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Review

What Teachers Should Know for Effective Marine Litter Education: A Scoping Review

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Abstract: Marine litter has had a huge impact on the marine environment and the socio-economic activities that depend on healthy oceans. All members of the community must play their part to address marine litter. Teachers are agents of change that are capable of encouraging pro-environmental practices among the community that will reduce environmental issues, including marine litter. However, teachers were found to have limited knowledge regarding ocean literacy and marine pollution. A scoping review was conducted to identify various aspects of content knowledge related to marine litter education that has been recently conducted for school teachers and students. Web of Science, Scopus and ERIC databases were searched for articles published in English between 2015 and 8 July 2021. Fourteen peer-reviewed articles were selected for this study and were subjected to content analysis. Topics related to marine litter were frequently addressed. Meanwhile, topics related to teaching Environmental Education/Education for Sustainable Development (EE/ESD) were the least addressed. Benthic marine litter, solutions to marine litter and the introduction of new types of marine litter were identified as topics that need to be addressed in future marine litter education. This study lists content knowledge based on previous literature and identified the gaps, which will be useful for teachers to improve their knowledge and implement effective marine litter education in school.

Keywords: marine litter; marine debris; teachers; educators; marine litter education; education for sustainable development

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1. Introduction

Marine litter, also known as marine debris, refers to any solid materials that are processed to be persistent for human consumption, which are being discarded, disposed of or abandoned, either intentionally or unintentionally, directly or indirectly to the sea through rivers, sewage, stormwater or winds [1]. Marine litter is a result of complicated waste management problems [2] and is caused by land-based and sea-based activities [3,4]. Marine litter have been observed on beaches [3,5–7]. In Penang Island, Malaysia, marine litter was also found in a mangrove forest [8]. Other studies in the Mediterranean Sea and the Aegean Sea have recorded the occurrence of marine debris at the bottom of the ocean [9–11]. Marine litter constitutes materials such as plastic, paper, aluminium, glass, rubbers, clothes and metal [3,5,6]. However, plastic litter has always been recorded to be the most abundant marine litter compared with other types of marine litter [5,12–16].

Plastic debris has been reported to be accidentally ingested by marine animals such as seabirds, sea turtles and marine mammals, and it is present in their stomach content [17–21]. Although these studies indicate that the plastic litter ingested was not the cause of death, other findings indicate that the ingestion of plastic litter causes a blockage in the gastrointestinal tract, obstruction of the gastrointestinal tract and perforated gut, and may subsequently cause death [21–23]. Abandon, lost or otherwise discarded fishing gears (ALDFG), abandoned fishing gears, rope, fishing line and ghost nets [4] have reportedly

entangled marine animals. Entanglement of harbour porpoises and seals in German waters was caused by debris such as nets, fish lines and rubber bands on their jaw, body and neck [23]. Larger net mesh and smaller twine sizes have been observed to attract sea turtles [24]. Meanwhile, seabirds have mostly been found entangled by fishing gears compared with other types of litter [18]. Ghost nets are causing problems in marine habitats, when bycatch continues, even the fishing gears are abandoned which has resulted in the decline of endangered species and commercially important fishery stock [25,26].

In addition, marine litter could cause disturbance in the reef ecosystem when marine animals use plastic litter (non-natural materials) as shelter and substrate of attachment [27,28]. The ability of organisms to be attached to and inhabit plastic litter has alerted the scientific community to the introduction of alien invasive species in an ecosystem, which could be problematic for native species [28,29]. Marine litter, too, has been reported to cover or smother corals, which limits photosynthetic activity in the benthic ecosystem [27]. Damage to the benthic community has also been reported [25].

Valuing the overall cost of marine litter is a rather complicated process due to the wide range of business-related, environmental and social impacts that are affected directly and intricately by marine debris [30]. In Southern Brazil, for instance, an increase in the amount of marine litter may be possibly accountable for nearly a 40% reduction to the tourism income when beachgoers avoided polluted beaches [31]. Meanwhile, in Korea, the accumulation of marine litter due to heavy rainfall in 2011 has decreased the number of visitors to Geoje Island and caused an estimated loss of USD 29–37 million [32]. Using a Random Utility Travel Cost Model, Legget et al. [33] estimated that with a 25% reduction of marine debris at all beaches, residents of Orange County benefited up to USD 29.5 million in 2013. In the Asia Pacific region, it has been estimated that marine litter-linked losses related to marine industries cost an annual USD 1.2 billion, and this cost is avoidable by the implementation of regulations, technical interventions and market-based instruments that will reduce marine litter [34]. The marine economy in Malaysia contributed to USD 63 billion, 23% of the country's GDP, in 2015 [35]. Meanwhile, McIlgorm et al. [36] estimated that marine litter caused a total of USD 525 million direct damage to Malaysia's economy.

Accumulation of marine litter also causes health hazards to humans. There were over 160,000 claims of injury reported in New Zealand in a span of 10 years which are mostly associated with a puncture and largely affecting children of 0–14 years old at beaches with heavy tourist traffic [37]. Another study by Campbell et al. [38] highlighted wound as the most common injury at Tasmanian beaches, although the beaches are classified as "clean" using the Clean Coast Index. Separately, in an attempt to reduce plastic litter accumulation in the ocean, the local community on a remote island in Indonesia burned plastic litter together with organic materials, causing air pollution which poses a health hazard to the community [39].

Education as a Tool to Address Marine Litter

To address marine litter, Williams and Rangel-Buitrago [40] categorize the solutions to marine litter into Knowledge, Prevention, Mitigation, Removal and Behavioural Change. The study also noted that Behavioural Change is a cross-cutting measure that is necessary to implement across all categories of solutions. This may be achieved through changes in policy as well as education, which will encourage the improvement of the waste management system, reducing waste generation as well as reducing single-use plastic consumption [41–43]. All levels of the community will have to play a role to improve consumption patterns that will lead to the reduction of marine debris [42].

However, recent studies have observed that communities are not playing their part to solve the issue of marine litter as there are different perceptions of who should be responsible for it. For example, In Aceh Jaya, Indonesia, only less than 50% of the population sample felt responsible to address marine litter [44]. Local communities perceived that marine litter was caused by beachgoers [3,45]. However, beach-goers will not participate in beach cleanup activities unless they have previously participated in the activity [45].

Meanwhile, businesses, manufacturers and the government were perceived to be the most responsible for managing marine litter [46]. Efforts from government agencies and local authorities can become the driver towards local community participation in waste management activities [45,47]. Meanwhile, teachers and environmental NGOs were perceived as being the most motivated, responsible and competent to address marine litter [46,48].

Teachers and educators have a role to play in promoting environmental conservation and education in schools [49,50] because students obtain various knowledge, including knowledge on environmental conservation, from the teachers [51,52]. However, teachers should be trained and have access to related resources to teach about marine litter [53]. Furthermore, Raja Abu Bakar et al. [54] suggested that teachers' training is crucial as it allows teachers to improve their teaching approaches to allow students to embrace sustainable development through ESD competencies. This will enable teachers to help students to have the knowledge and necessary skills to promote sustainable development through education for sustainable education and sustainable lifestyle, which is Target 7 for SDG 4—Education for Sustainable Development [55]. For example, to ensure that teachers have knowledge concerning wildlife conservation, Lukas et al. [56] conducted conservation education training for teachers from schools adjacent to Kibale National Park, Uganda. After three years of training, the study was able to conclude that the training has been impactful. This was observed when students, who have been taught by the teachers, demonstrated an understanding of environmental problems concerning wildlife conservation. Separately, to promote plastic waste recycling among students, Cheung et al. [57] also supported that teachers' training will be able to help teachers to acquire knowledge related to environmental conservation as well as pedagogical to enable environmental knowledge to be imparted to students.

However, more efforts are needed to train teachers about marine litter [58]. Mcpherson [59] indicated that ocean literacy among teachers in Nova Scotia is limited. Meanwhile, Boubonari et al. [60] observed that pre-service teachers have a moderate level knowledge, but also held misconceptions related to marine pollution. Effective marine debris education will require teachers to have knowledge as well as a positive attitude and proper behaviour to address marine debris through formal, informal and non-formal teaching activities [61]. However, it is unclear what teachers should know and understand before they can implement effective marine litter education in schools. A synthesis of literature related to marine litter education may provide clarification to this issue. Therefore, a scoping review was conducted to systematically investigate content knowledge related to marine litter education that is highlighted in previous literature. This will enable the understanding of the key aspects related to marine litter content knowledge that should be introduced to teachers to ensure effective marine litter education. This paper will also find gaps in the educational intervention based on previous literature. There are two research questions defined for this review: (1) What are the characteristics of articles related to marine litter education?; (2) What is the content of knowledge related to marine litter that has been highlighted during education activities conducted for teachers and/or students?

2. Materials and Methods

This study employed a scoping review method based on guidelines recommended by PRISMA Extension for Scoping Reviews (PRISMA-ScR) [62], which is accessible at http://www.prisma-statement.org/extensions/scopingreviews. The PRISMA checklist was used to report the method and result of this scoping review (Appendix B).

2.1. Information Sources and Literature Search

To identify articles for this review, articles were searched using Web of Science, Scopus and Education Resources Information Centre (ERIC) databases. The search was conducted on 8 July 2021. Keywords were developed to identify relevant studies based on the aforementioned research question. The keywords used were "teacher", "educator", "school", "knowledge", "attitude", "behaviour", "practice", "literacy", "debris", "litter", "pollution",

"conservation", "sustainability", "marine", "sea" and "ocean". The search strategies had to be modified based on the availability of Boolean operators (such as AND and OR) and truncations (such as ENVIRONMENT* and EDUCAT*) in each database to maximize the search result. The final search string for the Web of Science database can be found in Appendix A.

Only peer-reviewed research articles that were published in English were considered for this paper. Articles published between 2015 and 8 July 2021 were considered for this paper as we anticipate educational intervention would follow the guidelines of ESD to achieve Goal 4 of Sustainable Development Goals by United Nations which was adopted by member states in 2015. In addition to that, review papers, conference papers, commentaries were not included in the review process.

2.2. Selection and Screening of Articles

Initially, there were 210 articles identified. The articles were imported into Mendeley Desktop Version 1.19.8 to enable efficient management of the articles. The software automatically removes duplicates. Search results were screened for duplication and were assessed for eligibility for being included for review (Table 1). To be included in the review, the articles need to describe the implementation of marine litter education activities that were conducted either for school teachers or school students or both. Pre- and post-activity surveys were included when the educational activities were described. Articles were excluded if they focused on university or pre-school students. We also excluded articles that are related to the population survey. Studies related to freshwater bodies such as rivers and lakes were excluded if the study did not mention the connection of the watershed to marine litter.

Table 1. Inclusion and exclusion criteria.

Criteria	Include	Exclude
Population	Teacher School students	University students Pre-school students
Exposure/Intervention	Implementation of educational activities Pre- and post-activities survey	Sample population survey
Context	Marine, ocean, sea, beach Sustainability	Freshwater body, lake
Outcomes	Improved knowledge, attitude and practice	
Study types	Research articles English language Published from 2015 to July 2021	Conference papers Non-English language Editorials Pre-2015 Review papers

Source: Field work data, 2022.

The authors began with title screening, followed by abstract screening and, finally, full-text screening of the selected articles. Discussions were conducted until a consensus was reached between the authors regarding articles that met the inclusion and exclusion criteria. Fourteen articles were selected for this paper. Figure 1 shows the flow chart of the search strategy used to identify selected articles that are being used for this paper.

2.3. Charting the Data

Upon identification of selected articles, a data charting was self-developed by the authors. The characteristics of each article such as sample, sampling site, study type and description of educational activities were extracted from each article selected. The data were coded according to the location of the sampling population. SA, NA, EU, AS and OC refer to sampling population in South America, North America, Europe, Asia and Oceania regions, respectively.

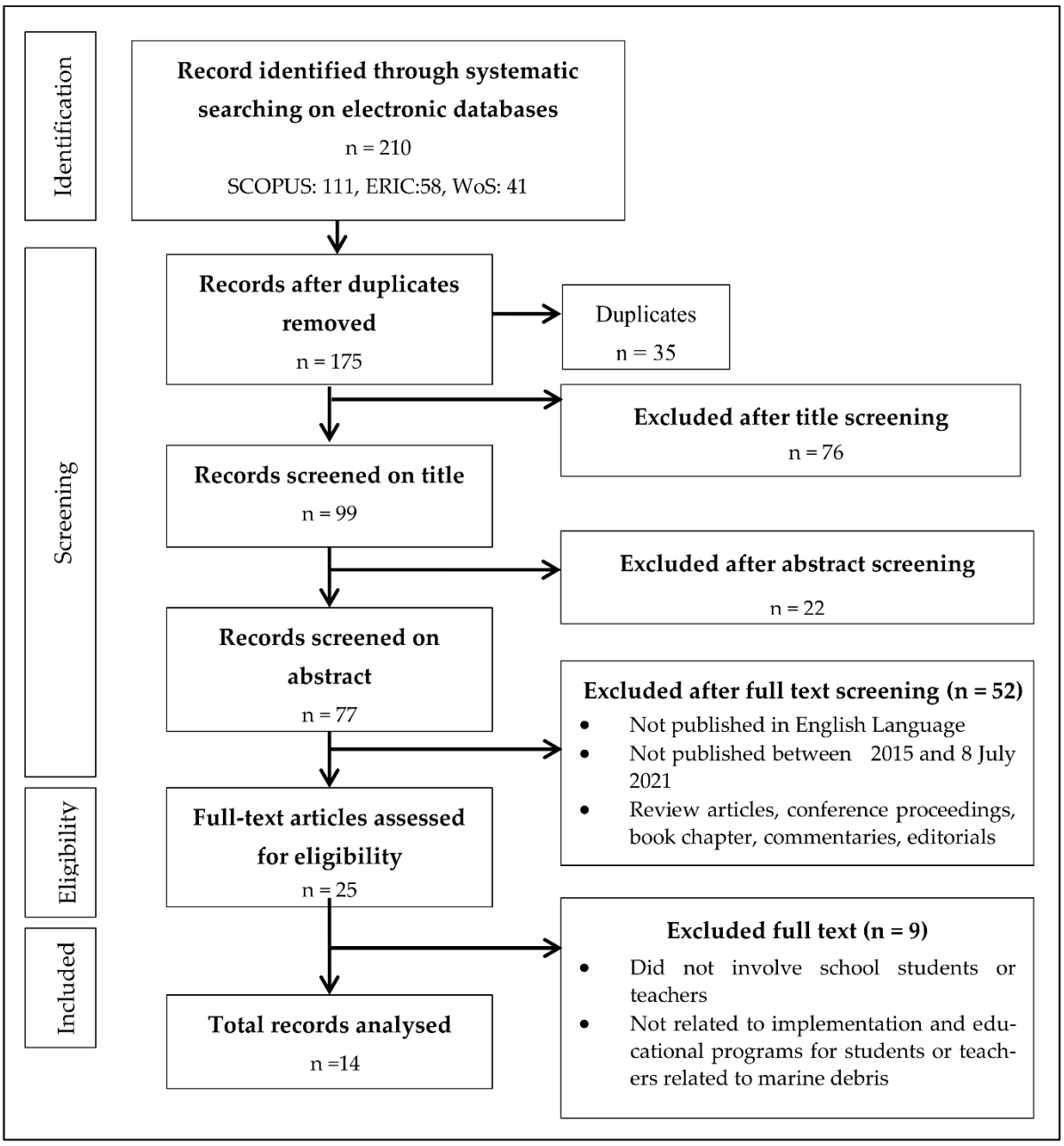

Figure 1. Search strategy flow chart.

2.4. Collating, Summarizing and Reporting Results

The grounded theory approach was employed through the use of content analysis to identify codes and categories that frequently appear in the articles selected for this paper. NVivo (QSR International—Version 12 Plus) was used to organize and code excerpts from the selected studies based on the research questions. The data were analyzed based on the methods of Hawa et al. [63]. The coded contents are called coding references. Subsequently, the codes were subjected to categorization to answer the research questions. For each category, we counted the number of coding references that have been categorized and classified for each category. We acknowledge the most and less frequent categories that appeared in the selected articles. We also defined the categories generated from the qualitative analysis. In Section 3, the outcome of the scoping review is presented.

To ensure that the analysis conducted has achieved rigour, the authors of the paper frequently met and discuss to review the codes and categories identified in this paper.

3. Results

3.1. Characteristics of the Selected Articles

From the 14 articles selected for this review, the largest number (six) of articles were published in the year 2019. The respondents or sampling population in these articles were from various geographic locations. Seven articles employed sampling populations from Europe, three from North America, two from South America and Oceania, one from Asia, but none from the African region. The selected articles focused on various educational approaches, such as citizen science action that aims to quantify marine litter on the beach, the effectiveness of education programs related to marine litter, development of educational materials, exploring children's mental model, exploring children's environmental identity and giving recommendations for improving marine litter education and outreach programs. Eleven articles used the quantitative method while two articles utilized a mixed method and another one used the qualitative method. Based on the selected articles, most education programs focused on educating students. Several articles highlighted what teachers were trained in and or if they were given educational materials with the aim of monitoring and supervising the activities involving their students, as well as to ensure marine litter education can be conducted in school after the educational intervention. The summary of information extracted from the articles is presented in Tables 2–6.

3.2. Content Knowledge Related to the Marine Litter Education

Using the content analysis method, this paper was able to highlight 132 coding references related to the content knowledge of marine litter education (Table 7). Based on the data analysis, the articles were predominantly focused on educating their target audience on marine litter including different types, characteristics, amount, source, impact and solutions of marine litter, with 63 (47.7%) of coding references followed by monitoring of marine litter and microplastics with 24 (18.2%) and 15 (11.5%) coding references, respectively. Meanwhile, teaching EE and ESD competencies in EE and ESD recorded only 3 (2.3%) coding references. Figure 2 shows the content knowledge of marine litter education highlighted in the selected articles.

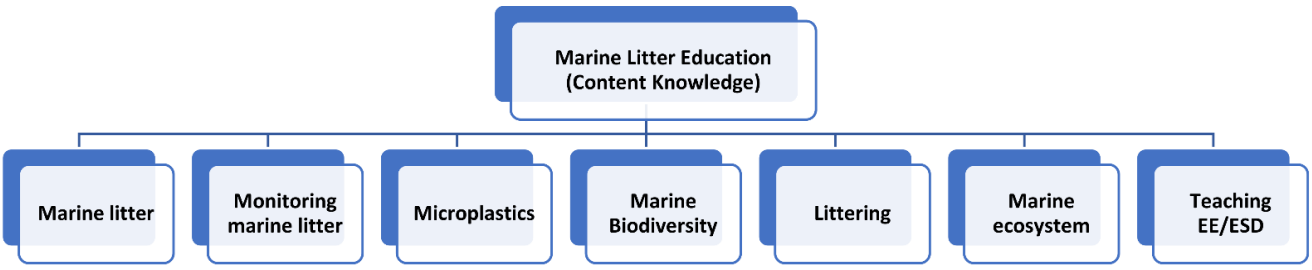

Figure 2. Different categories of marine litter education content knowledge.

3.2.1. Marine Litter

Ten articles (sampling locations in Europe, North America, South America, Asia and Oceania) with 43 coding references highlighted marine litter in their education program. The topics related to marine litter, such as different types of marine litter, impact and solutions to marine litter, were communicated during the educational programs through the creation of educational materials including e-game, online training, video contest, workbook, theoretical and experimental activities, practical sessions, lessons, lecture, seminar, open dialogue and discussions. The topics were introduced before marine litter monitoring activities. They were also introduced during field activities, workshops and conferences. In addition to that, one article introduced this concept through a case study of a local scenario.

Table 2. Summary of information from the selected articles with sampling population from Europe.

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
EU1	[16]	114 high school students enrolled in the internship program from 2013 to 2015. The students worked with researchers from the Institute of Marine Sciences of the National Research Council.	Italian Marine Protected Areas, Pelagos Sanctuary (Europe)	To address the lack of data on marine litter, using an app for Android devices, which was developed by interned students, to enable continuous census to be conducted, thus enabling effective waste management in the study area. This project was financed by Ligurian Cluster for Marine Technologies (DLTM).	This article reported an internship program that taught students about marine litter as well as the development of an Android App which helps to collect and monitor marine litter data. Internship students were divided into two groups. The first group were required to collect information about marine litter and current protocols that were used to sample and monitor marine litter by the beach. The second group were tasked with the development of the Sea Cleaner mobile Android App. The students were initially supported by engineers from the Faculty of Computer Engineering, University of Pisa.
EU2	[64]	Children from 2 Mai Elementary school who are members of the Junior ranger club (no mention of the number of students).	Bari, Italy (Europe)	To collect information on marine litter by public engagement and modern technology, such as the Marine Litter Watch (MLW) App. The MLW was developed by European Environment Agency (EEA).	Students monitored the beach of Vama Veche-2 Mai Reserve Area and collected waste on the beaches and used the MLW App to generate monitoring data on waste at the beach. The National Institute for Marine Research and Development is the custodian of the Vama Veche-2 Mai Reserve Area. The agency is part of the Policy-oriented marine Environmental Research for the Southern European Seas (PERSEUS), which is a research project that assesses the impact of anthropogenic and natural activities in the Mediterranean and Black Seas.
EU3	[58]	120 Teachers/educators from 18 EU Countries 341 school students	EU Countries (Europe)	To develop educational activities (for educators and students) that can increase understanding and empower educators, as well as school students, on topics related to marine litter and encourage them to find the solution to the problem. This article also aims to assess the impact of each activity on the participants' understanding, perception and behaviour.	Two activities were conducted. The first activity was a training course organized for teachers and educators. The training course focused more on pedagogy to enable teachers to integrate marine litter education in the classroom. Another activity was developed for students. Students were required to prepare a 2-minute video related to marine litter. The resource pack and educational activities used in this paper were developed with the support from Marine Litter in European Seas: Social Awareness and Co-responsibility (MARLISCO) by the Mediterranean Information Office for Environment, Culture and Sustainable Development (MIO-ECSDE).
EU4	[65]	20 school students aged 12–15 years	Plymouth, UK (Europe)	To adopt a framework that integrates social and behavioural research methods; using Theory of Change to assess the effectiveness of initiatives related to ocean literacy.	A film entitled "Rethinking Plastic" was screened as part of marine plastic and microplastic educational activities that were organized by the National Marine Aquarium. The film highlighted drivers of microplastic production and consumption that are impacting marine organisms negatively. The film was produced by Television for the Environment (TVE), a charity registered in the United Kingdom, founded by UNEP, WWF-UK and Central Television.
EU5	[66]	87 high school student	Northern Italy, Italy (Europe)	To assess students' attitudes and behaviours towards marine litter before and after their participation in SEACleaner (3–4 days internship).	Students participated in SEACleaner activities mentioned in EU1

Table 2. *Cont.*

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
EU6	[67]	Teaching community, pupils	UK, Greece, Cyprus and Romania (Europe)	The study focuses on finding the source of pollution in Europe, to project how future and seasonal climate can relatively control pollution.	There were three stages of this study. The first stage of the study focused on the collection of various parameters to understand the source of pollution and future and seasonal climate controls pollution in the region. In the second stage, data from the first stage of the study were used to develop a training curriculum which includes five modules: • Teaching competencies; • Teaching methods; • Scientific content knowledge (physical and chemical processes that leads to drifting and breakdown of marine pollutants); • Marine pollution; • Thematic examples (local scenarios as case studies). In the third stage, online material, games and tools were created to promote environmental awareness and consciousness among 10–14-year-old students by including environmental parameters to simulate the movement of pollution in the marine environment.
SA2/EU7	[68]	1463 teachers and students from coastal communities in Chile and Germany	Chile (South America) and Germany (Europe)	The study aimed to compare the density and composition of anthropogenic marine between Chile and Germany. Beach surveys were conducted by trained students and teachers.	Before the beach survey, students and teachers were trained. Each student was given a workbook that included information and activities related to the scientific method, marine ecosystem and marine litter problem. Teachers had been given earlier training and were guiding their students to complete the activities in the workbook.

Table 3. Summary of information from the selected articles with sampling population from North America.

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
NA1	[69]	Grade six students from one classroom in Fairbank Elementary school	Fairbank Elementary School, a public school in Canada (North America)	To explore environmental identity development (EID) of one grade six classroom during a program in school.	A program named Trash to Treasure (T2T) was organized in a school. The program included: • Clean-up activity in a natural area; • Recording data from the cleanup activities to a national citizen science initiative, Great Canadian Shoreline Cleanup; • Creating an art piece with an environmental message using the garbage collected previously. The art pieces created by the students were displayed during Earth Day. To successfully support the T2T program, teachers were given resources and lesson plans that could be used in classrooms.
NA2	[70]	195 Youth 2nd–12th grade	Pinellas County, Tampa Bay, US (North America)	This paper focuses on examining the social context of littering behavior (land-based marine debris source) from a youth's perspective, to improve marine debris education.	Educational activities conducted in this study include field trip excursions and a summer program that teaches students about marine litter, watersheds, types of marine litter, the importance of plankton in the marine ecosystem, microplastic, the connection of littering behavior with marine litter, microplastics and pro-environmental communication strategies.

Table 4. Summary of information from the selected articles with sampling population from South.

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
SA1	[71]	200 students aged 10–11 years	Sao Vicente, Brazil (South America)	To highlight the importance of the marine environment, impacts of inefficient waste management and solutions that can be undertaken by students to preserve the marine environment for future generations.	This article reported activities of an education program—"Pet Mar: using recycled material to teach about marine animals". Several activities were conducted, including: • Sensory activities; • Use of satellite images; • Zoological specimen exhibition; • Field activities; • Lesson on pollution; • Recycling competition; • Film screening; • Student debate session; • Recycling incentives; • Arts and craft activities.
SA2/EU7	[68]	1463 teachers and students from coastal communities in Chile and Germany	Chile (South America) and Germany (Europe)	The study aims to compare the density and composition of anthropogenic marine between Chile and Germany. Beach surveys were conducted by trained students and teachers.	Before the beach survey, students and teachers were trained. Each student was given a workbook that included information and activities related to the scientific method, marine ecosystem and marine litter problem. Teachers had been given earlier training and were guiding their students to complete the activities in the workbook.
SA3	[72]	22 students, aged 9–12 years old	Grenada, West Indies (South America)	To develop sea turtle conservation education programs for children and quantify their knowledge, attitudes and perceptions using pre- and post-program assessment	A teaching module was developed to include topics related to sea turtle biology and sea turtle conservation. The topics were taught to students using presentation, video and active learning participation. Active learning participation was used to teach about turtle flipper patterns, quantification of pollution on the beach, observing turtle hatchlings, as well as learning about approaches from communities that have a positive impact on the conservation of nesting grounds.

Table 5. Summary of information from the selected articles with sampling population from Oceania.

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
OC1	[73]	Local councils, local community, schools and students (no mention of the number of samples involve)	Beaches in the Greater Sydney region, Australia (Oceania)	To quantify plastic pollution, compare current and historical plastic load and determine the differences in pollution between beaches in the Greater Sydney region, by implementing a community–based science project involving local councils, local community, schools and students.	The authors trained students and teachers through a seminar that highlighted the impact of marine pollution on the marine ecosystem. The authors also conducted practical classes to teach students and teachers about scientific methods and experimental design. Later, students were tasked with designing a sampling strategy and developing a project that explored personal plastic consumption. They shared the findings of their task with their family, peers and community. Finally, students and teachers were taken to the nearby beach to sample marine litter.
OC2	[74]	7000 school teachers, students and corporate Personnel from SHELL	Australian coastlines (Oceania)	To analyze the quality of data obtained by trained citizen scientists (Students and adults) and data collected by researchers.	Before the actual survey, students and teachers were trained at school. A one-day program was arranged to engage students and teachers about marine litter using a lecture and activity format related to marine litter. Training on coastal litter monitoring was also conducted at the school by bringing in litter from survey sites to the classroom, so that students could be trained to identify different types of litter, as well as collect and record data. In addition to the training session at school, teachers participated in another training program. During this training program, teachers were engaged in an intensive course and field-based training on marine litter and data collection. Additional educational and field-based activities related to marine litter were also organized so that teachers could continue educating students in school.

Table 6. Summary of information from the selected articles with sampling population from Asia.

Code	Source	Sample	Study Site	Purpose of Study	Description of Educational Activities Conducted by Researchers
AS1	[75]	34 students (fourth grade to high school)	Japan (Asia)	The study aimed to understand the systemic characteristics of marine plastic waste through children's mental model.	Students participated in a workshop and poster session at the "EcoPro2019: Towards a Sustainable Society" in Tokyo. During the workshop, students were engaged in learning basic information and about the amount of marine plastic waste, as well as the negative social-ecological impacts. Participants were then asked to suggest solutions to address marine plastic waste.

Table 7. Number of coding references and descriptions of codes related to the different content knowledge of marine litter education.

Categories	Number of Coding References	Description of Codes	Source of Articles
Marine litter	63	Different types of marine litter Sources of marine litter Characteristics of marine litter Impact of marine litter on environment, human and animals Marine litter issues Physical and chemical processes lead to the drifting of marine litter Amount of marine litter (especially marine plastic waste) Solutions and action that can be taken to reduce marine litter Local examples or case study	NA2, EU3, AS1, EU6, EU1, OC2, SA2/EU7, SA1, EU5
Monitoring of marine litter	24	Identification of different types and categories of marine litter Data collection and recording Protocols for marine litter monitoring Presentation of results	OC1, SA3, EU2, SA2/EU7, EU5, EU1, OC2
Microplastics	15	Microplastics data collection activity Drivers of microplastics pollution Physical and chemical processes that lead to the breakdown of marine pollutants Solutions related to microplastics	NA1, NA2, EU6, SA3, EU1, EU4
Marine biodiversity	11	Marine animals Zooplankton and phytoplankton Meaning of biodiversity	SA1, SA3, NA2
Littering	9	Defining litter and littering behaviour Understanding the connection between littering behaviour and marine litter. Role of the watershed in transporting litter from land to the sea Role of rivers The implication of an inefficient waste management system	SA1, EU5, NA2
Marine ecosystem	7	Different types of marine ecosystems ie rocky shore, sandy beach, mud ecosystem Ecosystem ecology Meaning of ecosystem	SA1, SA2/EU7
Teaching Environmental Education and Education for Sustainable Development (EE and ESD)	3	Teaching competencies Teaching method Competencies in ESD	EU6, AS1

The impacts of these educational activities were studied in the selected articles. The impacts of educational activities were measured using various methods (such as pre- and post-activities questionnaires) and varying variables (such as knowledge, perception, self-reported behavior and willingness to communicate with others). The findings of the various studies highlighted the positive impact of educational activities, although several studies highlighted the ineffectiveness of the educational activities. For example, NA2 and SA1 highlighted that after participating in an educational program, students recorded an increased level of knowledge related to marine litter. EU3 also highlighted the positive impact of educational activities that were organized for students and teachers, where teachers were recorded to have a significant increase of perceived understanding and knowledge on the marine litter, as well as a sense of confidence, competence and skills to integrate marine litter education in their teaching activities. Similarly, the same study also found that students were also able to understand the persistence of plastic litter in the environment after participating in a video contest. In addition to that, students were reported to perform more waste reduction behaviors compared to before participating in the educational activities. However, despite the effectiveness of the educational program organized, EU3 and EU5 also reported that students' perception related to the impact of marine litter on the marine ecosystem and human well-being was not satisfactory. AS1 also reported that students have a limited understanding of systemic issues related to marine plastic waste. While EU3 and EU5 reported that students were able to communicate issues related to marine litter to raise awareness about the issue to their peers, parents and community upon completion of the educational activities, NA2 observed very few students willing to communicate with others about marine litter. These articles had provided insights on the impacts of educational activities which highlighted marine litter on different target audiences and how it can be further improved for effective educational activities in the future.

3.2.2. Monitoring of Marine Litter

There are eight articles (sampling locations in Europe, North America, South America and Oceania) with 24 coding references that highlighted monitoring of marine litter as part of their educational program. These educational programs also aim to train students to take action as citizen scientists to contribute to the need for marine litter data at beaches. EU1 and EU2 utilized a mobile app to facilitate marine litter data collection. Uniquely, EU1 taught internship students about marine litter, graphic design and computer programming, and together created the mobile app.

The potential of students and teachers as a resource to monitor marine litter has been highlighted. For example, before the litter monitoring activity at the beach, OC1 taught students and teachers about the impact of marine pollution, scientific methods and sampling strategy. Similarly, OC2 arranged a 1-day program that engaged teachers and students about marine litter using a lecture-and-activity format. In addition to that, coastal litter was brought to the classroom to allow students and teachers to identify different types of litter that can be found on the beach. In contrast, SA2 provided a workbook that included information related to scientific methods, marine ecosystem and marine litter, which had to be completed before marine litter monitoring activities. Teachers were given earlier training by the researchers so that they could assist in training students at school. Meanwhile, OC2 provided additional training for teachers so that they could supervise litter monitoring activities as well as continue marine litter education in school. With proper training, students and teachers were also able to effectively contribute to citizen science actions that quantify marine litter at beaches in their vicinity. OC2 also noted that the quality of marine litter monitoring data generated by citizen scientists was comparable to that of researchers. Monitoring marine litter has been highlighted as an important educational activity that provides students and teachers with experiential learning opportunities related to marine litter. The data collected from these activities will also be a useful tool for policy makers to decide on sustainable waste management activities that can reduce marine litter

in a particular area. These articles also highlight the important role of teachers in educating and supervising students during marine litter monitoring activities, as well as promoting marine litter education in school.

3.2.3. Microplastics

There are six articles (sampling locations in Europe and North America) with 15 coding references that highlighted microplastics in their studies. During the education intervention, the topics related to microplastics, which include microplastic data collection, drivers of microplastics and solutions to microplastics, were introduced. Microplastics can be difficult to teach as it requires students to visualize the size of fragmented plastic materials, biomagnification and their implication to the food chain. In some articles, the topic was introduced in resource materials. Yet in other articles, a stronger emphasis on this topic was given by introducing this topic through hands-on activities. For example, EU6 developed a training curriculum that highlighted the physicochemical processes that lead to the drifting and degradation of marine pollutants, including marine litter. As support and supplement to a school program related to science and sustainability, NA1 highlighted that teachers received resources and lesson plans that include microplastics data collection activities which they can opt to complete with their students. SA3 introduced the effect of plastics and microplastic pollution during educational activities that focus on sea turtle conservation. Meanwhile, in EU4, a film entitled "Rethinking Plastic", which highlighted drivers of microplastic production and consumption that is impacting marine organisms negatively, was screened as part of marine plastic and microplastic educational activities that were organized for students. In contrast, NA2 was more interactive in its approach, whereby students were taken to the laboratory to learn about the impact of microplastics on the ocean. Meanwhile, EU5 taught students to use a sieve to separate microplastics from sand in the field. EU1 required students to learn about mesoplastics and microplastics because the researchers and the students were developing a sampling protocol to include microplastics. Although there various teaching methods used to teach about microplastics were highlighted in the articles, EU4 indicated that video screening is a useful learning tool to teach about microplastics. Meanwhile, NA2 cautioned about the misconceptions among youth that arise from the communication using infographic materials.

3.2.4. Marine Biodiversity

There are three articles (sampling locations in Europe, North America and South America) with eleven coding references highlighted about marine biodiversity during educational activities related to marine litter education. These articles highlighted the biodiversity of the marine ecosystem including sea turtles and plankton. All three articles link the impact of marine litter to marine biodiversity. For example, SA3 highlighted the effects of marine plastics and microplastics on sea turtles. Meanwhile, NA2 introduced the impact of marine litter and microplastics in the ocean during a lab to teach students about plankton. SA1 taught about marine biodiversity by exhibiting various marine specimens and zoological collections in the classroom, organizing trips to the beach and art and craft activities as part of a three-phase educational activity focusing on the marine ecosystem, marine biodiversity, pollution impacts to the marine environment and society. Despite confining to very few marine organisms, these articles show that marine biodiversity can be introduced during educational activities either in the field or in the classroom. In addition to that, these articles also highlight the impact of marine litter and pollution on marine animals and how the community can take action to conserve marine animals and the ecosystem.

3.2.5. Littering

There are three articles (sampling location in Europe, North America and South America) with nine coding references that highlight the connection between littering behaviour with marine litter. However, few articles have indicated that the subject related

to land-based sources of marine litter and watersheds were difficult for students. For example, SA1 organized a competition to segregate recycled materials into the correct recycling bin colours, in addition to a film screening of "Isle of Flowers" that gives insight into the destination of waste in Brazil. NA2 and EU5 taught students about the sources of marine litter sources, as well as how the litter is transported to the sea or deposited at the coast. In addition to that, NA2 also identified factors that influence littering behaviour among youth. EU3 and NA2 observed that this topic is difficult for students. In addition, NA2 found that students were observant of the actions of adults and this has influenced their littering behaviour. Furthermore, the article also indicated that the placement of bins will also help the students to stop littering. These articles have shown that litter is a source of marine litter and littering behavior can be addressed using educational tools through non-formal or informal teaching activities. These articles also indicated a bigger role of teachers as well as the school administration to promote marine litter education by being a role model for students through the action of not littering, picking up rubbish, as well as administering a proper waste management policy in school.

3.2.6. Marine Ecosystem

There are two articles (sampling locations in Europe and South America) with seven coding references highlighted about the marine ecosystem. Topics related to the marine ecosystem that were highlighted include the meaning of ecosystem and different marine ecosystems. SA1 highlighted these topics in a classroom setting, by showing satellite images of different ecosystems near the school, as well as organising a sensory activity to differentiate the different ecosystems. Meanwhile, SA2 highlighted this topic in a workbook that was distributed to the students. These articles indicate that the marine ecosystem can be introduced in a classroom setting. This provides insight to educators as the current COVID-19 pandemic may hinder field activities for students that would otherwise provide experiential learning opportunities for students.

3.2.7. Teaching Environmental Education and Education for Sustainable Development (EE/ESD)

Only two articles (sampling locations in Europe and Asia) with three coding references highlighted teaching EE/ESD. Each one of the articles highlighted the importance of EE/ESD for teachers and students. For example, EU6 created education materials and modules based on the first stage of their study, which focused on finding sources of pollution in Europe and modelling future and seasonal climate. The education module highlighted the importance of teaching competencies in EE/ESD and among teachers, how teachers can have the competencies to teach EE/ESD and teaching methods to teach EE/ESD to students. Meanwhile, AS1 explored systems thinking among school children. These articles provided insights on EE/ESD concepts and competencies that should be taught to teachers and students to enable them to take proactive action to address issues related to sustainability.

4. Discussion

Using a scoping review method, this paper was able to find and list the themes of marine litter education that have been highlighted in previous literature. This finding is important to analyze the extent of marine litter education that has been communicated through educational activities and to identify the gaps that can improve marine litter education in the future. Marine litter education is one of the solutions to the issue of marine litter as it seeks to inculcate a positive attitude and environmentally friendly practices through the increase of knowledge.

Based on the articles selected in this paper, most educational activities focused on marine litter, which includes topics such as the different types of marine litter, its sources, impact and the solution to marine litter. This theme is particularly important for marine litter education as it links to several sustainable development goals. Marine litter and

marine pollution are addressed in SDG14 'Life below Water—Conserve and sustainable use of the oceans, seas and marine resources for sustainable development'. Monitoring of marine litter is one of the indicators for SDG 14. In addition to that, the solutions to marine litter are also addressed in SDG12 'Sustainable Consumption and Production' where member states are encouraged to develop, adopt and implement policies to shift from the current linear economy towards sustainable consumption and production, reduce waste generation, as well as promote the understanding of the sustainable lifestyle. Lastly, the marine litter issue can be addressed through SDG 4, especially target 7, which is to ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including among others, through education for sustainable development and sustainable lifestyles. The education system is an important aspect of sustainable development to ensure students, who will later become a leader in society, are given accurate information and knowledge that will support sustainable development [76]. Thus, integrating sustainable development concepts in marine litter education as well as school curriculum will enable students and teachers to increase their knowledge and inculcate positive attitudes and practices towards sustainability [77,78] that could potentially become a solution to marine litter.

4.1. Target Audience

Most of the studies discussed in this scoping review focused on educating students. Only several articles focused on training teachers to ensure teachers are empowered and have the skills to teach marine litter to their students such as EU3, OC2, SA2 and EU6. Despite the education program in the selected articles being largely targeted at students, the same categories of content knowledge that were highlighted in this study should be taught to teachers to allow them to play a role to address marine litter through teaching activities in school. This will enable students to understand the economic, social and environmental impact of marine litter as well as increase their knowledge and inculcate positive attitudes and pro-environmental practices which may reduce marine litter. Therefore, it is recommended that further study should assess the level of knowledge, attitude and practices of teachers towards marine litter and the development of marine litter education module that can be used to prepare teachers to teach and integrate marine litter education in the classroom.

4.2. Importance of Regional Cooperation for Successful Marine Litter Education

Marine litter is a global threat that knows no boundary. Therefore, regional cooperation addressing the threat and mitigation of marine litter is an important driver toward the solution to marine litter [40]. The European Union adopted the EU Marine Strategy Framework Directive which aims for its Member States to take action to achieve or maintain good environmental status (GES) of their marine waters by 2020 [79]. This could be the driver of marine litter education in the European countries, as highlighted in the findings of this paper, where most of the articles sampled a population from the European region. In addition, the marine litter education programs were successfully implemented due to collaboration with several agencies to achieve the EDMSFD target as seen in EU1, EU3 and EU4. Therefore, the adoption of regional policy frameworks such as the Bangkok Declaration on Combating Marine Debris in the ASEAN region and the ASEAN Framework of Action on Marine Debris can potentially be the driver to encourage marine litter education programs in the ASEAN region. Marine Litter Education program is particularly important in the South East Asian and African regions because countries in these regions have been listed as countries with mismanagement of plastic waste that contribute to the generation of marine litter [41].

4.3. Gaps in Marine Litter Education

In addition to the seven categories of content knowledge related to marine litter education listed in Section 3.2, several other categories of content knowledge can be highlighted

in the future to improve marine litter education. Firstly, we highlight the knowledge about benthic marine litter. Ioakeimidis [11] highlighted benthic marine litter by inviting students on a cruise and conducted education activities using Remote Operated Vehicle to monitor the presence and abundance of benthic marine litter. Secondly, knowledge related to policy implementation should be discussed. For example, Malaysia has recently adopted its National Marine Litter and Action Plan 2021–2030. The actions and key activities such as technology and innovation to address marine litter should be introduced to teachers, through school curriculum and other training activities. Therefore, integrating knowledge related to the current environmental policy will enable teachers to educate students, who are future leaders, who would implement and improve environmental governance to solve marine litter. The Ministry of Education Malaysia should follow the success of adopting elements of Global Citizenship Elements in their Primary School Standard Curriculum (KSSR) [78,80] to afford marine litter education in schools. Finally, the COVID-19 pandemic has introduced a new type of marine litter, such as face masks, which are now evident in the city [81], river outlets [82] and have made its way to the beaches [83]. Based on the articles selected in this paper, none addressed the management of post-pandemic waste. Therefore, awareness regarding this new type of marine litter should also be included in marine litter education programs to encourage sustainable management of PPE to reduce the impact on the marine environment as well as human health [84].

4.4. Limitation

There are several limitations of this study. Firstly, only studies in the English language were selected. During the selection of articles, several articles could potentially contribute to this study based on the title and abstract in English. Unfortunately, they had to be excluded because the main article was not in the English language and the authors are only able to comprehend studies published in the English language. There were also several articles published as commentaries or short notes that gave insights into educational activities related to marine litter. However, the articles had to be excluded as we were unable to access the method of the study as well as its result, unlike research articles.

5. Conclusions

One of the main goals of this paper was to investigate the content knowledge of marine litter education highlighted in previous literature. Therefore, this paper retrieved a list of peer-reviewed articles which described their efforts to educate school students and teachers about marine litter. The findings of this paper revealed different aspects of marine litter education content knowledge: marine litter, monitoring of marine litter, microplastics, marine biodiversity, littering, marine ecosystems and teaching EE/ESD. This paper also proposed several gaps to the content knowledge such as benthic marine litter and a new type of marine litter that has been introduced as a result of the ongoing COVID-19 pandemic. While solutions to reduce marine litter related to personal practices have been introduced in previous studies, solutions related to economic policy and instruments (such as circular economy and polluters pay principle) will need to be highlighted too.

The outcome of this paper has highlighted the content knowledge related to marine litter education that teachers will need to comprehend to implement marine litter education in school. Based on this outcome, further studies should look into understanding the level of knowledge among teachers, as well their attitudes and practices related to marine litter. This will allow us to understand if teachers are capable of implementing effective marine litter education in school. This study, too, shall be a driver for further investigation to develop an educational module for effective marine litter education. It may also provide a platform to discuss the topic, especially with different regions in the world that have different priorities and strategies to address marine litter.

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Appendix A

Web of Science Search String (Literature search performed: 8 July 2021). (TITLE-ABS-KEY (teacher* OR educator* OR school) AND TITLE-ABS-KEY (knowledge OR attitude* OR behav*r OR practice OR literacy OR education) AND TITLE-ABS-KEY (debris OR litter OR pollution) AND TITLE-ABS-KEY (conserv* OR sustainab* OR education) AND TITLE-ABS-KEY (marine OR sea OR ocean)).

Appendix B

Table A1. PRISMA Checklist.

Section	Item	PRISMA-ScR Checklist Item	Reported on Page Number
Title	1	Identify the report as a scoping review	Page 1, Line 3
Abstract (Structured summary)	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, source of evidence, charting methods, results and conclusions that relate to the review questions and objectives.	Page 1, Line 13–28
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 3, Line 133–142
Objectives	4	Provide an explicit statement of questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 3, Line 142–150
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Page 3, Line 153–156
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language and publication status), and provide a rationale.	Page 4, Line 169–174
Information sources	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 4, Line 159–168

Table A1. *Cont.*

Section	Item	PRISMA-ScR Checklist Item	Reported on Page Number
Search	8	Present the full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix A
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 4, Section 2.2
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any process for obtaining and confirming data from investigators.	Page 5, Line 191–195
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 6, Section 2.3
Critical appraisals of individual sources	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Not applicable
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 6, Section 2.4
Selection of sources of evidence	14	Give the numbers of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusion at each stage, ideally using a flow diagram.	Page 5
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Page 6, Line 217–234
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Not applicable
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Page 6–14
Synthesis of result	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 14–17, Line 267–429
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 17, Line 426–456
Limitations	20	Discuss the limitations of the scoping review process.	Page 19, Section 4.4
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 19, Section 5
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 19, Line 549

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