Science Learning for Students with Visually Impaired: A Literature Review

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Abstract. Science learning should be accessible for all learners including students with visually impaired (VI). Students with VI apparently have the same cognitive abilities range and can master higher-order science concept as well. The purpose of this study is to explain that students with VI can learn science well if there is the right learning support tool by in-depth literature review. This in-depth literature review uses the following steps: selection of the articles, analysis the studies and categorization of the articles. A total of seventeen journal articles from the year of 2009-2018 written in English on the topic of science learning for students with VI that divided based on how do the students with VI learn and teaching and learning science to students with VI. This literature was collected via the ERIC database and the Google Scholar website. Based on this literature reviews, students with VI can learn science well if there is a proper support tool for them to learn. If the teachers are able to apply the right learning model and are supported with good facilities such as orientation and movement, tactile and kinesthetic learning, auditory learning and accommodations, and assistive technology, it is possible that students with VI will be able to learn about science very well.

1. Introduction
Science learning should be accessible by all learners [1],[2],[3] including the student with special educational needs. Science Education for All is one of the manifestations of Education for All (EFA). A student with visually impaired (visually impaired hereinafter: VI) is one of the types of students with SEN who has limitation to obtain information through their eyesight sense. Besides accessible to all learners, science learning also should be prepared for further education, employment, and independent living (Individual with Disabilities Education Act (IDEA)) and should help students in developing an understanding and habits of thinking, which is needed to solve the problems in life [4] for students who have VI.

Students with VI have the same cognitive abilities range as sighted students [5] and the students with good accommodations help can master higher-order science concepts as well as sighted students [6]. Some research studies on the implementation of science learning to the students with VI have been conducted such as by [7]-[9]. The study which is conducted by [7] reveals that the teacher motivation
and mentorship in science learning are lacking. Then, [8] reveal that students with VI need more instructional and environmental accommodations like an audio experience than a visual instruction to learn science. In addition, [9] find that visual impairments do have an impact on academic performance, i.e., the students with VI are more likely to have poor academic performance.

The study which has been done before has shown a clear conclusion about teaching science learning to students with VI. A deeper literature study is needed to summarize the result of previous studies comprehensively. This in-depth literature review would be useful for further research in teaching and learning science to the students with VI.

2. Methods

In order to provide an overview of available and convincing research, literature reviews were conducted by choosing articles from recently published peer-reviewed journals (an arbitrarily chosen 10-year period). The steps taken in this research are a selection of the areas, analysis, and categorizations. Sixteen relevant peer-review articles have been chosen in the current study and focused on teaching science learning to the students with VI in the inclusive classroom.

2.1. Selection of the Articles

Articles selection started from peer-reviewed research journal in the Google Scholar database. The keywords which are used in the search are ‘science learning,’ ‘students,’ and ‘visually impaired’ with a span of time from 2009 to 2018. In the beginning, the researchers used the Google Scholar website “https://scholar.google.com/” and ERIC database website “http://www/eric.ed.gov/” a total of 286 full texts was found. To limit the search of match articles which were appropriate with keywords, only peer-reviewed research articles were selected. The numbers of articles were 89 on Google Scholar and ERIC database.

At the second phase screening, the researchers select journals that focus on how the students with VI learn and how to teach science learning for the students with VI. The researchers excluded articles from the corpus articles that not mention of focus in this study. As a result, seventeen articles were identified for thorough analysis according to the research question. There are 11 articles for answering the question how do the students with VI learn and 6 articles for answering the question of how to teach science learning to the students with VI.

2.2. Analysis of Studies

The literature reviews were conducted utilizing a best-evidence approach, based on the analysis of the seventeen journal articles selected according to the research question. Each article was analyzed by two people and one verification. In this process, the researchers used the same criteria that were mentioned above, according to the questions.

2.3. Categorization of the Articles

Each article was reviewed in light of the developing set of research questions until the entire set of data was treated. The researchers also ensured that each article had the potential to fit into more than one finding (and sometimes many more). For example, some articles show different types of achievements. Therefore, the study divided the results based on how do the students with VI learn and how to teach science learning for the students with VI.

3. Results

After applying the selection criteria, 17 studies were selected for this review. There are how do the students with VI learn (Table 1, 11 articles) and teaching and learning science to students with VI (Table 2, 6 articles).
3.1. How do the Students with Visually Impaired Learn?

[10] determined understanding 18 students with VI to use assistive technology in instruction and assessment. From the entire total sample, 13 students had low vision (2 students had hearing loss, and 4 students had another documented disability) and 5 students were totally blind. The result revealed that the time for the students with VI reading large print or braille who take to complete a task is often far greater than that for their peers with full functioning vision. Assistive technologies which can increase students’ efficiency were highly dependent on the knowledge and teacher’s mastery on it. In line with research that conducted by [10]-[11] have been provided an examination of the voiced-based framework for the VI learners in ODL. Based on the usability evaluation, the voiced-based examination system has an “average usability” rating of 3.48 out of 5 scales. It means that the developed application would improve the accessibility of examination in the distance learning for students with VI.

In the other studies that conducted by [12] and [13], they also use assistive technology to teach science learning. [12] study aim is to scrutinize the reading fluency effects in learning contracted English braille to 12-year-old male students with VI. The total number of errors of the first phase is 68 in 128 seconds (0.91% accuracy) and the second phase is 70 in 120 seconds (0.94% accuracy). This study noticed that contracted braille has some advantages over the alphabetical form. Compared with alphabetic braille, improving reading skills and saving a great deal of space are among the advantages of the contracted form. Furthermore, [13] finds that information technology application in the transcription of reading materials into alternative format for the students with VI in Nigeria are embosser (59.3%), tape recorders (58.2%), talking calculators (29.2%), scanners (28.8%), computer with brailing software (22.9%), handheld magnifier (20.0%), jaws computer (18.6%), dolphin pen (13.2%), electronic Braille system (11.4%), optical characters recognition system (9.2%), synthetic speech software (9.2%), Kurzweil reading machine (8.5%), data technology (7.4%), Braille 2000 (7.4%), closed-circuit television (6.0%) and converters (5.4%) from the total 470 responded to the survey. The study indicates that there is a positive linear correlation between the application of information technology and the transcription of reading materials into the alternative format. In addition, [14] find that information and communication technology are used to support learning for the students with VI are computers (77.8%), Braille embosser (75%), tape-recorder (69.4%), special software (61.1%), note-taker (55.6%), internet (50%), talking dictionary (33.3%), closed circuit TV system (25%), Perkins Braille (19.4%), magnifiers lenses (16.7%), talking watch (11.1%) and PAC mate (8.3%). This study reveals that the most required ICTs facilities include hardware and software that match to the user needs and preferences of the students with VI to facilitate their learning and allow them to participate effectively in the learning environment. Based on study findings, it can be concluded that students with VI face some limitations in assessing and utilizing ICT facilities to enhance the quality of their learning experience.

[15] believe that Math-Learning App held the most potential for effective delivery of math instructions for students with VI. Based on two-hours training and then introduced the app and materials to the students with VI are reported that the app was interesting, intuitive, and enjoyed learning about the animals described in the world’s problems. In general, the results point to the potential of technology to support access to instruction for students with VI.

[16] study aim is to determine 5 students with VI (3 students are blind and other are low vision) knowledge about museums, museums contributed to their learning, and their gain expects from museums visiting. The result of the study revealed that visiting museums are very beneficial and the learning process becomes more exciting and effective when the proper physical conditions are provided for students with VI. Blind students are expected to have the copies of the works of art, embossed forms of the drawings, and some explanations in the Braille alphabet. Students who suffer from low vision are expected to have more spacious and better-lighted interiors, contrasting colors in exhibitions, and scripts in large-prints.
Table 1. How do the students with VI learn.

| Author(s) | N   | Learning Media                  | Findings                                                                                      |
|-----------|-----|---------------------------------|-----------------------------------------------------------------------------------------------|
| Johnstone et al. (2009) | 18  | Assistive technology and assessment | The time for students with VI reading large print or braille requires a longer time to complete the task when compared to students who have normal vision. |
| Azeta et al. (2018) | 10  | Assistive technology: Voice-based e-examination system | The voice-based e-examination system can immensely benefit to the VI students in ODL in respective of distance and complement the existing web-based method for online examination. |
| Suveren-Erdogan & Suveren (2018) | 15  | Verbal Communication and physical help | The help with verbal and physical communication is an excellent benefit in movement training and progress of students with VI. |
| Mobarak et al. (2017) | -   | Learn English in alphabetical braille and contracted braille. | Positive effect on the reading skills of VI students who are learning English as a foreign language when studying with contracted braille learning. |
| Nkiko et al. (2018) | 470 | Information technology | The application of information technology in the transcription of reading materials into alternative formats is crucial and indicated a significant positive relationship for the students with VI. |
| Eligi & Mwantimwa (2017) | 32  | ICT-based assistive technologies | Students with VI face some limitation in accessing and utilizing ICT facilities to enhance the quality of their learning experience. |
| Beal & Rosenblum (2015) | 29  | Math-learning app: Animal Watch online math tutoring program | The Animal Watch online math tutoring program is the potential of technology to support access to instruction for students with VI. |
| Buyurgan (2009) | 5   | Museums | Blind students are expected to have the copies of the works of art, embossed forms of the drawings, and some explanations in the Braille alphabet. Students who suffer from low vision are expected to have more spacious and better-lighted interiors, contrasting colors in exhibitions, and scripts in large-prints. |
| Matchinkski & Winters (2016) | 14  | Portable electronic magnifiers | Reading and writing rates, as well as ease of writing tasks, were superior in desktop electronic magnifiers when compared to all portable electronic magnifiers. |
| Nannemann et al. (2017) | 3   | Oral Braille Reading | Students demonstrated several decoding errors and utilized a variety of decoding strategies while reading. |
| Arslantekin (2017) | 402 | Orientation and mobility skill | The level of mastery of the traffic concepts required for orientation and mobility was very low. The performance levels regarding concepts related to body plane relatively higher. |

[17] study objective is to gain an understanding of preferences, and reading and writing performance of subjects with visual impairments using different portable electronic magnifiers. Based on the results from 14 subjects were tested, reading and writing rates, as well as ease of writing tasks, were superior.
in desktop electronic magnifiers when compared to all portable electronic magnifiers. Desktop electronic magnifiers allow faster reading rates and more comfortable writing than portable electronic magnifiers do, and these devices should be considered first when prescribing assistive technology, especially in the education of children.

[18] investigated students with VI (n=320) and among the inclusion students in the immediate surroundings (n=82) from 16 schools. In this research, the students with VI percentage of implementing body plane and traffic concepts were reviewed by Orientation and Mobility Skill Assessment Tool (OMSAT). This study concluded that the level of mastery of the traffic concepts required for orientation and mobility was very low and their levels performance levels regarding concepts related to body plane relatively higher.

In the other side, [19] observed 15 students with VI which in basic training activates posture training exercises to their as a step to learn more difficult movements. As a result of this study, it can be concluded that VI students have significantly increased successfully learned the basic postures. The basic poses that such as verbal communication and physical help. This help can apply movements with difficult conditions more easily and with fewer mistakes compared to the early attempts and movement qualities significantly increased. [20] showed three middle school students with VI there are Justine, John, and Bill. Decoding errors of Justine evidenced as a result of the unknown meaning of words (11), braille errors (41), word substitutions (8), proper nouns (3), word omissions (4), and mispronunciations (3). John’s decoding errors are braille errors (50), unknown meanings of words (13), word substitutions (7), proper nouns (1), omitted words (2), and mispronunciations (2). Bill’s reading errors are braille errors (115), unknown word meaning (1), word substitutions (1), mistakes (3), letter reversal (1), and unidentified errors (22). These study findings that students demonstrated several decoding errors and utilized a variety of decoding strategies while reading.

3.2. Teaching and Learning Science to Students with Visually Impaired

In the study which is conducted by [21], it is aimed to reflect upon their experiences of supporting a VI student through a nine-month level two undergraduate biological psychology module. In teaching sessions, they adopted a student-centered approach to ensure that all students were supported and learning was facilitated. Therefore, finding innovative ways is the primary adaptation to communicating the intricacies of biological diagrams without capable students to visualize them. For example, pin-dot diagram, the 3D diagram of brain structure, and 3D models. The students’ evaluation was very positive.

One week of VI summer school [22] on the theme of structure and bonding with the practical elements interspersed with talks and workshops. Available materials are audio tape recordings and Braille which was delivered before the course. The students’ learn about the atom and its structure, electron shell, bonding, structure (water, silica, and salt), solids (diamond & graphite). The used learning media is molecular modeling kits. Classroom sessions where practicals were run successfully. In that, the students were much more familiar with the surroundings and the smaller space made noise management much easier.

[23] examined an animal-assisted good education course effect on the knowledge of students. The students’ understanding that examined is about caring for dogs physically and psychologically and making informed decisions about dog ownership, including working dogs. Based on the eight-week animal-assisted individual education course, students learning how to greet, feed, play with, obtain, and pay for dogs, and appropriate equipment and the roles of working dogs. The findings indicate that although students did not master all of the knowledge and skills which were taught in the course, they became more knowledgeable about the care and ownership of dogs.
Table 2. Teaching and learning science to students with VI.

| Author(s)         | Subject                          | Method                                      | Finding                                                                 |
|-------------------|----------------------------------|---------------------------------------------|-------------------------------------------------------------------------|
| Betts & Cross     | Biological psychology            | Students centered approach                 | The ways to communicate biological diagrams for student with V, i.e., pin-dot diagrams, 3D diagrams, and 3D models. |
| Shallcross et al. | Practical chemistry: structure and bonding | Audiotape recording, diagrams, and Braille. | The practice class sessions run successfully despite some obstacles: many students do not read Braille, noise. Students with VI learn about atoms, electron shells, bonding, structure (water, salt, and silica), and solids (diamond and graphite). |
| Bruce et al.      | Species: working dogs            | Animal-assisted humane education course     | Students learn to greet dogs with their owner's permission, to feed a dog twice daily, and to play with exercise a dog. |
| Maghuve (2015)    | Science                          | Face-to-face interview                      | The teacher motivation and mentorship in science methodologies and the use of tools for learner empowerment are lacking. |
| Sahin & Yorek     | Science                          | Interviews and observations                 | Students with VI need instructional and environmental accommodations to learn science. |
| Urquhart (2012)   | Comet                            | 3-D models                                 | Comet is frozen water, dry ice, and other sandy/rocky material that is mixed and is the remnant of the early formation of our solar system. |

[7] study is reported by interrogating a blind technician on factors that limit of blind and partially sighted learners in science education. Based on faced-to-faced interview, it reveals that; 1) the science curriculum is accessible; 2) the state of teacher was not trained to teach students with VI and lacked the necessary innovation where resources for the teaching of science were limited; 3) teachers were lack on specialist training to guide blind and partially sighted learners; 4) science teachers need to attend regular staff developments workshops covering selected topics in science and accommodation suitable for blind and partially sighted learners; 5) science education is essential for the students with VI and 6) Student with VI find that it is difficult to pursue science subjects because the limitation of resources and not prepared teacher to do the best in each learning process to their learners. The conclusion of findings of this study that successful science education for students with VI requires teacher empowerment through rigorous development and training on both approaches to subject matter to the students with unique learning needs.

The purpose of the study by [8] was to investigate, describe, and explore the ways that students with VI learn science. The results of this study are the students very comfortable with walking around the classroom; know the locations of all the desks, chairs, and equipment in the class; and can use the computers very well. Students with VI need instructional and environmental accommodations to learn science such as preferential seating; assessable laboratory equipment; safety and proactively prevent any possible dangerous situations; reading and measurement for some of work (mixing chemical and heating solutions); avoid using term such as “look at this; and rather speak a loud than written on the board.

The that conducted by [24] is aimed to define comet concepts in students with visual impairment. Students who do not have vision problems will easily define comets as "a relatively small extraterrestrial body consisting of a frozen mass that travels around the sun in a highly elliptical orbit," but not with students with VI (never seen comet, either in a night skyhelp). The result is the framework in Visualizing Science with Adapted Curriculum Enhancements (ACE). Most of the teacher had no prior knowledge of how to address the needs of their students with visual impairments, but during the process, everyone learned.
4. Discussions
Science education should enable the students to: bring the forefront consideration of the impact of science on society and environment, and include environmental education [25] and know the fact and principle of science and its application, consistency with the stage of cognitive development, acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge [26]. Human development in some conceptualizations of learning is an essential aspect of teaching and learning of science [27]. Furthermore, [28] explains that the roles of values in teaching and learning science are curiosity, parsimony, creativity, open-mindedness, rational thinking, empiricism, and skepticism.

In the relation to the students with VI in learning science, some researches have been done as which is done by [21]-[23] and [7]-[8] and [24]. Despite the enormous challenge, the Students with VI can learn concepts about science such as biological psychology [21], chemistry: structure and bonding [22], species [23], and comet [24]. They can learn because students with VI have the same range of cognitive abilities as the other students, but instructions typically rely heavily on vision [5]. The of VI reflect their ability to use vision, as well as how much they use other senses for learning [29]-[31]. There are three types of VI namely low vision, functional blindness, and blindness. Low vision is able to learn with visual sense, and functional blindness typically uses a combination of modalities to function within surrounding, and blindness that receive no stimuli from their visual channel [30].

In this study, the students with VI can learn by assistive technology [10]-[12],[14],[17],[20], verbal communication, physical help [19], information technology [13]-[14], and orientation and mobility skill (OMS) [18],[16]. In accordance with the study which is conducted by [30], the students with VI can learn with orientation and movement, tactile and kinesthetic learning, auditory learning and accommodations, and assistive technology. That is because the students with VI have some usable visions, lack opportunities for incidental learning, use the tactile and kinesthetic input to learn, and use the auditory input to gain information.

According to a study conducted by [10], they revealed that assistive technology could increase students' efficiency highly depending on the knowledge and teacher's mastery of it. Furthermore, the facilities in the classroom should be tailored to students with VI [32]. In line with this, the assistive technology of the teachers of students with VI that values technology [33]. The most efficient assistive technology to use in learning is Braille embosser [13] and computers [14]. While related to the tactile and kinesthetic learning of students with VI, students can learn directly from the object, e.g., museum [16], create 3-D models, e.g., biological models [21] and Comet [24]. By contact with and use directly from the object or model, students with VI can provide with information about object [30].

5. Conclusions
The literature review indicates that the students with VI can learn science well if there are appropriate supporting tools for them to learn. The supporting tools in learning that can be used among others orientation and movement, tactile and kinesthetic learning, auditory learning and accommodations, and assistive technologies which depend on the student's vision level. So, it is possible that the students with VI will be able to learn about science very well.

6. Recommendations for Future Research
The findings in this literature review indicated that students with VI could master science well. This study strongly shows that research on implementation of science learning approach in students with VI is highly recommended to be conducted to identify its impacts on the student's achievement through science learning. Learning model that can be used is the students center approach with assistive technologies. In addition, classroom settings are tailored to the needs of students with VI.
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