IJOLAE Indonesian Journal on Learning and Advanced Education

http://journals.ums.ac.id/index.php/ijolae

STEAM Approach to Improve Environmental Education Innovation and Literacy in Waste Management: Bibliometric Research

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DOI: 10.23917/ijolae.v3i2.12782
Received: December 2nd, 2020. Revised: December 27th, 2020. Accepted: December 30th, 2020.
Available Online: January 11st, 2021. Published Regularly: May 1st, 2021.

Abstract

The need for environmental literacy in development agenda has been pressing since the UN proposed the agenda of achieving Sustainable Development Goals (SDGs). One of the vital aspect of in sustainable development is about waste management to reduce earth's pollution. Environmental Literacy were considered as one of the few perspectives necessary for SDGs to be achieved. Education for Sustainable Development (ESD), formerly known as Environmental Education, through science education is one way to develop the environmental literacy of the society through classroom activities. One approach that fits closely to this need is STEAM approach. STEAM is a combination of five different disciplines namely Science, Technology, Engineering, Art and Mathematics. This approach has a room for developing students' environmental literacy within its Arts aspect. Teaching Environmental literacy through STEAM would help students not only learning how to be a scientist or engineer, but also building their scientific awareness to environmental issue, which will be the underlying value of their STEM insight. This study seeks to find the current state of the arts of this concept through a bibliometric research. This research was conducted using the Publish or Perish application to create a database of journal articles, which further managed using Zotero application. After managing the database, this study classified and visualized the database using VOSviewer software. The terms "Environmental Literacy", "STEAM", and "waste management" were used to search the relevant published journal article related to all three concepts, as indexed in Google Scholar since 1969 to 2020. This study found only a total of 163 result from Google Scholar Index. Further refinement of the results shows that published research are still scarce in the last 51 years and in need of further study to strengthen the concept. Authors also discuss about several suggestions on how STEAM could be considered as a way to develop students Environmental Literacy on waste management.

Keywords: environmental literacy, environmental education innovation, STEAM, literacy in waste management

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1. Introduction

Facing twenty first century, people in the world has become aware that the earth needs wise and better environmental management. The future of next generation relies on the ways people currently live on the earth. It is our responsibility to take care of the earth for the sustainability of human and other living organisms. Through SDGs, the United Nation has proposed the agenda of Sustainable Development Goals (SDGs) to achieve civilizations that is not only focus on economic growth, but also about environmental-friendly development. This agenda has been met with many challenges in its realization. One of those challenges are on waste management to

reduce earth's pollution (DSDG UNDESA, 2020)

World Bank report shows that each year, 2.01 billion metric tons of municipal solid waste (MSW) are produced annually worldwide. About 1 third to 40% were not managed, which resulted in more problems on earth. Global waste production accounted for about 5% of global emissions in 2016, with an output of 1,6 billion metric tons of carbon-dioxide-equivalent. Food waste accounted for 47% of those emissions, showing both a monumental problem and an opportunity for gases released by food waste to be harnessed for energy. Meanwhile some underdeveloped waste management structure could even cause hazards such as pollution on fresh water source and deadly landslide (Kaza et al., 2018). Environmental Literacy (EL) is one of the aspect that is expected to help in reducing such condition (Maurer and Bogner, 2020), and the means to develop it was through Education for Sustainable Development (ESD).

Environmental Literacy Task Force defined environmental literacy as an ability to act individually and with others to support healthy, prosperous, and equitable ecology for present and future generations (Environmental Literacy Task Force (ELTF), 2015). Environmental literacy has been studied at multiple age's students, including K-12 students (McBeth et al., 2008; Ozsoy, Ertepinar and Saglam, 2012; Saltan, F., & Divarci, 2017); and university students (Kaplowitz and Levine, 2005; Lloyd-strovas, Moseley and Arsuffi, 2018). Roth describes four strands of environmental literacy: knowledge, skills, affect, and behavior. These components are: (a) knowledge of ecological concepts, human impact on natural systems, environmental issues and environmental action strategies; (b) skills to help social groups and individuals acquire the skills for solving environmental problems; c) affective dispositions that relate to an individual's sensitivity, attitudes, personal responsibility, locus-of-control, values, and worldview; and (d) behavior that could be expressed through specific activities orientations to act (Goldman, Yavetz and Pe'er, 2014; Liu et al., 2015; Hodgkinson and Innes, 2001; Tikka, Kuitunen and Tynys, 2000). Knowledge is an important predictor of environmentally responsible behavior since it is usually regarded as a prerequisite to intentional action (Frick, Kaiser and Wilson, 2004). This finding is analogous to problems of decision making in other field such as women decision to engage in formal banking institution, where knowledge become a factor that influence their action (Sabic-El-Rayes, 2019). However, knowledge alone is not a sufficient requirement for pro-environmental behavior by an individual (Zsóka et al., 2013). Other non-environmental, factors might play such as economic factors (Azizah et al., 2020). This perspective is also reflected in the formulation of ESD.

Segalàs, Mulder and Ferrer-Balas (2012) listed several competences that that is related to sustainable development and its education. Those are systemic thinking, inter-trans-disciplinary, values, and ethics, and critical thinking. This means that and pedagogical approach to use in ESD should correspond to these competences. Authors argued that STEAM approach should be considered as the approach to use in ESD to improve environmental literacy.

STEAM is an instructional approach that combine five different disciplines namely Science, Technology, Engineering, Art and Mathematics. STEAM has been reported to be able to 1) improve academic learning processes and outcomes, students' problem solving, critical thinking and collaboration skills, and integrity (Perignat and Katz-Buonincontro, 2019) develop students' understanding, creativity and improve students' real-

life problem solving skills (Keane and Keane, 2016; Herro and Quigley, 2016; Yakman and Lee, 2012; Sharapan, 2012) 3) foster creative thinking, creative skills, creative processes, innovation, or imagination in STEAM connecting STEM with art (Bequette and Bequette, 2012; Glass and Wilson, 2016).

STEAM learning combines art with STEM subjects to increase students' involvement, creativity, innovation, problem solving skills, and other cognitive benefits. This combination was also reported to improve work skills (e.g. Teamwork, communication, adaptability) needed for career and economic progress. Adding "A" in STEAM is to combine other non-STEM disciplines such as liberal arts, humanities, and areas of interest such as environmental studies and community involvement (Keane and Keane, 2016; Herro and Quigley, 2016). Watson & Watson (2013), Gettings (2016), and Miller & Knezek (2013), refer to "artistic thinking" in addition to "A" in STEAM to "stimulate innovative problem solving" and add "creative components through artistic thinking". Meanwhile (Mungmachon, 2013) also adds that local culture values or local wisdom is also considered as the art, which could be included STEAM education. Therefore, STEAM Education accommodate many forms of artistic aspects that could pose as facilitator to the learning of science. STEAM approach can produce meaningful learning for students through the systematic integration of knowledge, concepts, skills and attitudes that will make students able to solve problems better including in terms of environmental literacy.

For a deeper understanding about the topic, authors conducted a bibliometric study for a structural literature study in the topic using STEAM approach to enhance environmental literacy in waste management. In the following section, authors will discuss about the methods used in this study, followed by findings, and discussions.

2. Method

This study is a review bibliometric literature review that use a systematic explicit method (Garza-Reyes, 2015). This could also be classified as a mind-mapping method to create a map of exploration limits (Tranfield, Denyer and Smart, 2003). Similar study has been conducted such as by Hudha et al. (2020). This study has five-stage in its process (Tranfield, Denyer and Smart, 2003) as seen in figure 1.

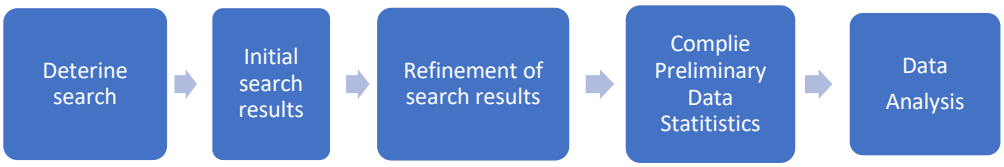

Figure 1 Five-Step Method in Bibliometric Analysis

Determine search keywords. Literature search was conducted in July 2020 with the keyword 'STEAM, environmental literacy, waste management'. Google Scholar database was chosen for this study to ensure that researchers could gain as much literature as possible, since it is currently the largest scholarly article database (Baneyx, 2008). A software called Publish or Perish was used to systematically search and filter journal article form Google Scholar. The keyword used in PoP software are "STEAM", "environmental literacy", "organic waste management".

Initial search results. This search is specific to 'journals', 'title words' only, and the

year '1969-2020' 105 articles were found at the initial search. The results are exported from the software in Research Information Systems (RIS) format to include article information such as paper titles, author, abstracts, keywords, and references.

Refinement of search results the search result were then filtered manually. RIS file from PoP software is imported to Zotero Software bibliographic software. Zotero identified the article based on its type, whether the indexed bibliography from PoP software was book or article. In this process, proceedings, newspapers, books, book reviews, and book chapters are removed from the database. Authors only keep journal articles within the database.

Compile preliminary data statistics. After all journal articles that is appropriate for this research is compiled from the previous step, authors checked complete components of the journal articles (publication year, volume, number, page, etc.) and added required information incomplete data were found. Data analysis was carried out so that articles could be classified by year. This change was saved and become the main database that will be used as the database for visualization process in VOSViewer Software.

Data analysis. The bibliometric analysis in this study employed PoP software and Zotero (Baneyx, 2008; Parmar, Ganesh and Mishra, 2019). Meanwhile, analyze and visualize bibliometric networks, VOSviewer software is used (Shukla et al., 2020)(Shukla et al, 2020). VOSviewer is used because it could provide visualization of bibliometric data, such as publication maps, author maps, or journal maps based on co-citation networks or to build keyword maps based on shared networks (van Eck and Waltman, 2010).

3. Result and Discussion

This review of the bibliometric literature is based on a systematic and explicit method (Garza-Reyes, 2015) or a mind-mapping method emphasizing the limits of research with environmental literacy as the center of the research. In red cluster, the themes are "science, technology, engineering, arts and mathematics"; "STEM education"; "Teacher"; "Engineering"; "Technology"; "Environmental literacy". In green cluster, the themes are "Steam"; "waste management"; "Sustainable development"; "Student"; "Electricity".

The bibliographic search yielded 163 results of article. However, after being sorted based on the type of publication were only 29 article in the span of 51 years. The summary of the search refinement could be seen in the following Table 1.

Table 1 Result after Refining The Search, Managed by Zotero

Refinement aspects	Total items left
POP	163 items
Removing non-article manuscript based on Zotero's classification (e.g. books, thesis, etc)	90 items
Removing non-article manuscript based on manual investigation (e.g. books, thesis, undetected article. etc.);	29 items

The total of article that was refined and managed in Zotero were exported in .RIS format and then imported to VOS Viewer. Using VOS Viewer, authors able to visualize the findings. The visualization could be seen in the following figures 2.

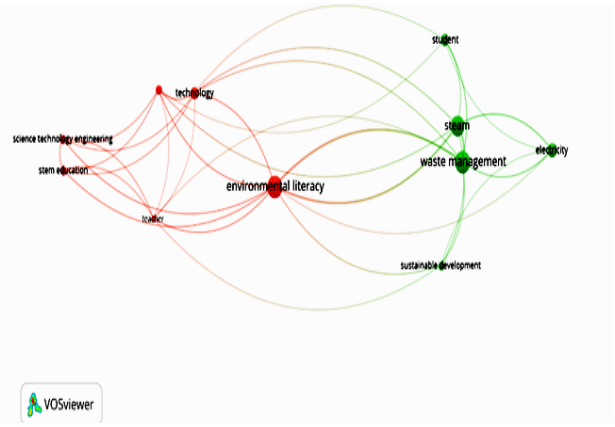

Figure 2 VOS Viewer Network Visualization Based on Themes

In figure 2, it could be seen that there were only a few themes that could be identified. Authors has designed so that a phrase that could be found at least three times in all of the articles to be included. Based on this condition, researchers identified 11 phrases that could be associated to themes that is relevant to this study. When visualized by VOS Viewer, it is clear that there were two clusters of themes.

Three themes other than scientific literacy that need to be examined were "steam", "waste management", and "science technology engineering art and mathematics". First, the network shows that the term "steam" and "science technology engineering art and mathematics" were not connected, as seen in figure 2 and 3. This finding implies that when "steam" were discussed within the articles it is not referring to the abbreviation of STEAM, but steam as a topic in related to "electricity". This is apparent since this study can be included in engineering research and the steam topic were networked to electricity. Electricity is the topic that is most excluded from red cluster (red cluster being mostly education research themes). When authors made a manual check to the article that had been refined, authors found that out of 8 studies that mentioned steam, 5 of those studies were unrelated to STEAM, and there were 4 of the studies were related to electricity.

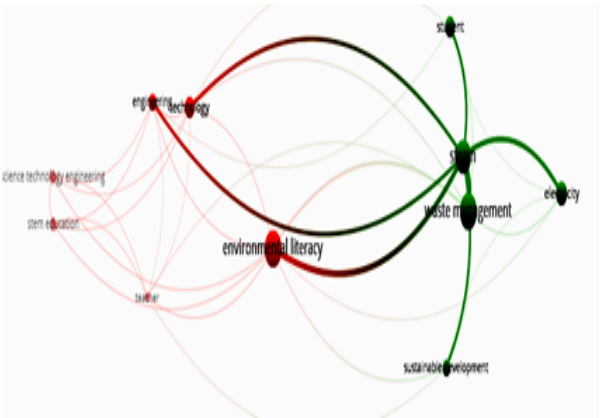

Figure 3 STEAM Network

Secondly, as seen in figure 4, the waste management topic is not connected to "science technology engineering art and mathematic". This indicates that no article has discussed both topics at the same time within one article.

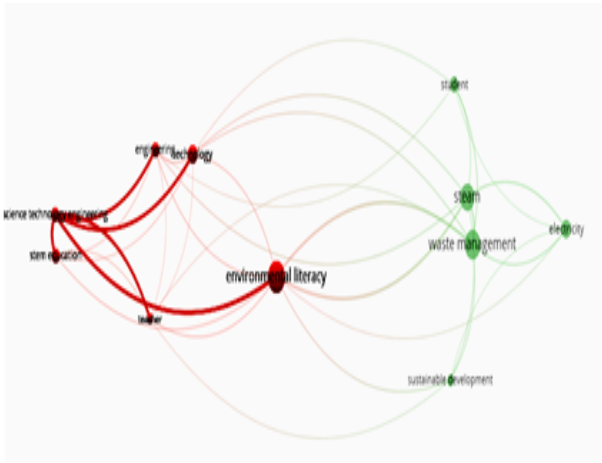

Figure 4 Science Technology Engineering Art and Mathematic Network

However, when manually checked, one article mention "STEAM" the pedagogic approach, "waste management, and science, technology, engineering, arts and mathematics. The study were conducted by Kaya and Elster (2019). Further reading to the article shows that they mainly discuss about STEM, and only mention briefly about STEAM, without mentioning what it stands for. This explains why there is no networked that connected "waste management" and "science, technology, engineering, arts and mathematics".

Time analysis based on year of publication (Figure 6) also shows interesting trend shift. "Science technology engineering arts and mathematics" were colored green to yellow. It indicates that research in this topic emerged recently. This is unlike research in waste management, which is colored purple, which indicated that many researches about this theme were conducted before 2015. However, it could also be seen that research about waste management that is related to "teacher" theme could be found recently it (teacher theme in this research context are considered a newly emerged topic, as indicated by the color yellowish green).

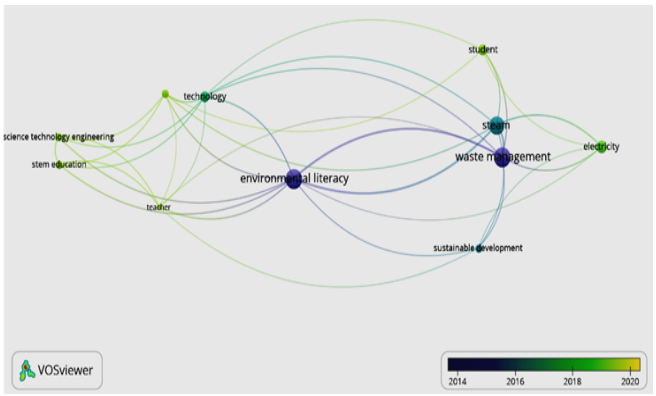

Figure 6 Time Analysis

Further, the two least researched topic within this research context is about teacher and sustainable development, as seen in Figure 7 that displayed the Density of Research analysis. This means that the state of the art is still in need of more research contributions. However, considering the overall result this bibliographic analysis, the whole niche is still in a dire need of more studies. Previous studies has shown that STEAM crucial for the 21st century, along with the achievement of Sustainable Development Goals (Taylor,

2016).

STEAM has also been chosen as the approach of 21st century pedagogy because: (1) STEAM give a positive impact in terms of motivating students, learning process and learning outcomes (Simamora, Saragih and Hasratuddin, 2019); (2). Developing collaboration, creativity, problem solving skill that is not limited to school activities (Guyotte et al., 2015; Liao et al., 2016; Allina, 2017; Payton, White and Mullins, 2017; Kant, Burckhard and Meyers, 2018; Perignat and Katz-Buonincontro, 2019; How and Hung, 2019) 3). Developing scientific literacy and environmental literacy (Sadoglu, 2018), 4). Developing creative thinking creative process, innovation, and imagination (Quigley, Herro and Jamil, 2017; Costantino, 2018).

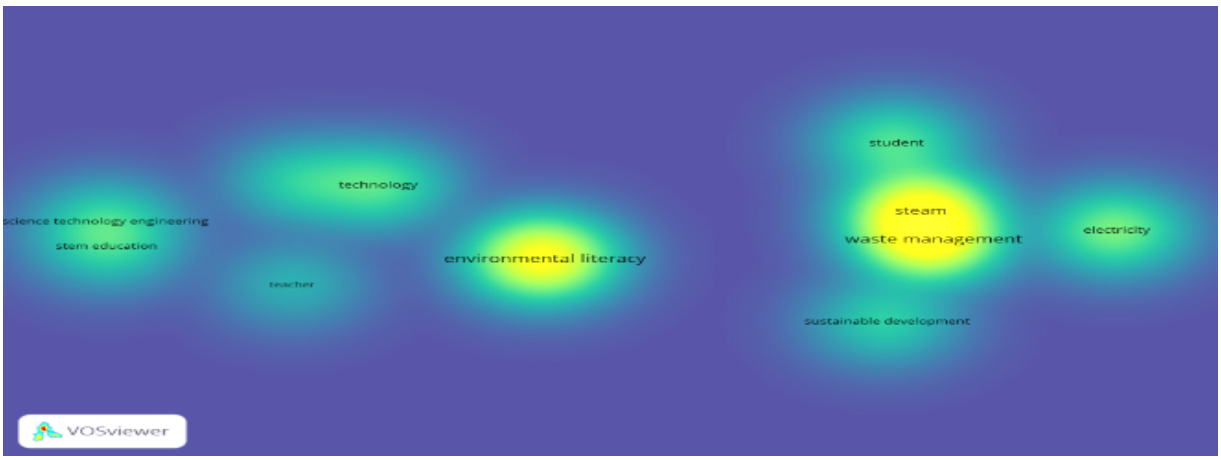

Figure 7 Research Density Analysis

It is unfortunate to found that STEAM was still a rarely used approach when teachers teach about waste management. As reported by Handayani (2014), STEAM approach are able to help students in gathering, analyzing, and solving problems. Bernstein and Liao also found that STEAM could increase student engagement, creativity, innovation, problem solving skill, and other cognitive benefits (Liao et al., 2016; Root-Bernstein, 2015). Meanwhile (Colucci-Gray et al., 2017) found that STEAM could improve work skills for career and economic advancement (Colucci-Gray et al., 2017). STEAM also have space for non-STEM discipline to be included as the important aspect in the approach. Those aspects such as liberal arts, humanities, and other areas of interest including environmental studies and societal interactions (Keane and Keane, 2016; Herro and Quigley, 2016).

The implementation of environmental education to the students could be increased in order to create an environment caring society (Miles, Harrison and Cutter-Mackenzie, 2006). Through STEAM, students could develop not only their knowledge about environmental related topic—which in this case, specifically about waste management—but also recognize the social dimension that support and define the topic. Students could experience a transformation process that is recognized by the teachers, where students start as a beginner in the environmental discourse, into an expert, through cognitive apprenticeship (Johri and Olds, 2011)

Currently, researchers on STEAM in general are discussing on the effectiveness and usefulness of various STEAM approach empirically as a way to improve the quality of learning process, student learning retention, and achievement (Brown and Crippen, 2016; George, 2013). However, such studies are still limited to certain topics. Future researchers might need to consider to check on the

implementation of STEAM that used other context, or the use of STEM in the context of waste management.

It is also productive for future STEAM researchers to: (1) consider imitating other studies that successfully use hands-on activities or projects to develop certain desired attitudes (Leng and Buang, 2019; Christidamayani and Kristanto, 2020; Ismail and Buang, 2019) ; (2) assess collaboration STEAM in the problem solving process and critical to honing negotiation skills to arrive at potential solutions (Land, 2013), (3) develop a multi-level approach to effectively educate students for environmental literacy (Ever, 2012), (4) update their pedagogical content knowledge and their experiences in the light of the increasing importance of STEAM education (Allen, Webb and Matthews, 2016). With STEAM-PCK, teachers have knowledge of both the environment and STEAM and gain experience in how to integrate these two concepts into each other. By this means, science education might meet expectations of present and future generations.

Adaptation might be necessary; yet, it should have presented several possibilities on how to develop this niche further. Institutions or schools are also responsible for supporting the development of teacher environmental content knowledge, pedagogical skills, interdisciplinary work, teaching approaches, effective assessment practices, and the ability to use innovative technologies. By doing so, teachers could be more competent in providing environmental education and deliver it in a more innovative way (Suryani et al., 2019).

4. Conclusion

Although STEAM has been reported to help students to achieve competences that correspond to Education for Sustainable Development, formerly known as Environmental Education to achieve environmental literacy, research on using STEAM, especially using waste management context, is still scarce. This study found that in the span of 51 years of study, there were only 29 article that is related to this topic. Only one study that closely match with author's conception of STEAM role in enhancing environmental literacy on waste management topic. Authors encourage more researchers to contribute to this area considering previous success of STEAM and what is needed to prepare environmentally literate citizens, especially on waste management.

STEAM should become the main alternative to enhance Environmental Literacy in aspect of scientific content and competency in EDS, especially in the context of waste management. This teaching should be integrated in the related context such as, science subjects, sociology, or arts to achieve SDGs through education. Density analysis (Figure 7) shows that research in environmental literacy, waste management and STEAM were the top three densest topic among all topics. However, if we consider that the term "steam" refers to engineering article, this means that the research about this topic were mostly in engineering field rather than educational field. Meanwhile research in educational field, as indicated by red cluster as seen in figure 4, were still scarce. Lastly, waste management and environmental literacy are practices that encompass student experiences in STEAM disciplines as well as overlaps across disciplines. These two dimensions need to be explored further because learning progress is coherent, developing and comprehensive. Identifying and articulating such developments is a major challenge today for STEAM education.

Many breadths of studies could be considered for future researchers considering these studies are still scarce. Several suggestions include empirical studies

(experimental, correlational, etc.), meta-analysis, development studies (instruments, teaching materials) that involve STEAM as the pedagogical approach and waste management as the context regarding enhancing Environmental Literacy. For example, introducing and implementing STEAM project to environmental management system in the school, inside or outside of the classroom as a form environmental education that is innovative, hands-on, and unconventional.

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