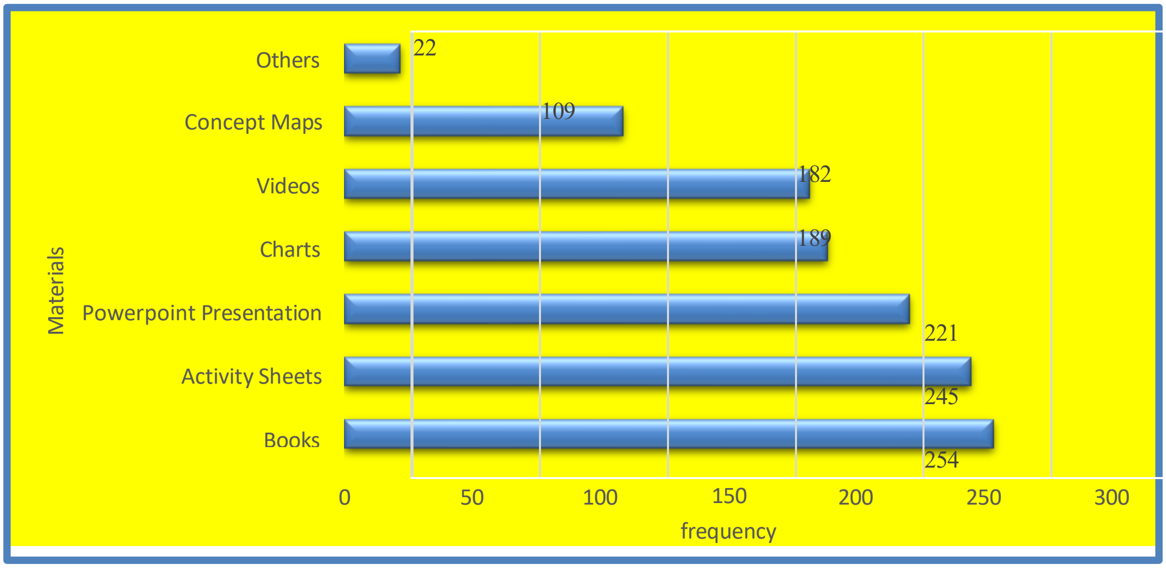


Figure 1. Materials that are Available in Teaching Science 4 (n=266)

Books were the most frequently used resource, with 254 respondents (95.49%), highlighting the continued reliance on them by teachers. Activity sheets were preferred by 92.11% (245 respondents), as they are simpler and more accessible for learning. PowerPoint had a frequency of 221 (83.08%) and remains a popular tool for creative presentations. Charts were utilized by 189 (71.05%), effective for elementary pupils in enhancing information retention. Videos had a frequency of 182 (68.42%), indicating limited availability but effective for information transmission. Concept maps were less common, with 109 (40.98%) respondents, suggesting the potential for promoting student engagement, critical thinking, and problem-solving skills. Other materials had a low frequency of 22 (5.30%), indicating low favorability among teachers.

2. What is the level of appropriateness of using concept maps along with:

2.1 matter;

2.2 living things and their environment;

2.3 force, motion, and energy; and

2.4 earth and space?

Table 1 shows the level of appropriateness of concept maps for the topics on Matter as perceived by the teachers is much more appropriate based on the obtained composite mean of 4.15.

Table 1. Level of appropriateness of concept maps for the topics under the competency, Matter (n=266)

	Topics	Mean	Descriptive Interpretation
1	Classifying materials based on the ability to absorb water, float, sink, and undergo decay.	4.26	MA

2	Describing changes in solid materials when they are bent and pressed.	4.14	MA
3	Describing changes in solid materials when they are hammered.	4.09	MA
4	Describing changes in solid materials when they are cut.	4.12	MA
5	Describing changes in properties of materials when exposed to certain conditions such as temperature or when mixed with other materials.	4.07	MA
6	Identifying changes in materials that are useful to one's environment.	4.18	MA
7	Identifying changes in materials that are harmful to one's environment.	4.21	MA
	Composite Mean	**4.15**	**MA**

Source: Most Essential Learning Competencies (MELCs) in science

The highest mean (4.26) was for classifying materials based on water absorption, floating, sinking, and decay, while the lowest mean (4.07) was for describing changes in material properties under specific conditions. Concept mapping is a useful tool for note-taking and research support. This aligns with Tumaneng (2010), who emphasizes how concept maps enhance learning, encourage concept connection, and improve thought organization. Teachers can employ concept maps to clarify core concepts, connections, and provide a comprehensive understanding of the subject, aiding comprehension and recall (Wang et al., 2008). Novak and Gowin (2013) describe mapping as a creative exercise for expressing fundamental concepts, relationships, and knowledge structure, promoting effective learning.

Table 2. Level of appropriateness of concept maps for the topics under the competency, living things and their environment (n=266)

	Topics	Mean	Descriptive Interpretation
1	Describing the main function of the major organs.	4.32	MA
2	Communicating that the major organs work together to make the body function properly.	4.01	MA
3	Inferring that body structures help animals adapt and survive in their particular habitat.	3.97	MA
4	Identifying the specialized structures of terrestrial and aquatic plants.	3.98	MA
5	Comparing the stages in the life cycle of organisms.	4.16	MA
6	Effects of air on the life cycle of organisms.	4.03	MA
7	Importance of space in the life cycle of organisms.	4.06	MA
8	Effects of water on the life cycle of organisms.	4.11	MA

9	Describing some types of beneficial and harmful interactions among living things.	4.17	MA
10	Describing the effects of interactions among organisms in their environment.	4.08	MA
	Composite Mean	**4.09**	**MA**

Source: Most Essential Learning Competencies (MELCs) in science

The topic "describing the main function of major organs" received the highest mean of 4.32, indicating its suitability for concept mapping. This suggests that concept maps can effectively define core concepts and provide an overview of the subject to students. On the other hand, the topic "inferring how body structures aid animals in adapting and surviving in their habitat" received the lowest mean value of 97. Concept mapping can be valuable here as well, as it can help visualize connections, structures, or hidden characteristics not easily conveyed in text alone. Visual representation aids in understanding and retaining information, as emphasized by Elshaer (2010).

Table 3. Level of appropriateness of concept maps for the topics under the competency on force, motion, and energy (n=266)

	Topics	Mean	Descriptive Interpretation
1	Effects of force when applied to an object.	3.95	MA
2	Characterize the magnetic force.	3.77	MA
3	Describing how light, sound, and heat travel.	3.80	MA
4	Investigating properties and characteristics of light, and sound.	3.73	MA
	Composite Mean	**3.81**	**MA**

Source: Most Essential Learning Competencies (MELCs) in science

The highest mean (3.95) was for the topic of the effects of force on objects, and the lowest mean (3.73) was for investigating the properties of light and sound. Both were considered "much appropriate" for concept mapping, demonstrating their effectiveness in Physics learning (Akeju, 2012). Concept mapping is an engaging, student-centred strategy, especially for competencies like force, motion, and energy, promoting critical thinking (Dhull, 2020) and enhancing 21st-century critical thinking skills (Tseng, 2019). For Science 4, including earth and space, concept mapping was highly appropriate with a mean of 4.09, fostering meaningful learning and strengthening science process skills (Rao, 2011). Among seven topics, "uses of water from different sources in daily activities" had the highest mean (4.34), and "describing changes in the position and length of shadows around the sun" had the lowest mean (3.90), both considered "much appropriate" for concept mapping.

Table 4. Level of the appropriateness of concept maps for the topics under the competency, earth and space. (n=266)

	Topics	Mean	Descriptive Interpretation
1	Characteristics and different types of soil.	4.32	MA
2	Uses of water from different sources in the context of daily activities.	4.34	MA
3	Describing the importance of the water cycle.	4.16	MA
4	Uses of weather instruments.	4.13	MA
5	Identifying safety precautions during different weather conditions.	4.12	MA
6	Describing the changes in the position and length of shadows in the surroundings of the sun changes.	3.90	MA
7	Describing the effects of the sun on human activities.	4.20	MA
	Composite Mean	**4.09**	**MA**

Source: Most Essential Learning Competencies (MELCs) in science

3. What supplementary material can be developed to enhance the teaching-learning process in science 4?

Concept mapping, as supported by Khrais and Saleh (2017), is an effective intervention for developing students' cognitive abilities, generalization, and critical thinking in science learning. Their study revealed superior performance in concept mapping compared to traditional methods, promoting self-directed learning and the ability to make associations between concepts. Including concept maps in alternative instructional resources (AIR) enhances information retention, deepens understanding, and fosters critical thinking and problem-solving skills, aligning with previous studies.

4. What is the validity of the Concept Map-Based Alternative Instructional Resource (AIR) in science in terms of:

4.1 layouts;
4.2 organizations;
4.3 links; and
4.4 visual appeals?

Table 6. A panel of experts evaluated the validity of the concept maps along with the layout. (n = 7)

Indicators	Composite Mean	Descriptive Interpretation
1. Layout	4.82	VHV
2. Organization	4.97	VHV
3. Links	4.86	VHV
4. Visual Appeal	5.00	VHV

Over-all Mean	**4.91**	**VHV**

Source: The University of wisconsin-stout and university of waterloo, center for teaching excellence

Range of Means	*Descriptive Interpretation*
4.51 – 5.00	*Very Highly Valid (VHV)*
3.51 – 4.50	*Highly Valid (HV)*
2.51 – 3.50	*Moderately Valid (MV)*
1.51 – 2.50	*Slightly Valid (SV)*
1.00 – 1.50	*Not Valid (NV)*

The concept map received a very high validity rating with a composite mean score of 4.91.

Its layout rating of 4.82 resonate with Elshaer's (2010) emphasis on visual representation for holistic understanding. Dhull (2020) supported the suitability of concept maps' visual depiction.

The organization of concept maps received a very high validity rating (4.97), promoting practical learning and knowledge retention (Dhull, 2020). The hierarchical order, progressing from simple to complex, aligns with favorable approval.

Concept maps' validity for links and their placement received a very high rating (4.86), emphasizing their effectiveness in enhancing the meaning of connected concepts (Sangeetha, 2013). Soe's (2018) steps for linking relationships were followed.

The visual appeal of concept maps was rated very highly valid (composite mean of 5.00), indicating favorable and engaging designs for students (Elshaer, 2010). The mean score suggests the maps are clean and appealing, encouraging creative thinking and student engagement.

5. **What is the level of acceptability of the concept map-based Alternative Instructional Resource (AIR) in science in terms of:**
   5.1 usefulness;
   5.2 suitability;
   5.3 style and format; and
   5.4 illustrations and presentations?

Table 7. Key Teachers' evaluation of concept maps' level of acceptability (n=40)

Indicators	Composite Mean	DI
1. Usefulness	4.62	VHA
2. Suitability	4.62	VHA
3. Style and format	4.72	VHA
4. Illustrations and presentations	4.73	VHA
Overall Mean	**4.67**	**VHA**

The data shows that the teachers expressed a positive response to the usefulness of the concept maps. This is evidenced by the composite mean of 4.67 interpreted as very highly acceptable. Concept maps, endorsed by Elshaer (2020) and Ngu Wah Soe (2018), significantly enhance students' cognitive learning, earning a composite mean of 4.62 for usefulness and suitability. Lubert (2010) highlights the clarity gained through concept map activities, contributing to knowledge assessment and addressing misunderstandings.

Format and style, as indicated by the composite mean of 4.62, are crucial elements for providing consistency and facilitating discipline and adherence to standards (Fudge, 2015). The right style and format ensure focus across materials.

The composite mean of 4.73 for concept maps' illustration and presentation (MAAillustration, 2016; Center for Literacy in Primary Education, 2020) signifies their exciting and engaging nature. Illustrations play a crucial role in capturing attention and creating meaning in concept maps.

Results and discussion

The results of the study affirm the potential of concept maps and visually enhanced materials in promoting a deeper understanding of scientific concepts. The positive findings are consistent with existing literature, highlighting the significance of incorporating visual representation in educational materials to facilitate comprehensive learning.

Concept mapping is a valuable intervention activity that can enhance cognitive ability, generalization, and critical thinking skills required for learning science. This aligns with the findings of Khrais and Saleh (2017) and their support for self-directed learning through concept mapping. The inclusion of concept maps in the alternative instructional resource (AIR) would enhance information retention, deepen understanding, and foster critical thinking and problem-solving skills among students.

Conclusion

The study affirms the appropriateness of concept maps for the four competencies and their respective topics. This highlights the teacher-respondents' belief in the importance of using concept maps to enhance information retention and critical thinking. The Concept Map-Based Alternative Instructional Resource (AIR) in science is validated as very highly valid and acceptable for teaching and learning. These findings align with cognitive and constructivist theories, emphasizing the importance of connecting new knowledge to existing concepts and engaging students in meaningful activities that foster critical thinking and experiential learning.

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