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Infographics as a Visual Learning Tool in Science Education for Deaf Students: an analytical study

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ABSTRACT

The study aims to investigate the role of infographics as a visual tool for learning science for deaf students. Achieving this main aim entailed highlighting the challenges deaf students encounter while learning science, demonstrating how infographics as a visual learning tool would contribute to overcoming some of these challenges, identifying the effective criteria of infographics design for teaching deaf students science, and determining the instructional approaches for employing infographics as a science visual learning tool for deaf students. Results revealed many challenges hindering science learning for deaf students, which call for the adoption of visual approaches such as infographics. It was also found that infographics can serve as an effective visual learning tool of science for deaf students in addition to helping them in scientific communication; through practicing visual thinking processes and visual literacy skills, which are integral parts of science learning. Based on literature review, a set of instructional design criteria of infographics for teaching deaf students science were suggested, along with identifying the appropriate educational approaches for employing infographics in teaching science for deaf students. The study recommended teachers of deaf students to work on infographics design and employment as a science visual learning tool in light of sound educational approaches and foundations.

Key Words: Infographics, Science learning, Visual thinking,., Visual literacy, Deaf students.

Introduction

In the current era of global competition, human resources play a vital role in achieving community well-being in light of their being the founda-

tion of all development and progress efforts in various arenas. The preparation of highly qualified human capital has become a major concern of contemporary societies. This is done through the educational process.

Although the educational process is one of the most prominent prerequisite for the inclusive growth of society, it represents a challenging task for students with disability because of the unique problems these students would encounter (Zakia, Sunardi & Yamtinah, 2017: 105-106). Students with disability are integral part of the human resources of any society (Tamilarasi & Ushalayaraj, 2017: 318); thus achieving equivalent or at least convergent educational standards to their normal peers is a major issue of educational systems in different countries of the world. Deaf students are among the various categories of students with special needs who encounter multiple difficulties in their lives; including low language proficiency and lower levels of capacity for interaction and communication, as well as difficulties embedded in learning and acquisition of new concepts (Nugraheni, Salim & Sunardi, 2017: 74).

Like any population, deaf learners need to acquire a large amount of scientific concepts, especially those related to life circles, animals, plants, climate, astronomy, etc. (Andrews, 2017: 4). Nevertheless, the results of a study conducted by (Zainuddin et al., 2009) pointed to the occurrence of challenges to science learning for deaf learners, such as the absence of learning aids tailored to help deaf students learn science; the use of the same textbooks and curriculum applied to hearing students in the instruction of deaf learners; the difficulty of conceptual understanding of abstract scientific concepts; and the poor cognitive ability of deaf learners.

Given the nature of deafness and loss of hearing, deaf learners have to rely mainly on vision to compensate for hearing loss, making them primarily visual learners (Luckner, Bowen & Carter, 2001; Olatoye & Aanu, 2010). Deaf students, then, need tailor-made visual learning materials commensurate to their specified needs (Cooper, 2016). Thus, the best option for visual education for deaf learners is to combine simple texts with visual representations in a graphic format (Luckner et al., 2001: 38). The provision of information visually helps deaf learners achieve better levels of learning outcomes (Nunes, Bryant & Pretzlik, 2006). Besides, through appropriate educational practices, the principle

of fair equality of opportunity in learning science can be achieved for deaf students (Ross, 2017). On the other hand, deaf students live in a digital age that is heavily dependent on modern communication technologies, which requires these students to be technologically qualified to live like their listening peers. This, in turn, calls for preparing deaf students with various information and visual literacy skills and all needed 21st century skills.

We live in an era that is witnessing cumulative information flow; making people obliged to handle a huge amount of information, and thus should be able to systematically deal with, design, and represent this information in an easy-to-understand visual way (BanuInanc, 2014:40). This came up with a wealth of research documents indicating that people pay attention to visual representations more than words (Akhmad, Sugandi & Nandi, 2018). 'Infographics' has been known as an important tool for the visual representation of information in the digital age (Toth, 2013). There is currently a global extensive emergence of Infographics in various domains including presentation of status-quo events, clarification of traffic rules, and many such examples; because of their potential to outweigh texts in presenting ideas through highlighting the relationships between concepts in a more concrete way than embedded in texts (Ruottinen, 2014: 22).

In light of infographics potential to reduce text in communication in favor of visual representations, they are being utilized in paper and digital newspapers and magazines, in addition to its extensive use in social networking for being more attractive and easier to understand and communicate (Vanichvasin, 2013: 136). Moreover, in the scientific domains, it is now common for scientists to use infographics to simplify and introduce complex scientific knowledge in simple and easy fashions to society and public through journal articles, electronic periodicals and other media (Lamb, Polman, Newman & Smith, 2014).

Given their prominent feature, infographics have become well known as educational tools in different educational environments (Sudakov, Bellsky, Usenyuk & Polyakova, 2014); being used as a new approach for the development of effective visual teaching strategies for the present age (Martix & Hodson, 2014). Infographics can be best viewed as a form of creative learning environments that helps deliver information to learners in an effective visual way (Yildirim, 2016).

Based on the above, there is a growing interest in developing clearly defined frameworks for the design and development of infographics for educational purposes based on learning theories and other relevant fields (Almunive & Alshammari, 2018). The use of infographics in education can be an important primary step toward the development of an educational approach based on visual representation and appropriate to the characteristics of various students (Matrix & Hodson, 2014), notably the deaf.

Although infographics, as an effective tool for information presentation, can provide a meaningful approach for deaf students, this research line seems still in its infancy in terms of exploring and investigating employing infographics in teaching science to deaf students, which would be the focus of the present study. However, such needs do not constitute the sole impetus for carrying out this review.

The present study has its theoretical framework in two premises; starting to gain a philosophical and psychological ground; by the end of the twentieth century and the beginning of the present century. It advocates the hypothesis of cognitive penetrability, pertaining to the role played by cognition and emotion in shaping and altering visual perception. The second hypothesis claims perceptual integration, maintaining the compensatory role of vision in the presence of language receptive disorder. The visual system has the remarkable ability to integrate fragmentary visual input into a perceptually organized informative shape, and provides a meaningful learning experience; especially in teaching science. It also helps the learner to construct his/her perceptual justification for posterior interpretations (of any visual stimulus). Thus, the present study paves the way to visualization and mental imagery to help enhancing learning in other school subjects. It may also be helpful in the use of art and motion pictures in education and public communication; whether pre-produced or interactive material.

Problem of the Study

Deaf students encounter a great deal of challenges in educational environments. They are, however, expected to achieve equivalent educational standards for their peers under high-level accountable systems (Cooper, 2016: 2). Learning difficulties faced by the learners as a result of those problems include learning or understanding ideas and

concepts contained in the curriculum, as well as dealing with the learning environment and acquiring different types of skills (Tamilarasi & Ushalayaraj, 2017: 318). It is argued that deaf students suffer from two major types of learning problem: the first is attributed to the traditional patterns of teaching and learning based largely on filling students' minds with a huge amount of verbal information presented in a way that is neither interesting nor facilitates comprehension and understanding as concluded by (Sudak et al., 2014; Noh et al., 2015). These are the problems typical students suffer in general. Besides, deaf students face additional difficulties related to their own characteristics and conditions of disability.

These difficulties justify the students' need for visual approach to learning that relies on delivering information in a simple and visually appealing manner facilitating students' understanding, combined with a small amount of verbal information presented in a simplified form that would facilitate students' learning. This can be achieved by information graphics. In his review of literature, Cooper (2016) concluded that the combination of simple verbal texts along with visual representation of information can help support the learning process and understanding of students. Educational research investigating the use of infographics, however, is relatively scarce in general (Lyra et al., 2016), and in the field of deaf students' learning in particular, as studies examining the employment of infographics for the students of this category are, to the researcher knowledge, very few in number. Infographics are particularly useful for visual learners (Noh et al., 2015), among whom deaf students are included.

Through personal experience, some deaf student teachers are seen trying as much as possible to take advantage of infograhphics as tools for visual learning to support their students' learning process. However, literature (e.g. Toth, 2013) indicates that the use of infographics without considering the characteristics that must be available may impede rather than support learning.

According to (Noh et al., 2015), the misuse of visual communication would undermine its effectiveness. This is due to the fact that the inappropriate designs of visual elements hinder effective information presentation, adding to that impaired visual communication skills of learners may impede their capacity to learn from visually-presented-

information correctly. Therefore, there is an urgent need to investigate the factors that would facilitate or hinder deaf students' learning of science by means of infographics.

Furthermore, limited research available on science instruction for deaf students (Jones, 2014) suggests the need to employ infographics as a visual learning tool to help overcome the challenges they face in learning.

Questions of the study

The present study tries to answer the following main question: how can infographics be integrated as a visual science learning tool for deaf students? In order to answer this question, the attempt was made to answer the following research questions:

1 - What are the science learning challenges encountered by deaf students?

2 - What is the role of infographics as a visual tool for science learning?

3 - What are the criteria of designing quality infographics for teaching science for deaf students?

4 - How can infographics be used as an effective tool for science visual learning for deaf students?

Significance and Contribution to Knowledge

Theoretical significance: the present study can be a significant contribution to bridge some of the gaps observed in literature. The study may contribute to enrich literature related to educational use of infographics, explain how infographics may support visual learning process as well as the mechanisms they depend on, and identify the factors that deserve attention in future research. Moreover, the present study can provide a departure point for using infographics in the learning of deaf students; an area that has not received enough attention in literature.

Practical significance: the present study works to provide important implications for deaf students' teachers in their use of infographics as a visual learning tool; by highlighting the mechanisms through which infographics would support learning, determining the specifications

must be available, and identifying the possible obstacles of using infographics in learning, which eventually help teachers use infographics effectively in the learning process.

Limitations of the study

The study has been limited to the following main determinants:

1 - The study is restricted to static infographics for being the simplest form compared to interactive or motion infographics.

2 - Focusing on reviewing the visual approach in deaf education.

3 - The study is limited to investigating infographics applications in science instruction.

Definition of Terms

Deaf students: those students with complete hearing loss or full hearing impairment to the extent that their auditory loss is more than 120 dB, making them unable to apprehend information from audiogenic or acoustic sources.

Infographics: visual representations of concepts and ideas taught to deaf and are developed by the students or their teachers. These visual representations combine different visual design components as well as verbal educational content in a concise, interesting, and easy to understand way of learning.

Methodology of the study

In order to achieve the aims of the study, the descriptive analytic approach has been adopted that is based on reviewing and analyzing the literature and previous studies to derive ideas and answers to the questions of the study in a theoretical and analytical fashion. According to this approach, the study included the following topics:

1 - Challenges of science learning for students who are deaf.

2 - Infographics as a visual tool for science learning.

3 - Instructional design of infographics for science instruction for deaf students.

4 - Implementing infographics in teaching science for deaf students.

The challenges of science education for deaf students

Deaf students suffer from delay in science achievement compared to their typical peers. For instance, a study conducted by (Akram, Mehboob, Ajaz & Bashir, 2013) compared the acquisition of scientific concepts by two groups of eighth-grade of deaf and hearing students in Pakistan in terms of the acquisition of 32 main scientific concepts. The results revealed that there were statistically significant differences in the acquisition and proficiency of scientific concepts in favor of hearing students.

Similarly, Vosganoff, Paatsch and Toe (2011) compared scientific and mathematical skills for ninth-grade deaf students or hard of hearing in blended environment to their typical peers. It was found that the performance of 88% of students with hearing impairments had been lower than the overall average in Australia. In particular, the results showed that students had difficulties with questions with advanced linguistic content or those requiring written explanation, while performing better in areas requiring spatial visual skills such as space and measurement concepts. In the same vein, the comparative study conducted by (Olatoye & Aanu, 2010) investigating science achievement for deaf and typical high school students in Nigeria pointed out the significant outperformance of hearing students.

In the attempt to interpret this low level of science achievement, several studies tried to highlight the challenges facing deaf students. For example, the qualitative study conducted by Naidoo (2008) listed many of the challenges facing deaf students in learning science including: lack of basic literacy; lack of motivation to learn science; the use of inappropriate learning strategies and resources; inconsistencies in the use of sign language symbols that express many scientific terms because of teachers' utilization of different signs for the same word or the same sign for different words or using different signals for various educational stages or among a school; and, finally, the lack of opportunities for informal learning of science at home as well as poor parental involvement in their deaf children education.

The challenges of science learning can be classified into several categories; some of which are attributed to their characteristics, others inherited in the content of science courses, and still others associated with inappropriate teaching methods, textbooks, and instructional

materials. Generally speaking, loss of hearing and the associated language delay are among the most pervasive learning challenges in general and for science especially (Zakia et al., 2017; Olatoye & Aanu, 2010; Namukoa, 2014; Hidayat, Gunarhadi & Hidayatulloh, 2017). The language delay resulting from loss of hearing from birth or early childhood along with the complete dependence on eye language is called language deprivation, and has major implications for students' learning of science (Andrews, 2017).

Added to that, the very abstract nature of scientific concepts that are primarily taught through traditional methods by means of lectures and textbooks exacerbate the difficulties encountered by deaf learners (Jones, 2014). In such cases, deaf learners face severe difficulties in dealing with information printed in the traditional form and in traditional teaching of science (Wang, 2011: 239). This is because textbooks tend to include texts rather than images (Naidoo, 2008), along with the lack of instructional materials tailored to this population of students (Hidayat, Gunarhadi & Hidayatulloh, 2017; Adesokan & Reiners, 2016; Cooke, 2011). Nonetheless, despite the critical importance of visual learning materials in science education, and in teaching deaf students in particular, several studies point out that the use of visual learning modalities that are appropriate for deaf students is still limited. For instance, the qualitative study conducted by (Zakia, Sunardi & Yamtinah, 2017) on a sample of Indonesian deaf learners emphasized the limited use of visual learning modalities in teaching science to deaf students in favor of the more reliance on textbooks. The final challenge is the adoption of teaching strategies which do not meet needs and characteristics of deaf students. In this respect, the results of Namukoa's study (2014) demonstrated that although a sample of high school science teachers had been aware of a number of best practices and strategies for developing the scientific literacy of deaf learners, these strategies either are not applied or perfunctory implemented in practice.

Finally, on the contrary to their peers who take advantage of informal learning situations outside the classroom, deaf students almost cannot due to their need to sign language, thus there should be specialized professionals to help teacher in the classroom (Andrews, 2017: 4). Based on the above cited challenges, there are needs for deaf students within learning science should be met. Since abstract scientific

concepts are difficult for them, they need visual tools that would facilitate understanding and strengthen their ability to remember these concepts (Zakia et al., 2017). Hearing impediment has a direct impact on science learners' preferred learning styles, making them more inclined to visual learning (Olatoye & Aanu, 2010: 90). They also need to be trained on how to access diverse scientific sources related to what they learn (da Fonseca Flores & Rumjanek, 2015).

The study conducted by (Adesokan & Reiners, 2016) lists a set of main learning needs of deaf students when learning science. These are: 1- language skills: the need to develop general language skills to learn specialized basic scientific concepts, the need for sign language specifically relevant to the subject matter, and for more real-life experiences to relate them to learning; 2- Communication: the need for special communication systems; 3- Cognitive competence: it includes many needs related to the competencies required for learning science such as: the need to develop the ability to formulate hypotheses and scientific questions, the need to provide descriptions and reports of the results of experiments, the need for further training to follow the instructions for experiments, the need to build models to represent abstract concepts especially using visual representation, and the need for training on thinking of the problem; and 4- teaching staff: the need for specialized teachers in teaching students with hearing disabilities. It is argued that many of these needs can be met through the adoption of visual approaches of learning by means of tools like infographics, which will be further discussed in the following sections. So far, question 1 of the study has been answered.

Infographics as a visual learning tool in science education for deaf

This section addresses the answer to question 2. The concept, types, components, and the educational affordances of Infographics are introduced. This is followed by reviewing the role of visual learning in science as well as its significance for deaf students, and finally highlighting the importance of Infographics as a visual learning tool in science education for deaf students.

Definition and components of infographics:

According to (Noh, Shamsudin, Nudin, et al., 2015), the term "infographics" is derived from two words: information and graphics,

which means the visual representation of information. Infographics can, therefore, be defined according to denotation of the term as graphical representation of information (Toth, 2013). Scanning existing literature reveals that there is a consensus defining infographics as "visual representations using various visual elements such as images, tables, concept maps, and maps, along with the use of written texts and verbal content to express different data, ideas, and information in a visual manner characterized by attractiveness, clarity, and easily understood by readers'' (Noh et al., 2015; Kibar & Akkoyunlu, 2015; BanuInanc, 2014; Dyjur & Li, 2015; Ruottinen, 2014).

In light of the above mentioned definition, infographics consist mainly of three components, these are: the visual component, which includes graphs, diagrams, icons, and depends on the use of colors as well, (b) the content, which includes statistics, time frames, and references, and (c) the knowledge contained, including facts (Ru & Ming, 2014: 985; Ouf, 2018).

Types of infographics:

Infographics can be classified according to various classifications. The most prominent of which is (Damyanov & Tsankov's, 2018: 84) taxonomy which classifies them into three main types as the following:

1 - Static infographics: these consist of static visual representations that do not contain any motion elements and are the simplest form to introduce infographics. They refer to diagrams designed to be used in printed form (e.g. posters, illustrations published in newspapers or advertisements), or digital form without including any motion features; as is the case on different websites (Hassan, 2016: 3).

2 - Animated/motion infographics: in addition to involving visual representations of the data and information provided, this type includes motion components to help represent a large amount of data and information in a single shot.

3 - Video clips infographics: involve both visual representations and text.

Hassan (2016) further adds a fourth type for infographics that is interactive, which are characterized by the same features of motion infographics beside the addition of elements allowing the user to interact with the content.

In another classification (as cited in: Dyjur & Li, 2015), these are: flowcharts, timelines, infographics displaying processes, image-based infographics, data-focused-infographics, narrative infographics, and comparative infographics, in addition to infographics blending two or more types of these informatics templates

Characteristics of infographics

It is argued that the prominent characteristic of infographics would be the possibility to consider it as an entity involving both verbal communication and visual representations simultaneously so that each element is not presented in isolation, which improves the learner's ability to understand (de Oliveira et al., 2016). In the educational environment, infographics have been utilized as an effective learning and communication tool that can promote classroom engagement, stimulate motivation, develop understanding capacities, and develop evaluation skills (Ozdamli & Ozdal, 2018).

In light of reviewing literature, the following characteristics of infographics can be concluded:

- Infographics have a unique aesthetic character that distinguishes them from all other visual representations used for learning purposes.
- Infographics provide visual tools to represent the relationships among different scientific phenomena and concepts, and introduce attractive and concise examples of complex scientific concepts and ideas.
- Infographics can be used as tools for instructional communication, learning and assessing students' learning outcomes.
- Infographics can easily be widely disseminated among various students, especially if they are produced in digital formats used across social media.
- Infographics can be used as assistance tools in classroom management, as well as in overcoming the common behavioral problems for deaf students by developing infographics that explain the rules of classroom behavior, task schedules, and so forth.

The need for infographics in education

Some studies indicate the existence of several problems and difficulties students encounter in learning, which call for the urgent need

to use infographics in the educational process. For example, (Sudakov et al., 2014) reports that amongst the problems faced by students are: the intensity of information introduced in lectures, the lack of illustrative examples, the need for visual representation of information, and the need to deliver information in an interesting way.

(Noh et al., 2015) further added that students have difficulties in understanding the lecturer's explanation and maintaining their attention on learning while providing a large amount of information through slides, in addition to the students' need for visual or image representation or at least the use of simple texts, attractive colors, and good design. These results clearly suggest the students' need for informatics templates in their learning. This is more vital for deaf students who lack auditory information, and thus are more reliant on visual information; making them need more infographics comparisons compared to their typical students.

Educational affordances of infographics:

Lally, (2016) points out that there are plenty of affordances associated with the use of infographics in teaching such as, students' satisfaction on learning, the increased ability of students to retain learning and its effect, simplifying complex concepts, and providing a step-by-step visual manual for learning process and tasks. Despite the relative scarcity of research investigating the educational use of infographics (Lyra et al., 2016), the few educational studies conducted demonstrate the existence of significant privileges associated with the use infographics. For example, the results of Rueda's study (2015) indicate that the use of infographics in teaching Boolean algebra has contributed to the improvement of university students' learning through developing a learning content based on graphic design. In similar vein, Nash (2015) found that teaching physics using infographics based on visual thinking has contributed to significant improvements of visual thinking skills, academic achievement, and attitudes towards learning physics among high school students in South Korea. The results of Yildirim's study (2016) conducted on a sample of Turkish university students reveal that students considered infographics more effective in supporting their learning compared to traditional texts. Similarly,

Rueda (2015) concluded that using infographics in teaching Algebra for students at tertiary education in Mexico has contributed to statistically significant improved levels of academic achievement.

Furthermore, the results of other studies point out that the use of infographics supports various learning skills, including the development of self-organized learning skills (Ott, Robins & Shephard, 2014), enhancing students' information literacy skills (Toth, 2013), and improving visual literacy that is viewed as one of the 21st century skills (Kibar & Akkoyunlu, 2015). Moreover, infographics have the potential to result in significant affective influence on the learning process. Given they take the form of a unique visual method for information presentation, infographics would lead to increase learners' interest, in addition to helping them engage well in learning (Bradshaw & Porter, 2017).

In this context, the results of the studies conducted on the educational use of infographics demonstrate the existence of positive perceptions and attitudes among students of different educational levels concerning the use of infographics in learning. For instance, Aydin (2009) observed positive attitudes among university students towards the use of infographics in learning mathematics. Similar findings have also been reached by others investigations (e.g. Sudakov et al., 2014; Noh et al., 2015; Martix & Hodson, 2014).

3.6 Properties of Effective infographics

Existing literature demonstrate a set of prominent characteristics that must be available in infographics to achieve the desired outcomes. The most important of these requirements include: the sufficient quality of the information, concepts, explanations, examples and conclusions delivered; information should be presented in a balanced and harmonious hierarchical structure, and images and colors must be consistent and clear (Kibar & Akkoyunlu, 2015). Marabella (2014) argues that infographics should use short texts in addition to the effective employment of design elements. Davidson (2014) further adds five main properties of good informatics templates, these are: to serve as a narrative of a story; a clear and appropriate title to the content; ease of reading and contrasting text with the background; relevant, clear, and

original images, and consistency between shapes, colors and fonts in infographics. BanuInanc (2014) concludes that the topic of infographics is more significant than visual design (p. 45).

The role of visual learning in science education

Science is a content area of a visual nature due to its heavy reliance on multiple forms of visual representations and skills required to learn. Perhaps the most outstanding feature of science visual learning is that it opens up new prospects for problem solving, provides alternative opportunities for students to think in other ways, increases the ability to explain and present complex concepts to students and others, and at the same time increases students' academic engagement and helps them understand the complex relationships between scientific concepts and ideas (McGrath & Brown, 2005: 56). For example, in a qualitative ethnographic study conducted by Plow (2004) on a sample of primary school students in America, it was found that employing a visual approach that stimulates visual thinking for science learning in a web-based environment, and ensures that students provide visual representations, has enabled students to better understand scientific knowledge. Students also perceived that their practicing visual thinking had enhanced their ability to learn science and make links among different scientific knowledge structures. The implementation of visual approaches in science education would help students learn and practice many of visual literacy skills as well as visual thinking processes that are of paramount importance for learning science.

Visual literacy refers to a cohort of skills and abilities that enable learner to read, understand, interpret, and evaluate multiple visual representations and messages such as images, illustrations and charts (Aberšek, 2008). (Shaltout & Albarrak, 2015) define visual literacy as the ability of an individual to comprehend the ideas and the interactions among them, which are represented via different images. Whereas Omar (2016: 219) defines visual thinking as a set of mental processes which enable learner to identify and describe the visual form, compare its components, interpret the phenomena involved, and predict, arrange and evaluate events based on it. Visual literacy, on the other hand, includes the ability to read, construct and use visual representations for communication purposes. It can be seen as the practice and application

of visual thinking in science learning. Visual literacy skills equip a learner to understand and analyze the contextual, cultural, ethical, aesthetic, intellectual, and technical components involved in the production and use of visual materials (ACRL, 2011).

In light of the critical importance of visual literacy skills for science education, the main standards documents in science education support the direct and explicit teaching of these skills in order to develop students' academic achievement, which is documented in the "Framework for Science Education in k-12 Education" (NRC, 2012) and Next Generation Science Standards (NGSS Lead States, 2013) which state that "learners should be asked to use maps, diagrams and other abstract models as tools enabling them to broaden their concepts or outcomes and to present them to others" (NRC, 2012). Visual literacy includes the following skills:

- Determine the nature and extent of the visual materials needed
- Find and access needed images and visual media effectively and efficiently
- Interpret and analyze the meanings of images and visual media
- Evaluate images and their sources
- Use images and visual media effectively
- Design and create meaningful images and visual media
- Understand many of the ethical, legal, social, and economic issues surrounding the creation and use of images and visual media, and access and use visual materials ethically (ACRL, 2011).

As for science education, visual literacy skills include: transforming the complex language of science into visual representations easy to understand for various purposes such as problem solving, task performance, and scientific communication. They also involve the explanation of the visual representations students face, and through which they recall the previously learned concepts in an attempt to interpret these visual representations (Galyas, 2016: 30-32).

Many studies have documented the great importance of visual literacy skills in the teaching/learning science, which highlights the need to work on their development (Suzak, 2017; Aberšek, 2008; Galyas,

2016). For example, the results of a mixed-methods research study conducted by Galyas (2016) on a sample of American seventh-grade students showed that explicit teaching of visual literacy skills employed in the context of an inquiry learning setting has contributed to enhancing academic achievement levels.

Similarly, the results of (Chen, Dipinto & Newman's, 2017) qualitative study investigating practices applied in science education at the intermediate and secondary stages revealed documented various uses of visual literacy skills to support the learning of science content, and to help learners analyze visual representations, apply content and provide visual representations for that knowledge. It was also found that although visual literacy practices were not used formally; they have been eventually exercised, indicating that visual literacy skills are an integral part of science teaching/ learning.

Infographics as a visual tool for science learning

Infographics can be seen as a pivotal tool for visual learning of science, through which students can learn and practice visual literacy skills and visual thinking processes which significance for learning science has been verified in the previous section. In this section, this is presented as a prelude to presenting infographics as a visual tool for learning science for deaf students.

Visual literacy standards state that students should be able to assess and develop infographics for a variety of purposes (Bradshaw, 2018). This is due to the fact that infographics have become an integral part of the development and practice of information literacy skills. Research demonstrates a significant relationship between the use of infographics in instruction and visual literacy skills; a relationship of mutual influence. That is, in order to achieve the most effective use of infographics in education, it is necessary to equip students with visual literacy skills. Besides, the use of infographics would enhance students' visual literacy skills (Kibar & Akkoyunlu, 2014; Matrix & Hodson, 2014; Dur, 2014; Kibar & Akkoyunlu, 2015).

In their review of 55 studies, published between 2004-2016, investigating the use of infographics in instruction, (Naparin & Saad, 2017) concluded that infographics contribute to developing visual literacy skills, and help students and teachers understand and evaluate visual

information. In a same vein, (Shanks et al., 2018) present an intervention in which a number of higher education students in the US were encouraged to use infographics for presenting and communicating health information. Moreover, a study conducted by (Kibar & Akkoyunlu, 2015) demonstrated how assigning a sample of high school students to design infographics as a visual representation in the framework of a cooperative model between science and technology teachers has resulted in developing students digital literacy skills.

Assigning students to develop and share infographics lead to develop many of the significant skills required for them in their prospective careers, such as communicative and design skills (Fridman, 2018: 21). (Omar, 2016: 223) outlines some of the important aspects of the use of infographics in science education, including the following: It may help develop visual thinking skills such as: the recognition, interpretation, comparison, construction and evaluation of images; to contribute to the formation of sound schema and perceptions on scientific concepts and correcting misconceptions, as well as making science learning more attractive to students.

In light of this documented correlation between infographics and the development of visual literacy and thinking skills in science, the results of many previous studies highlighted the importance of utilizing infographics in science education in terms of enhancing cognitive, affective and skills learning outcomes. For instance, (Hassan, 2016) study focused on determining the effect of employing infographics, both fixed and motion, on developing students' learning of complex scientific concepts of the phases of the moon. Implementing the study on a sample of secondary students using a pre-post-experimental design, the results revealed that both types of infographics were effective in developing students' understanding of complex scientific concepts. These findings were explained claiming that infographics had worked to increase students' interest in learning as evidenced by the comments they reported on the use of infographics in learning. The results showed as well the superiority of the static form of infographics over the motion one; assuming that the former has provided the flexibility for learners for visual navigation in the entire schema information with its components, in addition to allowing them to read texts and visual representations simultaneously to complete the understanding of each part of the scheme.

The attempt was made in (Omar, 2016) study to develop scientific concepts and visual thinking skills along with the enjoyment of learning science for a sample of fifth grade students through a suggested strategy using scientific infographics. Using a quasi-experimental design with experimental and control groups, the results showed statistically significant differences in the three dependent variables in favor of students who studied using the suggested infographics-based strategy.

Asbi (2015) examined the potential of infographics on improving science achievement and attitudes and motivation towards learning among a sample of fifth-grade students in Palestine. Utilizing a quasi-experimental pre-test-post-test experimental and control groups design, the results documented statistically significant differences in the science achievement test, the attitudes scale and the motivation scale in favor of students who studied using infographics.

The study of (Noh & Son, 2015) aimed at investigating the effect of using visual thinking-based infographics in teaching physics to a sample of high school students. By using a quasi-experimental methodology with experimental and control groups to examine the effect of an intervention involved students' developing of infographics for physics learning purposes, it was found that the students studied though infographics statistically significant outperformed their peers in the control group in terms of understanding scientific concepts, developing communication skills, and developing attitudes towards science and scientific inquiry.As for the specific utilization of infographics as a visual learning tool of science, they may be used as a learning tool or a communication tool. In mixed methods research conducted by (Vanichvasin, 2013) on a sample of computer science students at Kasetsart University, it was found that infographics can work as a visual learning tool and as a visual communication tool simultaneously. The results demonstrated that infographics had played several functions as a learning tool. The use of infographics as a learning tool has contributed to improving understanding and retention levels. Moreover, the results also showed that university students studying the knowledge management curriculum had high levels of satisfaction on using infographics a communication tool. It was concluded the use of infographics contributed to changing learners'

roles towards more active roles along with helping engage in communicative activities using infographics as a tool for visual communication during the learning process.

Vanichvasin (2013) listed various uses of infographics as a visual learning tool including: presenting the learning content in a concise and attractive manner; better explaining the content and helping learners understand and connect it to their prior knowledge; using it as a learning activity such as case studies or mental maps, using for presenting various examples of concepts and ideas, and employing it as a tool to summarize content.

Learning science for deaf students using infographics as a visual learning tool

Given their special characteristics, deaf students are basically visual learners, as explained above. (Namukoa, 2014) stated that visual support tools, such as cognitive maps, graphic organizers, and various visual tools, are among the most important strategies that can be used by science teachers when teaching deaf students. (Luckner et al., 2001) provide various examples of the materials that can be used to promote deaf students' learning, such as: job and choice menus; task organizers; time charts and cards; daily schedules and charts of class rules. (Luckner et al., 2001: 38) further add that deaf students can better learn through the design of visually rich learning environments that depend on: diversifying contact with deaf students using sign language, lip reading or finger spelling; reliance on technological facilities such as computers, and visual aids like images, illustrations, graphs, videos, etc. The results concluded by (Nugroho & Kristiyanto, 2017) pointed out that the use of visual learning materials has resulted in significant development of achievement for a sample of deaf primary students in Indonesia, as documented in the statistically significant differences in favor of students who studied visual learning materials.

In another study conducted by (Hasanah & Kusumah, 2018) on a sample of deaf students in Indonesia where data was collected by means of questionnaires and interviews, it was found that the design of learning modalities based on visual learning considering the unique characteristics of deaf students has contributed to the development students' basic skills of mathematics learning, in addition to helping them constitute positive

attitudes towards it. Furthermore, a plethora of previous studies support the importance of visual representations and tools in improving the performance and learning of deaf students. For example, the results reached by (Nery & Batista's, 2004) study demonstrated positive effect of systematic use of three visual representations forms (I.e. drawings, photos, and pictures) in the context of teaching deaf adolescents. This positive effect was explained not only due to its appropriateness to the needs of deaf students but also by enhancing these representations with extensive descriptions and by helping deaf students connect different learning topics of engage in dialogue and discussion.

Scholars have also devoted a substantial amount of attention to the importance of using various visual representations of content for helping deaf students learn, understand, and overcome language difficulties they face by making them focus on important content and key concepts and ideas; eliminate extraneous information; and help them in visual understanding of the relations among different concepts, the conclusions which are documented in several studies examining the use of multiple forms of visual representations such as: concept maps (Nikolaraizi & Theofanous, 2012), maps (Boucher, 2010), Graphic Novels (Smetana, Odelson, Burns & Grisham, 2009), Graphic representations of sign language (Hoffman & Wang, 2010), and presentations involving graphics (Prince, 2010). In this context, infographics can be seen as a form of graphic organizers which, according to (Luckner et al., 2001: 39), express visual representation of information and knowledge students have to learn, thus helping them link their prior knowledge with new concepts and ideas. The main feature of infographics as a form of graphic organizers is that they help in eliminating extraneous information (that would cause extraneous cognitive load on learners) and allow, at the same time, learners to focus on key facts and concepts and to link various concepts and ideas. In addition, infographics facilitate the memorizing and retention of information; provide learners with opportunity to play active roles in their learning (Luckner et al., 2001); and explain the organization information and ideas introduced. They can also be used prior to learning (for warming up and activating cognitive background), and after learning taking place (to conclude main ideas and link different concepts), and most importantly, they invest the main strengths of deaf learners on the basis of their sight acuity. The point that is closely correlated with what have been discussed in the above section

regarding the pivotal role of visual literacy skills and visual thinking processes in science learning in general, is that such skills are significant for deaf students, especially if they are to learn science. Taking advantage of visual literacy helps deaf students overcome the language barriers using their visual acuity (Ying, 2008; Olatoye & Aanu, 2010), a finding that is illustrated by the results of several studies. For instance, a study conducted by (Nikolaraizi, Vekiri & Easterbrooks, 2013) highlighted the role of employing multimedia in developing reading comprehension for a sample of deaf students aging between 8-12 years. In particular, the results revealed that teaching visual literacy skills had mediated the effect of multimedia on students' reading comprehension by means of strengthening successful processing of visual representations and aids provided in multimedia. Based on these findings, the study concluded the need for systematic development of visual literacy skills among deaf students so that they could maximize the potential of the visual approach of learning as a main vehicle for information acquisition. The authors recommended the need for studies examining whether direct instruction of these skills can help deaf learners employ visual learning resources efficiently in different learning situations.

In a study investigating the effect of employing Augmented Reality Book as a visual learning method for deaf students' science education, (Zainuddin et al., 2009) collected data on the development of science skills by means of observing a sample consisting of 3 middle school deaf students in Malaysia. The results revealed that employing that method has helped students learn science by making them able to understand the visual information provided and visualizing ideas, in addition to enhancing their ability to communicate visually using sign language and to provide scientific justification according to the images provided, and help them improve visual literacy and use it in learning science. In the same vein, the results of a study conducted by (Nunes et al., 2006) demonstrated that taking advantage of visual skills would result in improving deaf students' academic performance. In this study, it was found that deaf students managed to achieve better performance in learning mathematics when information was successively introduced in a visual fashion.

In light of the above, it is concluded that infographics can be used as a visual learning tool for deaf students that helps them develop and practice visual thinking processes and visual literacy skills, which are vital to learning science. In this respect, infographics can be used either

as a learning tool to read and understand visual representations or as a communication tool for writing or developing infographics for scientific communication purposes as illustrated in the following figure.

In conclusion, (Bilbokaitë, 2008: 11) suggests a model for practicing visual thinking processes in the science education framework that can be used effectively when employing infographics as a visual tool for teaching science to the deaf. According to this model, visual thinking starts when students begin to see. Here, there are three visual thinking skills: 1- visual recognition that helps learners recognize, decode, store, and store visualizations; 2- Visual Imagery, which includes several processes such as: imagining objects in space, reconstructing visual images based on information encoded in symbols; modeling, retrieval, selection, planning, drafting, in addition to building mental models, understanding and learning, thus constructing students' knowledge; and 3- Visualization: through which students develop visual representations expressing their scientific ideas and increasing to their ability to remember what they have learned (Bilbokait,, 2008: 11). Implementing this model in teaching science for deaf students, the educational use of infographics should encourage the practice of the above visual thinking processes through helping students in visual recognition by modeling cognitive skills and making them practice under the direction of the teacher. Students should also be helped to use infographics to formulate mental models of learned scientific knowledge, besides assigning them with activities aimed at constructing information schemes themselves to represent their scientific ideas and to understand their relationships.

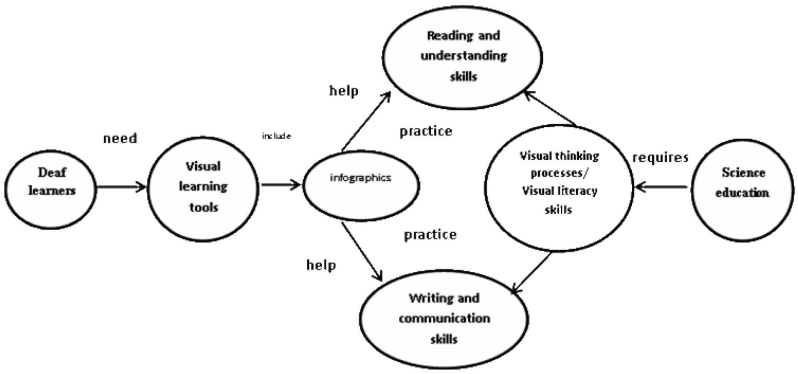

Figure 1: a conceptual framework for the role of infographics as a visual learning tool in the science education for deaf students (developed by the researcher).

Challenges of using infographics in education

As in any instructional approach, the benefits of implementing infographics are associated with challenges and difficulties. The first challenge is that professional design and development of infographics requires specialized programs such as Photoshop, CorelDraw, Illustrator and InDesign, which can be problematic for teachers because many lack the skills necessary to use this advanced type of software (Taspolat et al., 2017).

The empirical study conducted by (Ozdamli & Ozdal, 2018) on a sample of Turkish teachers with the purpose of examining their experience in the use of infographics has concluded a number of challenges teachers face within the use of infographics including: time restrictions that impede the effectiveness of infographics design; the fact that infographics require a great deal of creativity by teachers; as well as the difficulty in finding visualizations and images that fit the particular subjects.

Similarly, the results of (Fadzil, 2018) study on a sample of prospective teachers identified some difficulties within infographics design, most notably were: requiring a great deal of time and effort in their development, in addition to a high degree of proficiency in skills to use infographics development software. The development and production of infographics require a great deal of brainstorming, thinking about the audience of learners, the concepts to be delivered, and the best ways to communicate these concepts through infographics (Fadzil, 2018:16).

On the other hand, textbooks used in teaching science are still ignoring the appropriate use of infographics, which is often shallow and restricted even for textbooks tailored for science education to deaf students. For example, the results of (Noh & Son, 2014) study that analyzed the content of secondary stage physics textbooks in South Korea concluded that physics books do not provide rich infographics but rather limited to some minor visualizations.

Instructional design of Infographics in the context of science education for deaf students

Ruottinen (2014: 11) argues that despite the importance of infographics as a learning tool, when are not designed appropriately they

may be misunderstood and could lead to negative influence on learning. Instructional design of Infographics involves the integration of several components like as shapes, symbols, images, graphic representations and verbal content, which are used individually or in combination to transfer information visually (Ozdamli & Ozdal, 2018: 1199). It is critical to comply to visual design principles that affect the content and the form of infographics along with their influence on appearance and quality of the educational value of infographics as learning materials (Ruottinen, 2014: 2).

Taspolat et al. (2017) identified four key phases for the development of infographics: 1- Develop a plan: in this phase the focus is on the purpose and content of infographics, as well as on the context, structure and script of infographics; 2- Initiate Design: the actual design process is initiated according to the predefined plan. Specialized programs and online tools are used to translate the plan into actual design. Consideration should be taken in this phase to some of the specifications that must be met in the information provided should such as: simplicity, conciseness, visual clarity and highlighting the relationships among information; 3- check: this phase includes an initial assessment of infographics in terms of how visualization and content are introduced, whether there are errors, or redundant information; and finally 4- Conclusion: where the infographics are completed and disseminated.

Finally, (Fadzil, 2018) and (Krauss, 2012) cited a nine-step approach to infographics design. These are: identifying a science curriculum subject to design. relevant infographics; setting educational goals of using infographics; developing a summary or flow map that defines infographics agenda; laying out the plan using infographics design software; evaluating information in terms of accuracy and relevance; determining the best method for information visualization; selecting fonts, colors and appropriate design elements; evaluating infographics and obtaining feedback; and considering issues of property rights and documentation.

Moreover, principles or criteria to be considered when designing infographics are given front-page attention in the literature. For instance, in a study conducted (Ozdamli & Ozdal, 2018) with the purpose of identifying the considerations of good instructional design of infographics

used for teaching from the perspectives of a sample of teachers and students in Turkey, results derived from semi-structured interviews and survey questionnaires documented a set of infographics instructional design requirements from teachers' points of view, namely: considering the characteristics of the target learners; involving a clear scenario or organized structure; focusing on instructional objectives; being linked to content; consistency with visual design principles; to be attractive; provision of reliable and up-to-date information; simplicity, clarity and ease of understanding; drawing the attention of learners to important information; summarizing the main ideas of learned topics; teachers in charge of design should have adequate knowledge of the content introduced in infographics; including a preliminary preparation stage prior to actual use; not to be poorly designed to avoid multiple interpretations by students; to be free from extraneous or unnecessary information and data; and considering the opinions of experts in design.

The results of a (Yashodharakumar, Venkatesan & D'Souza's, 2017) study identified some significant considerations for infographics design from the perspectives of prospective teachers, these are: to be interesting graphically; to stand on an organized and appropriate structure; to involve in-depth information and accurate content; and to enable students should to identify the main idea at first glance. In the review by (Naparin & Saad, 2017), a set of considerations have been identified within infographics design for educational purposes, including: attention to the structure above all, taking into account the accuracy, depth of information and its function, and thinking about the aesthetic form. Likewise, Vanichvasin (2013) lists three key considerations for infographics design as a visual learning tool, namely: appeal: that means devoting students' interest, attention and involvement in learning; help understanding: to provide information in an understandable and comprehensible manners to students; and assisting in retention: to make learning content easier to memorize and retain.

Asbi (2015: 20-21) suggested some guidelines for the appropriate design of instructional infographics, these are: 1- developing streamlined constructive structures that integrate with one another to help simplify and facilitate understanding of the information provided; 2- selecting a color system that helps readers visually connect ideas and devotes the reader's attention without distraction; 3- choosing the appropriate

graphics, whether objective thematic, or referencing graphics; 4- infographics designer should be aware of the data presented so that he can organize and connect them sequentially; and 5- stimulating the reader to infer conclusions, which motivates the realization of the mind and increases the linkage of information with each other.

In the same vein, (Krauss, 2012: 13) identifies some simple principles of infographics design including: providing a context for information introduced in infographics by designing it to tell a story; to be clear; to rely on reliable and valid data; and to attract students' attention. In the attempt to develop a standards-based instrument to assess the instructional design of infographics for learning purposes, (Nuhodlu Kibar & Akkoyunlu's, 2017) study managed to determine a set of key criteria with their sub-indicators as follows; generating content criteria; visual design development criteria of the big picture; visual design development criteria of the texts; and visual design development criteria of colors and visualizations.

It is worth observing that in light of literature review and according to the best knowledge of the researcher, specific criteria for instructional design of infographics used in teaching deaf students have never been introduced, a gap to be filled in the following paragraphs:

- The title is well-suited to the content.
- Reduction of the verbal or textual contents as much as possible to take into consideration the linguistic difficulties experienced by deaf students.
- Employing familiar symbols for deaf students.
- Helping and encouraging deaf students to employ visual thinking processes and visual literacy skills in understanding and visualizing scientific concepts.
- The design of infographics should contribute to highlighting the diverse relationships among phenomena, concepts and scientific principles, especially cause and effect relationships.
- Providing deep content and advanced scientific ideas, rather than the mere repetition of superficial ideas that students have already mastered.

- Infographics should be formulated in a narrative or storytelling format that presents a particular position or idea.
- Consistent use of elements such as colors and shapes across infographics.
- Ensuring that design helps manage the cognitive load appropriately.
- Infographics should include examples from the authentic to deaf students to help them apply what they have learned.

The following is a highlight of a cohort of suggested infographics design principles tailored to deaf students that are based on cognitive load (Sweller, 2010) and multimedia learning (Mayer, 2009) theories: eliminating information irrelevant to key scientific ideas and concepts; bringing about convergence of words and associated visualizations; highlighting key ideas and concepts compared to the whole text; highlighting linkages among different concepts and ideas; progression in presentation from simple to complex; and ensuring that visualizations are not repetition of texts but rather complementary to each other. So far, question 3 of the study has been answered.

Pedagogical approaches and practices for the integration of infographics in teaching science for deaf students

The value of modern and innovative instructional technologies and materials does not lie in their use per se, but rather in the way they are used in light of the recent educational studies. Thus, it is important to address the teaching approaches through which infographics can be used to prime active learner-centered learning processes in teaching science for deaf students. The educational use of infographics should contribute to developing the skills required to the use of a various set of visual representations, including mental maps, concept maps, graphs, tables, and charts. Infographics would also lead to developing informatics literacy, as well as enhancing learners' ability to access complicated information, analyze, organize, and using it in other contexts (Ruottinen, 2014).

An example of the educational employment of infographics in teaching science is provided by (Damyanov & Tsankov, 2018) in their study that investigated the use of infographics as a modeling tool in the context of science instruction. Infographics were employed as a method

for modeling scientific phenomena and concepts with the purpose of developing many cognitive skills such as interpretation, analysis, evaluation, and reasoning, which are integral parts of modeling processes. In order to this, the study utilized a cohort of relevant tasks, including: modeling tasks using infographics, coding information from one model to another, comparative tasks for modeling meaningful abstractions, generalization tasks for modeling gender relationships, and evaluation tasks to model cause and effect relationships.

In a similar vein, Gebre (2017) suggested an educational approach based on scaffolding learning for teaching science by means of infographics. According to this approach, secondary school students were assigned to work collaboratively in the classroom to develop infographics for two purposes: knowledge representation and applying what they have learned in authentic learning contexts; and to use these infographics in evaluating students' understanding of the scientific and concepts notions delivered.

Moreover, (Lamb et al., 2014) proposed an interesting instructional approach for the educational use of infographics in teaching science, called visual read-aloud approach. According to this approach, infographics are introduced in science course. The teacher, then, visually reads-aloud the content of infographics explains and models for students how to read data involved in infographics and how to understand and interpret the meaning behind these data, as well as raising questions to provoke discussion.

Another example of the educational utilization of infographics is presented by (Omar, 2016) in his study that proposed a strategy for using infographics in which four main procedures are applied, these are: 1- considering the objectives and uses of infographics with students; 2- helping students explore infographics within their work in small flexible groups according to their needs and preferences, in addition to practicing specific activities to explore infographics; 3- interpretation of infographics: through dialogue and discussion in groups, students attempt, under the guidance of the teacher, to interpret and explain infographics, while the teacher seeks to ascertain the accuracy of the students' conclusions about the targeted scientific concepts; and 4- evaluating the learning of scientific concepts through infographics: this would take place by means of a set of oral and written questions to

make sure that students comprehend and understand the scientific content and that the learning objectives of infographics have been achieved. This process takes the form of a circle in which the eventual use of infographics at the end of the lessons serve as a beginning of another one.

Sommer et al., (2016) introduced a collaborative approach for using infographics in developing scientific literacy in informal learning environments. The suggested approach has been implemented on secondary school students who were encouraged to engage in the process of infographics production regarding scientific information in an informal learning environment. The design considered to be applied collaboratively, where students should represent the scientific knowledge associated with news published in the form of infographics according to specific rules they have been trained on. Results revealed that the approach had a positive impact on increasing the levels of students' scientific literacy in addition to improving their literacy in (STEM).

Krauss (2012: 12) introduced an instructional approach for employing infographics in teaching as a tool aimed to develop interpretation and creativity skills. Interpretation is developed through the introduction of infographics requiring learners to understand different types of relationships among the main concepts of content; to develop their critical skills by providing various visualizations such as graphs, maps, etc.; and to help students understand the infographics' intentions to develop their information literacy to be capable of comprehending the purposes behind the introduction of various infographics. Creativity, on the other hand, is developed training students to visualize data by assigning them to produce infographics on their own; to develop students' ability to represent important scientific and statistical data and to highlight their relationships through their schemes; and to train students to develop infographics that provide valid and accurate information.

It is argued that the use of infographics in teaching science for deaf students should proceed in accordance with bases derived from contemporary educational ideas that call for learning to be learner-centered where students play active roles. The use of infographics should contribute to changing the conventional roles played by students and teachers. For instance, the results of a study conducted by (Vanichvasin, 2013) revealed that the use of infographics in teaching students has

contributed to making students more interactive, engaging in thinking, as well as being more integrated and involved in the classroom and more able to communicate their ideas and understanding. It was also concluded that the use of infographics contributed to the transfer of teacher's role from the source of information to the facilitator of students' learning.

The previously cited approaches can, thus, be considered appropriate and useful if applied in the science instruction for the deaf students. Prior to the use of infographics in teaching deaf students, however, this should be well prepared by means of clarifying the objectives of infographics use and the idea on which they are based, providing intensive training for students on visual literacy skills and increasing their ability to understand and interpret information involved in infographics, as well as training them on producing simplified infographics for use in learning and assessment. Infographics can be used as well as an assessment tool for deaf students' learning by assessing students' ability to extract and use information delivered in infographics in other contexts, or identifying the extent to which students can link and organize their ideas, concepts and knowledge. By the end of this section, question 4 of the study has been answered.

Recommendations of the study

- Work to promote science textbooks for deaf students with an appropriate level of infographics to help in visual learning of science.
- Incorporating a large number of infographics of various subjects and scientific concepts in teachers of deaf students' guides to encourage them to design and use infographics in science instruction.
- The adoption of infographics design standards and principles introduced in the present study as a basis for designing infographics appropriate for the characteristics of deaf students.
- Providing specialized programs for professional development purposes tailored to teachers of deaf students to help them use different types of infographics in science instruction.
- Science curriculum for deaf students need to involve an implicit training on visual thinking, visual literacy, and informatics literacy

skills in light of the paramount importance of these skills in helping students use visual learning approach and taking advantage of various visual representations.

Suggested research

Research on infographics and its use in learning are generally considered relatively modern fields, which may need further investigation. There is a dearth of research as well on the use of infographics with deaf students. In this regard, it is suggested to conduct the following research and studies:

1 - Mixed methods study exploring the effect of using infographics on the development of scientific concepts and attitudes toward science among deaf students.

2 - The effect of deaf students' training on visual literacy skills through an infographics-based- strategy on the development of science processes skills.

3 - Relative effectiveness of multiple patterns of infographics (static, motion, and interactive) on developing science achievement for deaf students.

4 - A qualitative study on deaf students' teachers' perceptions and experiences regarding the use of infographics as a tool for visual learning of science.

5 - The effect of a suggested program based on infographics on the development of informatics literacy and its applications in learning science for deaf students.

المخططات المعلوماتية (الإنفوجرافيك) كأداة للتعلم البصري للعلوم لدى الطلاب الصم: دراسة تحليلية

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السعودية

الملخص

هدفت هذه الدراسة إلى الكشف عن كيفية توظيف المخططات المعلوماتية كأداة بصرية لتعلم العلوم للطلاب الصم. واستلزم تحقيق هذا الهدف الرئيس، إبراز تحديات تعلم العلوم للصم وبيان كيف يمكن أن تساهم المخططات المعلوماتية كأداة بصرية للتعلم في التغلب على بعض من هذه التحديات، وبيان معايير التصميم التعليمي لمخططات معلوماتية فعالة لتعليم العلوم للصم، والمداخل التعليمية لتوظيف المخططات المعلوماتية كأداة للتعلم البصري للعلوم لدى الطلاب الصم. ولتحقيق أهداف الدراسة تم الاعتماد على منهج البحث الوصفي التحليلي القائم على مراجعة وتحليل الأدبيات والدراسات السابقة لاستنتاج الأفكار والإجابات على أسئلة الدراسة بطريقة نظرية. وبينت نتائج الدراسة وجود العديد من تحديات تعلم العلوم للصم وتستلزم الاعتماد على المداخل البصرية للتعلم بالأساس مثل المخططات المعلوماتية. كما أبرزت النتائج أن المخططات المعلوماتية يمكن أن تكون بمثابة أداة بصرية فعالة لتعلم العلوم مثل الصم ومساعدتهم على الاتصال العلمي؛ وذلك من خلال مساهمتها في مساعدة الطلاب على ممارسة عمليات التفكير البصري ومهارات التنور البصري التي تعد بمثابة مكون حاسم في تعلم العلوم. واستناداً إلى مراجعة العديد من الدراسات تم تحديد عدد من معايير التصميم التعليمي للمخططات المعلوماتية لتعليم العلوم للصم، وتحديد عدد من المداخل التربوية لتوظيف المخططات المعلوماتية في تعليم العلوم للصم. وأوصت الدراسة أن يعمل معلمو الصم على تصميم وتوظيف المخططات المعلوماتية كأداة بصرية لتعلم العلوم وفقاً لمداخل وأسس تربوية متينة. وتم اقتراح إجراء دراسة مختلطة المناهج البحثية للكشف عن أثر استخدام المخططات المعلوماتية في تنمية نواتج التعلم المختلفة لدى الطلاب الصم.

الكلمات الدالة: المخططات المعلوماتية، تعلم العلوم، التفكير البصري، التنور البصري، الطلاب الصم.

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