Enculturing Sustainable Development Concept Through Chemistry Curriculum for Education for Sustainable Development

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Abstract

The enculturation of sustainable development concept through education system, especially via STEM subjects, is vital in developing citizens who are able to adopt sustainability as a life principle. Although STEM agenda has been emphasized in the national education blueprint, attention is needed on the role of STEM education especially chemistry subject toward education for sustainable development. In this chapter, a framework that encompassing six main areas, namely education policy, awareness, resources, curriculum orientation, pedagogical approach and stakeholder's engagement is proposed in guiding the enculturation of sustainable development concept through chemistry curriculum. The government and institutional policies play an important role to create awareness in understanding the concept and relevance of the sustainable development concept in chemistry subject. Training, finance and time have been identified as resources that need to be considered while integrating sustainable development concept in syllabus and contextualizing chemistry content that should be considered in the curriculum. In addition, the learning outcomes need to be revised based on the pedagogical types, learning approaches and pedagogical techniques used. Lastly, the framework will be instrumental for administrators and teachers to develop a sustainable chemistry teaching toward achieving education for sustainable development with the participation of stakeholders, including government, experts in the field of ESD, administrators and chemistry teachers, in enculturing sustainable development concepts through chemistry subject.

Keywords

Education for sustainable development • Chemistry • Sustainable development • STEM

1 Education for Sustainable Development

The concept of sustainable development was adopted at the United Nations General Assembly in 1987. Since the introduction of the concept of sustainable development, education approaches that support the sustainable development agenda have been explored. This is because education is recognized as the human right and foundation for a country's development where education today is essential to enhancing the ability of leaders and citizens to find new solutions and directions for a better and sustainable future. Generally, sustainable development requires change in terms of human thought and action (UNESCO 2013). Therefore, the approach through education is one of the important efforts in transforming society toward sustainable development (Foo 2013; Mahat et al. 2014).

Education for Sustainable Development (ESD) was given attention when world leaders agreed that the concept of sustainable development should be intensified as a global goal through education. ESD was formally recognized for the first time through the Earth Summit in Rio de Janeiro in 1992 known as Agenda 21. In Agenda 21 (1992) report, Chapter 36 specifically emphasized education in terms of: (1) improving basic education; (2) the adaptation of existing education toward sustainable development; (3) enhancing community understanding and awareness; and (4) training.

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Therefore, practitioners have considered education as one of the key components to sustainable development. ESD is part of Agenda 21, covering environmental, social and economic dimensions to emphasize global issues. In addition, ESD is also defined as the integration of key sustainable development issues into the teaching and learning process (Crespo et al. 2017). According to Lenglet et al. (2010), ESD comprises a variety of concepts, theories, policy prescriptions and practical methods aimed at restructuring the education system with a particular focus on environmental, social and economic dimensions that are key dimensions for sustainable development. Considering the issue of sustainable development is complex, it is important to integrate these three dimensions to achieve sustainability successfully. ESD is an education that embraces the past, relevant to the present, and has a vision for the future (Pigozzi 2010).

Sustainable development has been a focus of Malaysia since the 1970s, with a special emphasis on eradicating poverty, improving people's well-being, providing universal access to education and caring for the environment. In 2009, Malaysia developed the New Economic Model (NEM) which identified three main goals of achieving high income, inclusiveness and sustainability, as the basis for Malaysia's development plan by 2020. In general, the NEM reflects the three dimensions of sustainable development, namely economic, social and environmental. At the same time, the Eleventh Malaysia Plan 2016–2020 (11MP) also forms the basis of the three dimensions. The theme of the 11MP is "Anchoring Growth on People" in which the people are central to all development efforts by ensuring that no community groups are left out to participate and benefit from national development. Critically, the 11 MP is in line with most of the Sustainable Development Goals (SDGs) (Economic Planning Unit 2015).

Malaysia has also given special attention to the ESD where Malaysia has adopted the principles of Agenda 21 as one of the most important sustainable development documents in the national planning process (Hassan 1998; Ngah et al. 2011). To promote ESD in Malaysia, six strategies have been implemented by the Ministry of Education at all levels of the education system in Malaysia. Among these strategies are: (1) expanding the supply of skilled and knowledgeable labor; (2) improving access to quality education and training; (3) improving the quality of education and training delivery system; (4) promoting lifelong learning; (5) increasing the supply of science and technology labor; and (6) reinforcing positive values (UNESCO 2011). In the UNESCO (2011) report, it is stated that ESD's priority in Malaysia is divided into three categories, namely environment, education and poverty reduction. Climate change is a new priority that the Ministry of Education is working to address through ESD.

At the same time, academic institutions have taken various initiatives to incorporate aspects of Agenda 21 into academic syllabus as well as campus-based activities. Studies have also shown that aspects of sustainability have been covered in science, social science and engineering at the school, graduate and postgraduate levels. In addition, aspects of sustainability have been introduced through various programs at school level, such as Technical and Vocational Education (Minghat and Yasin 2010) and Environmental Education (Said et al. 2007). However, students often fail to integrate sustainability concepts with their lessons (Reza 2016). For example, students from Ecology and Natural Resource Management have difficulty in integrating the knowledge gained with sustainability into sustainable urban infrastructure development or planning. This is because the aspect of sustainability is not emphasized in detail in the syllabus taught in Malaysia (Reza 2016).

2 STEM Education

Literacy in Science, Technology, Engineering and Mathematics (STEM) is an essential element of science-related programs in the twenty-first century. STEM education and research play a vital role in advancing technology, medicine, sustainability, agriculture, national security, economics and society, as well as finding answers to most questions related to human life. STEM education is a global concept that integrates critical, analytical, systematic and collaborative thinking processes in which students integrate their processes and concepts into the real world (Ndinechi and Okafor 2016).

Therefore, the vision of most STEM academic programs is to focus on workforce development and research to meet the needs of local and regional industries, national security and efforts to become more competitive in the global market (Egarievwe 2015). There are various definitions of STEM education that have been discussed based on different approaches, such as silo, implicit and integrated approaches. In the silo approach, each STEM subject is taught separately, and the focus is on the core subject. This approach uses a college-based method or high standard instruction, and students are expected to gain a deeper understanding of the course content. Implicit approach focuses on real-world problems in the social, cultural and contextual aspects of the knowledge domain. Students are exposed to problem solving and learning techniques through a variety of contexts. An integrated approach involves integrating STEM content to teach as a subject. This approach is divided into two types: multidisciplinary and interdisciplinary. Multidisciplinary enables students to associate knowledge domains with specific subjects, while through interdisciplinary, students can associate domains of knowledge and skills across subjects with critical thinking skills, problem solving and knowledge to solve real-world problems (Le et al. 2015). Each approach has its own strengths and weaknesses. Therefore, teacher's initiative is important in assessing the

subject knowledge domain and selecting the best teaching approach to attract students toward STEM education.

Proposal to teach integrated STEM in the secondary curriculum has been encouraged in some countries, but it has recently become more and more important (Williams 2011). This integration is considered a solution to educational reform in the USA. This is because there is a need to provide a technologically qualified and sophisticated engineering workforce to develop a high-tech knowledge-based economy. However, the main focus of STEM education is to increase the competency of students in various disciplines to meet the needs of the workforce in the twenty-first century (Obama 2009). The lack of STEM workers that threaten the USA has demanded STEM education reform in the country and subsequently spread to many countries around the world (Marginson et al. 2013; Pitt 2009).

The Malaysian Education Blueprint was launched by the Ministry of Education for 2013–2025. In the blueprint, strengthening STEM has been identified as one of the key elements, whereby the main goal of the STEM initiative is to ensure that Malaysia has a sufficient number of STEM graduates to meet the industry needs that serve as the engine of national economy. This is important to achieve the national goal of the Malaysian government of producing one million STEM professionals by 2020. Therefore, various key criteria have been proposed to strengthen STEM delivery through the education system, including (1) increasing student interest through new learning approaches and strengthening the curriculum; (2) improving teachers' skills and abilities; and (3) increasing student and public awareness. STEM approaches refer to pedagogical strategies that emphasize the application of knowledge, skills and values from the disciplines of Science, Technology, Engineering and Mathematics to help students in solving real-world problems. As such, Malaysia sees education as one of the ways to achieve advanced countries to meet STEM-driven economic challenges and demands (Ministry of Education Malaysia 2013).

3 Knowledge, Attitude and Behavior of Sustainable Development

ESD serves as an "umbrella" for education and now has the potential to bring about change and innovation in education, teaching and learning. Various studies have been conducted to find out how knowledge of sustainable development concepts that can influence students' attitudes and behaviors.

3.1 Knowledge

Azapagic et al. (2005) conducted a study to determine knowledge of engineering students on sustainable development. The study was conducted on engineering students from 40 different universities from developed and developing countries. The results show that the level of student knowledge is modest, and there is a significant knowledge gap between the social and economic dimensions of sustainable development. However, students feel that sustainable development is more important to future generations than themselves.

Furthermore, Sheikh et al. (2012) studied the perceptions of first-year undergraduate engineering students on sustainable development at a public university in Malaysia, indicating that students are unaware of sustainable development and most of the students do not know how to explain the definition of sustainable development because it has never been exposed to the concept. Although students cannot explain the definition of sustainable development, most students are found to be involved in daily activities based on sustainable development, such as Earth Hour, recycling, green technology, and climate change. This study shows that students understand the importance of caring for the environment, but primary and secondary education that do not associate environmental dimensions with sustainable development causes a lack of knowledge about sustainable development.

3.2 Knowledge/Awareness and Attitude

Aziz et al. (2012) conducted a survey on first-year engineering students to develop a structural model to assess students' attitudes toward sustainability. The findings of the study show that the structural model produced is reliable and is compatible with the influence of knowledge on sustainability attitudes among first-year engineering students. In addition, the analysis also shows that basic knowledge of sustainable development is strongly linked to developing and enhancing student attitude. The model also measures the level of knowledge and attitudes about the need to understand the concept of sustainable development and changes students' attitudes toward sustainability.

At Plymouth University, Kagawa (2007) explored perceptions, understandings and attitudes on sustainable development and related concepts and issues. The study found that students relate the concept of sustainable development and sustainability to the environment in relation to economic and social dimensions. In addition, the study found that students have a common pro-sustainability attitude and express a variety of feelings about the future of society in facing sustainability-oriented challenges. In terms of changing themselves toward a more sustainable lifestyle, students are often exposed to responsible consumer behaviors, such as changing purchasing habits, recycling, saving energy and/or water and changing modes of transportation. Therefore, Kagawa (2007) suggested that students' learning

more relevant to specific contexts is important for establishing a curriculum change process where student needs, aspirations and concerns for sustainability are addressed. These changes are expected to help students become more responsible citizens.

In addition, a study was also conducted to examine the change in attitude and perceptions of twelfth-grade students on chemical and environmental issues after studying environmental subject. The results show that students are experiencing significant changes in awareness of environmental issues as the subject is closely related to students' personal lives. It is suggested that increasing student awareness at the secondary level may affect students' attitudes toward environmental issues in the future. Researchers also believe that such programs can promote ESD concepts among students. However, curriculum changes in this study were found to be insufficient to induce significant differences in students' attitudes toward chemistry learning. Curriculum modification is necessary in order to have a more profound impact on changing student attitudes and to create a more environmentally conscious mind (Mandler et al. 2012).

3.3 Knowledge and Attitude

Said et al. (2007) conducted a study to find out students' understanding of the extent to which environmentally responsible behaviors and students' involvement in activities related to the nature. The results show that students' understanding of environmental concepts is relatively poor and that students are less clear in defining sustainable development concepts. However, the findings show that environmental education, both formal and informal, has increased students' awareness of the environment. However, environmental education has been found to be less effective in changing students' attitudes and behaviors. This study also suggests that by overcoming barriers, such as pedagogical approaches, changes in student behavior can be seen to facilitate a more sustainable lifestyle.

In addition, a study conducted by Meerah et al. (2010) primary, secondary and urban secondary school students in Malaysia prove that the use of environmental education as a medium to deliver sustainable development content in primary and secondary education in Malaysia. The results show that only 35% of school students have knowledge of environmental issues. However, the levels of knowledge and behavior are low among the students. Therefore, more emphasis should be placed on environmental education both inside and outside of the classroom. Although 35% is a low percentage of knowledge, this indicates that undergraduate students who have essentially completed primary and secondary education are exposed to environmental knowledge as one of the dimensions of sustainable development.

3.4 Knowledge, Attitude and Behavior

Idros (2006) discussed the levels of knowledge, attitudes and behaviors of university students in Malaysia toward the environment and its implications for education in explaining sustainable development. The results show that the students do not have a high level of knowledge of environmental facts but do show a better understanding of the concept of the environment. Students were also found to have a strong pro-environmental attitude despite the students' willingness to act' is less than the students' actual actions. This means that the strength of the students' behavioral patterns toward the environment is modest, indicating that there is a need to plan or reformulate the curriculum systematically with a focus on promoting a deeper understanding of environmental conditions. Students also need to be equipped with knowledge of action strategies, understanding the complexity of the problems involved, and more importantly, identifying the causes that lead to a less sustainable future.

Fah and Sirisena (2014) conducted a study to assess the level of knowledge, attitudes and behaviors among high school students (grade four) in urban and rural areas in Sabah, Malaysia. The analysis shows that grade four students do not show the expected results where the knowledge is the lowest compared to attitudes and behaviors. In general, the students' attitudes and behaviors toward the environment are high. It is also found that the low knowledge is due to less time spent by the Ministry of Education on environmental education, especially on some key topics in the environment. Fah and Sirisena (2014) emphasize that the purpose of environmental education in Malaysia is not achieved and that improvement is necessary to create awareness about the importance of environmental education in Malaysian secondary schools.

Gusti (2016) conducted a study in Indonesia on primary school students to assess the relationship between knowledge, attitudes and behaviors in sustainable waste management. The result shows that knowledge and attitudes toward sustainable waste management are significantly associated with sustainable waste management behaviors. Increasing students' interests or behaviors in sustainable waste management can be achieved by enhancing students' knowledge of sustainable waste management which includes reducing, reusing and recycling waste for more environmentally friendly energy production.

3.5 Knowledge and Awareness

Hassan et al. (2010) conducted a study to assess the level of environmental awareness based on the concept of sustainable development among high school students in the Hulu Langat District, Selangor, Malaysia. High school students show a

high degree of awareness of the environment in relation to the concept of sustainable development. In addition, science students have a higher level of environmental awareness of the concept of sustainable development, indicating the need to learn more about environmental and ecological concepts resulting in higher knowledge of science students than those of literature students studying basic science where the syllabus is not sufficient.

Yuan and Zuo (2013) assessed students' level of awareness about sustainability and perceptions of students about higher education for sustainable development. It reveals that students generally have a high level of awareness of sustainability issues, but the level of students' interpretation of the meaning of higher education for sustainable development is low. In general, it is found that aspects of sustainability in the environment are given priority to students compared to other factors such as social responsibility.

Fabbrizzi et al. (2016) analyzed the level of knowledge and perceptions of the concepts of sustainability and well-being of high school students in Tuscany. The analysis reports that young people are less stressed about sustainability in schools where students' perceptions show that the concept of sustainability is related to environmental aspects. In relation to well-being, it shows how factors that can be associated with individual aspects are considered more important. The role of well-being indicators is important for policy making. Discussions about the perceptions and definitions of well-being indicators lead to forums where new ideas can be developed, and those indicators can be negotiated and agreed upon. Therefore, the introduction of key aspects of shaping the concept of well-being for the younger generation and student perceptions is the first step in providing concrete ways of representing the various dimensions.

4 Integration of Sustainable Development Concept

ESD is an area of interest and has been promoted through various United Nations agendas and initiatives, such as Agenda 21, Decade of Education for Sustainable Development 2005–2014 and Global Action Program by the United Nations Educational, Science and Cultural Organization (UNESCO) to implement ESD (Agenda 21 1992). However, ESD is often considered to be closely related to environmental education (Darwish et al. 2010; Hoang and Kato 2016). Johannesson et al. (2011) suggest that differentiating ESDs with environmental education in terms of content and teaching methods is a difficult task. Sterling (2001) suggests that ESD actually covers more topics than environmental education and can explain all education for the purpose of change. As such, much of the existing support for ESD is seen in many different areas, namely architectural education (Shari and Jaafar 2006), technical, entrepreneurship, vocational education and training (TEVET) (Gomani 2010), construction projects (Abidin 2010), Green ICT (Suryawanshi and Narkhede 2015), mathematics (Sivapalan 2016) and many others.

The Earth Summit held in Rio de Janeiro in 1992 was the precursor to the declaration of Agenda 21, the first international document to introduce ESD. The document recognizes education as an agent for promoting sustainable development. Agenda 21 is an action plan that contains a comprehensive set of principles to assist governments and other institutions in implementing sustainable development policies and programs in their respective countries. Based on Agenda 21, various terms that focus on ESD have been suggested by researchers. Among these suggestions are education for sustainability (Sterling 1996), sustainability education (Wals 2010), sustainable education (Sterling 2001) and education for sustainability (Paulus 1996). Although these terms have minor differences in terms of emphasis, they are interchangeable and reflect the same goals as ESD.

Meanwhile, the SDGs launched by the United Nations are also promoting ESD through a fourth goal dedicated to promoting quality education. According to the United Nations General Assembly (2015: 21), one of the goals was to declare that everyone should acquire the knowledge and skills needed to support sustainable development whereby by 2030, all students must ensure they have the knowledge and skills needed to promote sustainable development, among others, through ESD and sustainable lifestyle, human rights, gender equality, promoting a safe and non-violence culture, global citizenship and appreciation of cultural diversity and cultural contributions to sustainable development.

ESD focuses on new visions and directions for learning and action that help people of all ages to be responsible for enjoying and creating a sustainable future (Haan et al. 2010; Khataybeh et al. 2010). In general, the learning process is found to be more important than the right learning content (Sterling 1996). Sustainable lifestyles cannot be defined in detail because their context depends on time and location. Therefore, a universal curriculum for ESD cannot be established (Wals 2010). Instead, ESD needs to be contextualized and reflect local needs that can be linked to global sustainability issues (Hofman 2015).

4.1 Approaches

To date, ESD has emerged as a unifying theme for many types of education and focuses on different aspects of sustainability. In addition, ESD is seen as a catalyst for innovation in education where ESD is increasingly emphasized

in almost every country and is seen as a relevant approach to the global problem. As such, various networks and structures have been created at different levels, whether in schools, universities, communities and the private sector to develop ESD.

Mehlmann et al. (2010) state that at the school level in Ukraine, a new integrative and inclusive curriculum was designed for the purpose of ESD to offer additional material for an existing subject. In their teaching, teachers in Ukraine have linked the concept of sustainable development to the field of natural science. However, the social aspect has also attracted the attention of ESD as a sustainable society cannot function without democracy, continuous dialogue, participation and empowerment of society. From a standard school curriculum perspective, social aspects have been revealed through social studies, social psychology, social engineering or philosophy.

In China, cities such as Beijing, Shanghai, Jiangsu, Guangzhou and Mongolia are pioneering the implementation of ESD. The government has also initiated ESD in the education system through the development of ESD curriculum and institutions in teacher education. For prospective teachers attending State University of Education, guidelines on ESD and textbooks as a learning resource have been developed. Meanwhile, the Beijing Academy of Science Education, UNESCO and the Chinese Ministry of Education have developed a "Environment, Population and Education for Sustainable Development" program with the aim of engaging students in activities that reduce social, economic, environmental and cultural problems for sustainable development. In addition, in China, secondary education is considered an important part of ESD practice (UNESCO 2012).

In addition, Manitoba is one of the regions in Canada that urges schools in the region to focus on sustainable development. The Ministry of Education of Manitoba has emphasized ESD as part of its mission statement. In addition, the ministry's main goal is also to ensure that education in Manitoba supports students in terms of experience and learning about a more sustainable lifestyle (UNESCO 2012). Manitoba Education and Training (2000) states that Manitoba has also developed a guidebook for curriculum developers, teachers and administrators focusing on ESD as a means of promoting teaching on sustainable development.

In addition, in the Swedish school system, the concept of sustainable development is not included as a separate subject, but rather as part of the statement for all subjects in the curriculum. Therefore, all teachers are expected to emphasize sustainability issues in the daily teaching process. In addition, sustainable development is considered one of the comprehensive perspectives of education in Swedish schools that need to be outlined (UNESCO 2005). Finland promotes sustainable development by integrating the national curriculum in elementary, general and vocational education at the secondary level. The National Board of Education is also working with schools to improve ESD teaching and learning (UNESCO 2012).

In Jordan and Malta, ESD is integrated into the curriculum of science education and other subjects by introducing the concept of sustainable development through complete pictures and lessons. ESD is also emphasized in the high school curriculum of Italy. However, most education projects on sustainable development are carried out outside of the formal curriculum framework, in collaboration with other environmental NGOs, institutions and organizations (UNESCO 2012). In addition, the Brunei Ministry of Education did not develop an ESD-specific framework and did not establish environmental education as a single subject. However, initiatives have been taken to integrate environmental issues across a range of subjects. In Indonesia, ESD is implemented in collaboration with the Ministry of Environment and the Ministry of Education (UNESCO 2011).

Although ESD has been successfully implemented in many countries, there are some countries that still expect government encouragement and involvement in the implementation. According to UNESCO (2012), countries such as Uganda have stated that there is a need for the government and major ministries to focus on ESD as part of education policy by building on existing school-based ESD approaches. China also hopes that in the future, more attention should be given especially to providing ESD training to teachers and principals in less developed areas. Similar views have also been observed in countries, such as Egypt and the Republic of Korea, where teacher training and guidance are important for promoting teacher and student engagement in ESD (UNESCO 2012).

ESD is interpreted with many interpretations around the world. However, there is a greater recognition of the need for localized interpretations that play an important role in achieving sustainable national status through the process of teaching and learning. In this regard, Malaysia is also not left behind in implementing ESD through various subjects in education. The Ministry of Education Malaysia (MOE) has taken important steps to ensure that education development plans are more practical, realistic and action-oriented, as well as responsive to the needs of the country. The Malaysian education system has been developed in line with national development whereby it is important that ESD is also defined according to the needs of a country. The definition of ESD in the Malaysian context covers aspects of preserving future generations' well-being and what we have today for future generations. To improve the quality of life of the nation, education plays a fundamental role in the development. Therefore, the ministry intends to adopt a holistic approach to human capital development comprising knowledge, skills and ethical values to create progressive thinking

and cultural, social and environmental awareness (UNESCO 2011). By 2020, Malaysia aspires to be a developed country that has achieved economic, political, social, spiritual and cultural development. To achieve this, education plays a vital role in the sustainability of the nation.

Various studies have been conducted focusing on different areas to assess the level of integration, implementation and awareness of sustainability issues among students and teachers. Shari and Jaafar (2006) have evaluated the degree of integration and implementation of sustainability issues in the curriculum at architectural schools in Malaysia. The findings show that sustainable design strategies implemented in Malaysian architectural studios focus more on issues related to energy and the environment. However, the study found that there is a lack of attention to social and economic dimensions. However, technology, history and theory and practice and management courses found that technology courses cover more sustainability issues than the other two. Based on an analysis of the integration of sustainability concepts in studio and non-studio teaching, it is recommended that a more balanced approach to sustainability in architectural education should be taken.

In terms of formal education, Ministry of Education Malaysia has played an important role in developing the curriculum for environmental education and introducing a variety of teaching and learning strategies. Curriculum-based environmental education has been introduced in primary and secondary schools since 1998, and the ministry also provides a guidebook on environmental education. Although the ministry has provided the necessary manuals for all schools, its implementation has been limited and unbalanced. This is because the handbook is rarely used by teachers. In addition, some teachers were also unaware of the existence of the handbook. In addition, teachers are of the view that while the handbook suggests and describes activities relevant to environmental education, the details of these suggestions are not sufficient to carry out environmental education programs (Pudin et al. 2004). Said et al. (2007) conducted a study to measure the level of environmental awareness, knowledge and involvement of high school students in sustainable development practices. The results show that students are aware of the increasing environmental problems, but the students' concerns are at a moderate level with regard to environmental issues. Therefore, it is important to look for steps to enhance the understanding and participation of Malaysian students in environmental education and sustainable development.

Karpudewan et al. (2009) have introduced green chemistry experiments integrated with the concept of sustainable development, Sustainable Development Concepts (SDCs) as an alternative approach to teaching existing courses with environmentally responsible modes while taking into account of social and economic aspects. The findings show that green chemistry can enhance students' understanding of traditional environmental concepts, Traditional Environmental Concepts (TECs) and even SDCs. However, from the students' perspective, the understanding of SDCs is much higher than that of TECs. The findings of this study serve as a good resource for student teachers to engage in science education programs and embed scientific concepts based on economic, environmental and social concepts. Furthermore, Minghat and Yasin (2010) have identified aspects of sustainable development in technical and vocational subjects that are expected to guarantee success in achieving sustainable development concepts whereby a sustainable development framework for technical and vocational subjects in secondary schools in Malaysia is proposed to be a guide in integrating sustainable development concepts. This effort is expected to show great potential in the development and conservation of human capital in Malaysia.

Abdullah et al. (2011) state that the introduction of a handbook for teachers to implement environmental education across the curriculum in all subjects shows the importance of environmental literacy to students in achieving environmental sustainability goals. However, the study found that students' level of knowledge about the environment is still poor. Therefore, a study was conducted to determine how well the curriculum in biology, physics and chemistry has integrated environmental knowledge in its core content. The findings show that environmental knowledge is provided only at the surface level in the current science curriculum. Some important aspects of environmental knowledge need to be discussed in depth and applied in science teaching and learning based on consideration of current environmental issues.

Sivapalan (2016) conducted research to reflect, explore and compare the perspectives and beliefs of higher education stakeholders on how sustainable development competencies can be incorporated into Malaysian undergraduate engineering education curriculum. This is because limited research is being conducted to propose holistic guidelines or institutional frameworks for the establishment or evaluation of engineering education for sustainable development at a young age in Malaysia. The guidelines are intended to incorporate holistic sustainable development competencies in the programs of undergraduate engineering and general module learning, and the institution's overall framework is expected to benefit stakeholders, in terms of curriculum and pedagogy, universities and engineering education in Malaysia as a whole.

Peter et al. (2016) have studied the extent to which ESDs are integrated at the community college level in Malaysia. This study found that seven dimensions of sustainability in higher education institutions are discussed, namely curriculum, research and scholarship, operations, faculty and staff recruitment, development and reward, outreach and service,

student opportunities, and institutional mission, structure and planning. The findings show that to some extent, the concept of sustainable development can be integrated into three out of the seven dimensions of sustainability, namely curriculum, outreach and services as well as institutional, structural and planning mission.

In addition, Malaysia has also implemented a sustainable school program aimed at promoting awareness of sustainability among students. The program is also known as the Sustainable School Environmental Program and has been in operation since 2005. It is open to primary and secondary students. The results show that interventions on ESD through the program at national level have a more positive impact on the context of participation, responsibility and environmental care indirectly increase ESD awareness. Thus, demonstrating that engagement in these ongoing activities can enhance students' and teachers' awareness of sustainable development and suggesting that the government's efforts to implement the program should be continued throughout Malaysia (Mahat and Idrus 2016). Although the program has been in existence for more than a decade, its curriculum is more environmentally friendly and implemented across curricula covering a wide range of subjects, such as science, geography, civic education and Malay as well as science-based subjects, such as physics, chemistry and biology. Karpudewan et al. (2011b) found that various teaching and learning strategies have been proposed in the syllabus description through environmental education. The aim is to increase the importance of environmental protection among students. However, it is not taught as a specific subject, but these environmental aspects are incorporated into the syllabus at the end of certain chapters.

In addition, Karpudewan et al. (2011a) argue that there is still no specific curriculum developed with a focus on ESD or green chemistry for school students. Therefore, a proactive action is taken by Karpudewan et al. (2011a) by developing a green chemistry curriculum that can support the integration of ESD concept as a course. However, this curriculum is applied to the teaching of chemistry trainees in order to educate and demonstrate more responsible behavior toward environmental sustainability.

4.2 Concept

ESD has found its way into the sustainable development movement since the 1990s incorporating concerns about economic and human development for environmental protection (McKeown and Hopkins 2007). ESD needs to provide a scientific understanding of sustainability simultaneously with an understanding of the values, principles and lifestyles that will lead to the transition toward sustainable development (UNESCO 2005). As such, Marks and Eilks (2009) state that science education must move beyond scientific problem solving and application to include socio-scientific decision-making capabilities, thus providing educated citizens who can participate responsibly in the real world. Malaysia has sought to promote awareness of the concept of sustainable development. However, more efforts need to be made in STEM to promote environmentally responsible, economically and socially responsible cultures.

Venkataraman (2009) suggests that ESD throughout the education system are important for the development of people who practice sustainable development as a principle and guide in daily life. However, Burmeister et al. (2012) state that ESD requires a more holistic approach whereby ESD not only requires the use of new questions about the concept of sustainability or the network of science and society as the content and/or context of science teaching, but more detail to enhance understanding. In addition, ESD requires a more comprehensive approach to relate social issues and multidimensional management. Diversity in this dimension should include an understanding of the background of the issues presented where it can also come from chemistry, and that perspective should also be introduced in compulsory science education in schools. At the same time, chemistry education based on ESD principles at all levels must also be oriented toward addressing the ecological, economic and social impacts as a whole, while focusing on real change in society at the local, regional and global levels (Haan 2006; Wheeler 2000).

Considering the concept of chemistry education in schools, the study of chemistry theory and facts alone cannot enhance students' ability to understand the concept of sustainable development. The use of more community-oriented approaches from multiple dimensions through chemistry education can provide the necessary encouragement to achieve educational goals for development (Ware 2001). With these improvements, education has become a leading field for learning how chemicals are embedded in people's daily lives including their environmental, economic and social impact (Hofstein et al. 2011). In addition, learning about how chemistry development is linked to the environmental, economic and social impacts and understanding that arises from these issues is more important. Thus, chemistry education has been shown to have important potential for improving the level of general education skills among students from a more participatory learning perspective. This is because recent societal developments are directly linked to chemistry and technology which are then managed through a multidimensional approach (Burmeister et al. 2012).

Yencken et al. (2000) suggest that daily experience and knowledge as well as three dimensions of sustainability, namely economic, environmental and social can be reflected in the curriculum by integrating sustainable development concepts. Among the 20 proposed sustainable development

concepts are carrying capacity, steady-state economy, ecological space, sustainable development, ecological footprint, natural resource accounting (natural resource accounting), eco-efficiency, life cycle analysis, sustainable consumption, 5 Rs. (the 5 Rs.), local global links, interdependence, biodiversity, interspecies equity, intra-generational equity, intergenerational equity, human rights, basic human needs, media literacy and democracy. All these proposed sustainable development concepts are expected to assist either researchers or teachers in integrating sustainable development concepts.

Karpudewan et al. (2011b) have adapted the integration approach suggested by Yencken et al. (2000) in the method of teaching chemistry offered to pre-service chemistry teachers. This study outlines new teaching strategies that contain scientific, environmental and social science concepts that will be a good resource for trainee teachers involved in science education programs especially green chemistry education. The results show that the integration of sustainable development concepts in green chemistry subjects can influence the value change among trainee teachers. It is important that these future teachers understand the right values because it is important for teachers to have a tendency to articulate values that are important to students through knowledge of pedagogical content (Veugelers 2000). In addition, Heaton et al. (2006) also suggest that the integration of green chemistry principles can assist in curriculum development and pedagogy that will lead to the development of values, knowledge and skills that can contribute to sustainable development.

According to Millar (2008), science education in schools aims to provide students with a multidimensional understanding of science in which students can apply the knowledge gained in personal, daily and community life. At the same time, Holbrook and Rannikmae (2009) state that one of the important goals of scientific literacy is to provide students with the ability to make responsible decisions based on their knowledge and ability to interpret, understand and apply relevant scientific concepts and ideas. Global and local perspectives state that it is important that education should focus on what will be truly useful and meaningful to every individual in the community in the future. Landorf et al. (2008) define education for sustainable human development as an educational practice that results in improvements in human well-being, both for the present and for future generations. However, Wals (2007) argues that ESD also needs to establish a close link between education and real-life experience by focusing on sustainability issues encountered in a society itself. In general, ESD aims to help students in developing the attitude, skills and knowledge needed to act on informed decisions for themselves, society and future generations (McKeown et al. 2002).

According to Venkataraman (2009), the inclusion of ESD throughout the education system is important for the development of people who practice sustainable development as a principle and guide in their daily lives. Therefore, McKeown et al. (2002) argue that if the basic level of education can be improved, the second priority of ESD is to reconsider elementary and secondary education to address issues of sustainability. In contrast to environmental education as a separate entity in the curriculum, McKeown et al. (2002) state that ESD skills, knowledge and values are reflected in the learning system. Similarly, in defining ESD, UNESCO (2005) has stated that the skills, values and practices of sustainable development need to be integrated in all aspects of education and learning. As such, the orientation of the chemistry curriculum shows a positive tendency to adopt a more sustainable lifestyle and this is a good starting point for educators to develop the curriculum. In this regard, ESD-related frameworks that can help to integrate the process need to be taken seriously.

A conceptual framework has been developed based on previous research and UNESCO documents related to the integration of sustainable development concepts toward achieving ESD. Models of knowledge, attitudes and behaviors (Ramsey and Rickson 1976) and Hines's model of Responsibility to the Environment (Hines et al. 1987) are used. The pro-environmental model of behavior is the earliest and simplest model proposed to measure and to explain environmental awareness and concern (Ramsey and Rickson 1976). This model has been widely accepted because it associates knowledge with attitudes and attitudes toward behavior. This model is then known as the knowledge, attitude and practice (KAP) model (Mahmud and Siarap 2013). Vandamme (2009) states that the KAP-based survey has received criticism in terms of reliability, validity and measurement related to the intensity of opinions or attitudes. However, KAP analysis is well accepted as a conceptual framework for assessing people's understanding, awareness, readiness and participation in a particular issue (Launiala 2009). Kollmuss and Agyeman (2002) also agree that most non-governmental organizations (NGOs) still have a simple assumption that knowledge depth will lead to behavioral excellence. In general, studies related to KAP are found to be useful for three general purposes, as a diagnostic tool to illustrate current knowledge, attitudes and practices of society to communicate current situation and plan appropriate interventions and as a tool for assessing the effectiveness of specific interventions or programs (Vandamme 2009).

Recently, various KAP-based studies have been widely used to determine the level of human behavior in various fields. These include food security, education (Idros 2006), management (Laor et al. 2018) and public health

(Launiala 2009). However, in the field of ESD, the KAP survey has been widely used to assess the level of knowledge, attitudes and practices or behavior of academic staff and students on issues related to awareness of sustainable development concepts (Azapagic et al. 2005), engineering education (Sivapalan 2016), campus sustainability (Choy et al. 2017; Wan Nur'ashiqin et al. 2011), the field of architecture (Emanuel and Adams 2011) and environmental sustainability (Idros 2006). Flamm (2006) states that the KAP model is also known as the knowledge, attitude and behavior (KAB) model where knowledge is given priority as the basis for determining attitudes and behaviors. Based on the KAP model, an increase in an individual's knowledge leads to a change in attitude. Changes in attitude will lead to changes in practice or behavior. Knowledge can be enhanced through exposure to new information through lectures, classes, media, lectures and other scientific activities (Isa 2016). Iyer (2018) argues that knowledge of concepts is important for a person to be positive. A positive attitude can lead to positive behavioral changes by organizing activities that can motivate peers and others. These behavioral changes are expected to be lifelong. Figure 1 shows the earliest model of pro-environmental behavior.

In 1986, Hines, Hungerford and Tomera introduced the Hines Model of Responsible Environmental Behavior. This model is proposed based on the Theory of Planned Behavior proposed by Ajzen and Fishbein (1980) as shown in Fig. 2. Hines model was introduced after conducting a meta-analysis on environmentally responsible behaviors and studies used to describe processes involved in fostering positive environmental behaviors through environmental education (Kollmuss and Agyeman 2002). The model identifies six variables, namely

(i) Knowledge of issues: One needs to know about environmental issues and their causes.
(ii) Knowledge of action strategies: One needs to know how to act to reduce the impact of environmental problems.
(iii) Locus of control: This represents the perception of the individual whether the individual has the ability to bring about change through his or her own behavior. Someone with a strong locus of internal control believes that their actions can lead to change. However, people with the locus of external control find their actions insignificant and feel that change can only be taken by more powerful people.

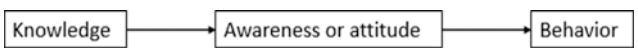

Fig. 1 Earliest model of pro-environmental behavior (Ramsey and Rickson 1976)

(iv) Attitudes: People with strong pro-environmental attitudes are found to be more likely to engage in pro-environmental behaviors, but the relationship between attitudes and actions has been shown to be weak.
(v) Verbal commitment: Commitment willingness to take action also provides some indication of a person's willingness to engage in pro-environmental behavior.
(vi) An individual's sense of responsibility: A person with a higher personal responsibility is more likely to engage in environmentally responsible behavior.

Based on this model, individuals who wish to take action are more likely to engage in environmental-related actions than individuals who do not have such desires. Before a person wants to take action to address a specific environmental issue, the individual must be aware of the existence of the problem. Therefore, knowledge of an issue is seen as a prerequisite for action. One must have knowledge of available behaviors in order to be more effective in certain situations. According to Davey (2012) and Kollmuss and Agyeman (2002), there are several situations or situations that influence environmentally responsible behavior. Situational factors in this model refer to constraints, social pressures and opportunities to choose different actions that may hinder or enhance one's desire to act. Therefore, this model is expected to predict one's behavior to be more environmentally responsible.

Based on the KAP model and Hines model, a conceptual framework in which the main variables of the concept includes three categories of variables and one category of variables that hinder the path to action. In this conceptual framework, the three main domains that refer to the KAP model are adapted to assess the level of awareness and knowledge, attitudes and behaviors as each aspect of awareness will begin with knowledge and subsequently result in changes in attitude and behavior as well as practice. In a study conducted by Sahin et al. (2012) at the Middle East Technical University on the attitude of university students toward the concept of sustainability, it was found that knowledge of environmental issues affects individual attitudes toward the environment. This attitude leads to behaviors that may encourage individuals to deepen their knowledge of campus sustainability. At the College of Alabama and Hawaii, Emanuel and Adams (2011) conducted a study to determine students' perceptions of campus sustainability. The study found that students' understanding, and perceptions of sustainability can provide insights into ways to practice sustainability in their students' daily lives whereby deep understanding can only be obtained through knowledge. Furthermore, Chen et al. (2011) argue that in achieving the sustainability objectives, changes in the

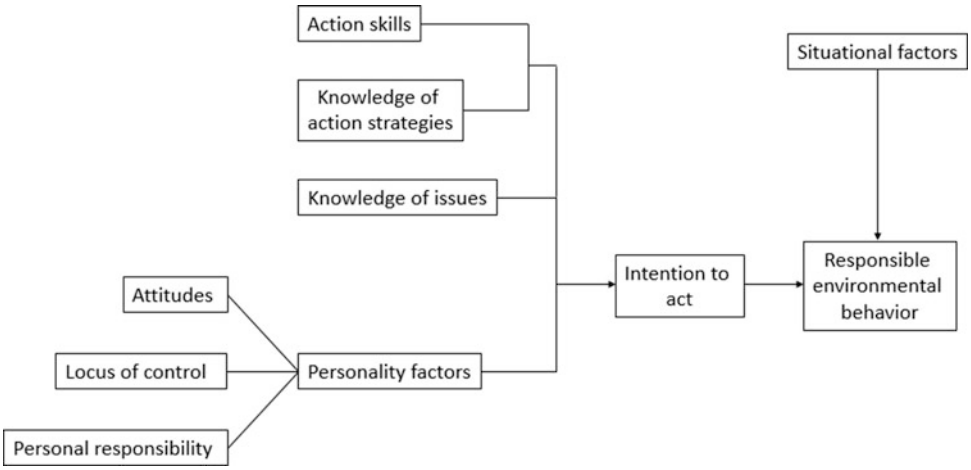

Fig. 2 Hines model of responsible environmental behavior

attitudes and behaviors of individuals at both faculty, staff and students are important. Arbuthnott (2009) has stated that attitudes that focus on sustainability actions where ESD programs include strategies that target personal or professional characteristics in the intention can assist in transforming the intention into action. Therefore, the alignment of ESD efforts toward decision-making in terms of institutional infrastructure, regulation and incentives will have a profound impact on more sustainable behavior.

The integration of sustainable development concepts is generally influenced by several barriers that can be generalized into six key areas, namely education policies, curriculum orientation, pedagogical approaches, resources, stakeholders and awareness, that may influence the process of integration of sustainable development concepts (Kanapathy 2018, 2019a, b). Figure 3 shows the conceptual framework is based on KAP model and Hines model that illustrates levels of knowledge, attitudes and behaviors toward sustainable development dimensions, namely economy, social and environment in the context of chemistry curriculum are dependent on education policies, curriculum orientation, pedagogical approaches, resources, stakeholders engagement and awareness.

a. Education policy

In general, educational policy pushes toward goals and procedures for achieving goals (Wright 2006). To fully integrate the concept of sustainable development into the curriculum, there is a need to integrate ESD principles in national education policy. In addition, shifting current educational goals by incorporating ESD principles or shifting national education policy aspects can accelerate the process of integrating sustainable development concepts (UNESCO 2015). In recent years, the existence of policies to support sustainability initiatives has been relatively rare; despite its policies, the enforcement of these policies has been found to be less or less effective in guiding day-to-day activities (Wright 2006).

Education policies, strategies and documentary guidelines can guide and define educational priorities and orientations. In order to integrate sustainable development concepts through curriculum, policies, strategies and specific policy guidance documents need to be reviewed. These include policies related to curriculum organization, teaching and learning strategies, assessment, classroom learning materials, school-community relationships and professional development among teachers. All these policies are designed to indirectly influence the learning system in terms of the knowledge, values, attitudes and skills that teachers convey to students (UNESCO 2015).

b. Curriculum orientation

The curriculum available does not include all relevant and essential elements of sustainability (UNESCO 2015). In addition, the complexity of the scientific concepts involved can also limit the understanding of the principles of sustainability among students. Therefore, the development of appropriate curriculum equipping students with knowledge of the concept of sustainable development can recognize that human behavior results in normative environmental complexity. In addition, there are studies show that students with the courage, the knowledge to explore and the desire to act are more likely to contribute toward a more sustainable future (Strauss 1996) where understanding the issue of sustainable development is essential to finding solutions (Hayles and Holdsworth 2005).

c. Pedagogical approach

Most literatures focus on pedagogical approaches to achieving ESD (Cotton et al. 2009). Traditional teaching methods have been identified as less suitable approaches for

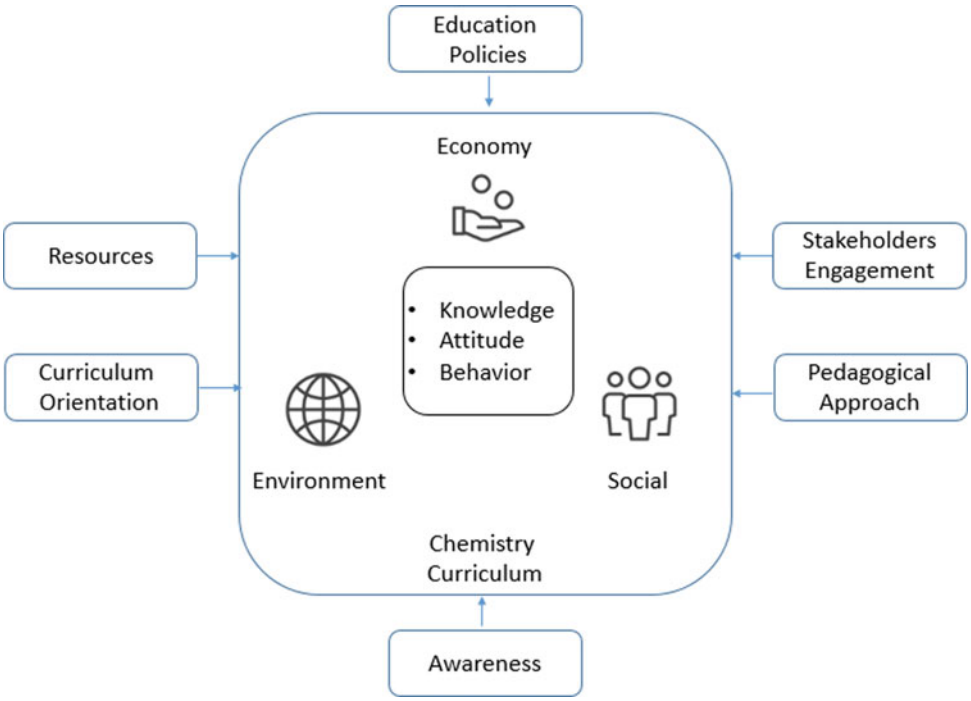

Fig. 3 Conceptual framework adapted from KAB model and Hines model (Ramsey and Rickson 1976; Hines et al. 1987)

teaching sustainable development concepts because traditional teaching is found to be less helpful to students in understanding the real issues of everyday life based on the knowledge gained (Papadimitriou 2004). ESD's focus is on the "what" and "how" of real-world problems where a more innovative approach to pedagogy is needed (Ryan and Cotton 2013). As such, there is a need to encourage teaching approaches that design, make decisions and focus on problem solving techniques and solution-seeking (Hayles and Holdsworth 2005).

The findings of previous studies have emphasized that the integration of sustainable development concepts requires a paradigm shift in the pedagogical approach which means the transition from transmissive learning to discovery learning; teacher-centered approach to student-centered approach; learning that focuses the theories on more practical learning which combines theories with practices (Sterling 2004). In addition, most researchers have also focused on transformative sustainable learning (Mintz et al. 2013; Sipos et al. 2008; Wals 2010). Transformative sustainability learning is a combination of transformative learning with ESD that focuses on cognitive, psychomotor and affective domains in which integration of these three domains can influence student behavior (Sipos et al. 2008).

In addition, by engaging students through pedagogical approaches based on student centralization, such as case study, learning by doing, service learning, problem-based learning, experiential learning, active learning and participation, self-directed inquiry, engagement with real-life problems and related issues, collaborative learning in the community, are suggested to enhance students' real-world learning opportunities (Figueiro and Raufflet 2015; Moore 2005a; Thomas 2004). However, among the proposed approaches, participatory, active and collaborative learning have been identified to provide the most meaningful learning experience for students. This is because the learning techniques encourage students to choose STEM fields by integrating socio-scientific issues in science education, students' motivation and interest in learning can be enhanced (Sadler and Dawson 2012; Tal et al. 2011; Tal and Kedmi 2006; Terenzini et al. 2001).

d. Resources

Some studies suggest that resources, such as time, finance, expertise and training are factors that hinder the implementation of sustainable development concepts (Chakraborty et al. 2016; Filho 2000; Jorge et al. 2015; Velazquez et al. 2005; Wilson 2012). In the eyes of teachers, time is a limited resource because any improvement or change in syllabus will affect a teacher's work attitude and orientation (Hargreaves 1994). Most teachers around the world want to develop interdisciplinary teaching and learning, but these teachers feel that the need to follow and complete the existing syllabus that causes time constraints (Borg et al. 2012). This opinion is in line with the findings of the study by Burmeister et al. (2012) that state a cohesive curriculum has a timely impact on innovation and discussions with colleagues. In addition, lack of time also influences formal planning, evaluation and reporting processes to enhance

sustainability issues in the curriculum that are typically found (Velazquez et al. 2005).

Financial resources are of the main concerns of teachers as they are not only increasing the risk of achieving all their goals, but achievements of future sustainability-related initiatives (Velazquez et al. 2005). In addition, at the university level, finance is distributed on the basis of priorities where integration of the sustainable development concepts through the subject is not viewed as an important priority causing the financial allocation of sustainability-based activities to be less focused (Filho 2000). Cebrian et al. (2015) suggest that the existence of specific financing schemes can encourage the integration of sustainable development concepts into the curriculum among teachers.

In addition, initiatives for the integration of sustainable development concepts are also limited by the lack of experts in the field of sustainability. This has caused the majority of academics to misunderstand the concept of sustainable development (Cebrian et al. 2015). In fact, only a few teachers are exposed and taught how to integrate the concept of sustainable development in order to gain knowledge of the field (Velazquez et al. 2005). Therefore, ESD professional development and training programs for academics are important to provide time and opportunity to gain insights and knowledge on sustainability, rethink the relevance of existing teaching practices and acquire the skills needed to teach on sustainability issues (Thomas 2004).

e. Stakeholders engagement

Steps toward integrating sustainable development concepts into the curriculum require cooperation from various stakeholders. Implementing ESD in the curriculum is a complex system that involves stakeholders from various levels, including management, academics, students and parents. Therefore, cooperation between all stakeholders needs to be strengthened in order to successfully implementing ESD (Blum et al. 2017).

Most studies related to the concept of sustainable development focus on students' awareness, knowledge, attitudes and behaviors (Emanuel and Adams 2011), senior management (Lozano 2006) and teachers (Cebrian et al. 2015). In addition, there are also several studies that look into the perspectives of parents and alumni students on the concept of sustainable development. Parents of students are suggested as one of the key external stakeholders that need to be involved in studies related to the integration of sustainable development concepts at school level (Disterheft et al. 2012).

To encourage the integration of sustainable development concepts, an integrative functioning organizational structure is proposed (Viebahn 2002). This is because any decision on policy, curriculum or resource-related changes can be made more quickly by management (Karabell 1998) where organizations play a role in explaining ESD's importance and ESD implementation requirements verbally and through action at all levels. In addition, appropriate strategies to engage academics in ESD are positively needed to prevent ESD being considered as mandatory agendas (Hegarty 2008).

Besides that, initiatives to engage students in achieving ESD goals have been focused either by integrating sustainable development concepts into public institution activities (Biedenweg et al. 2013) or through teaching and learning (Adomßent et al. 2014; Labodova et al. 2014). For example, sustainability education has taken steps to understand and achieve the concept of sustainable development by engaging students in activities, such as campus conservation initiatives, field trips, environmental courses and workshops (Matsuura 2004). However, in order to implement all these initiatives effectively, various challenges need to be met and require input from various stakeholders, including students, academics, management, non-governmental organizations and parents (Barth and Rieckmann 2012).

f. Awareness

The concept of sustainable development is a proactive and practical futuristic paradigm considering environmental, economic and social balance in development planning and improving quality of life as well as addressing sustainability issue (McKeown et al. 2002; Sterling 2004). In order to achieve sustainable development and to build a more sustainable community with the principles of sustainability, the balance between economic, social and environmental needs should be given attention (Zamhari and Perumal 2016). However, studies show that the understanding of the precise definition of sustainable development is still poorly understood and that awareness of the concept of sustainable development is still at an unsatisfactory level (Mahat et al. 2013a).

For example, in Manitoba, Canada, the government has taken initiatives to assist teachers in ESD or Educating for Sustainability (EfS) in the areas of knowledge, skills and values that contribute to sustainable development (McDonald 2006). In addition, a study conducted in Australian primary and secondary schools on teachers found that only three teachers are familiar with ESD. Although in general, teachers acknowledge the importance of education in achieving sustainable development, it is the lack of understanding that causes them to hesitate to do so (Taylor et al. 2003). Mahat et al. (2013b) argue that awareness can be enhanced if the knowledge and understanding of an individual can be applied in positive behaviors especially

through more sustainable practices in daily life. Therefore, in order to create sustainability for future generations, individuals need to be exposed to appropriate knowledge, skills and values and one of the agents that can successfully execute them is education (Burmeister and Eilks 2013).

The 2030 agenda is a holistic plan of action comprising social, environmental and economic dimensions. To understand the concept of sustainability, one must take into account these three main dimensions, which are the "Three Stages of Sustainability." These three dimensions are interrelated and, when combined and applied in real-world situations, can provide a solid foundation for a more sustainable world in which universal society can benefit (Vasiliki and Maria 2015). To achieve environmental sustainability, there is a need to maintain the functions and utilities of the natural environment for a long time. To support this, care in terms of natural environment and at the same time positive growth rates are encouraged. In addition, any actions that interfere with environmental balance should be avoided and in the event of any unforeseen occurrence should be promptly resolved taking into account the environmental impact. Environmental sustainability covers a wide range of issues ranging from pollution to natural resource management (Vasiliki and Maria 2015). Therefore, by protecting the planet from degradation, including through sustainable consumption and production, management of natural resources and taking immediate action against climate change, action plans for the planet can be achieved (United Nations 2015). Sustainability of the economy is the ability of the economy to sustain a fixed level of economic growth. Economic sustainability refers to any decision taken with the utmost caution after thoroughly reviewing other aspects related to sustainability. Economic sustainability also includes a wide range of things, ranging from "smart growth" to subsidies or tax exemptions for green development. In addition, economic sustainability also emphasizes lowering spending that is not important (Vasiliki and Maria 2015). Thus, the action plan for the economy is intended to ensure that the community can enjoy a prosperous and fulfilling life and to ensure that economic, social and technological progress is in keeping with the environment (United Nations 2015). Social sustainability depends on any decision or project that promotes social improvement. In general, the social aspect of sustainability supports the concept of intergenerational justice. This means that future generations have the right to enjoy the same quality of life or higher than the current generation. This concept also covers many other social-related issues. However, the social sustainability dimension shows a similar importance to the other two sustainability principles. If this dimension is not taken seriously, it can lead to the collapse of the entire sustainability process while also impacting the community itself (Vasiliki and Maria 2015).

As such, the relationship and nature of the integration of the 17 SDGs play an important role in ensuring awareness and achievement of the new 2030 Agenda (United Nations 2015). Students' understanding and awareness are essential to successful integration of sustainable development concepts into the chemistry curriculum. The three aspects identified to accelerate understanding of environmental, economic and social sustainability through the chemistry curriculum among students are

(i) Knowledge: Knowledge refers to the basic understanding and search for solutions in real life as well as developing social and environmental responsibilities and assessing values that are conducive to sustainable development.
(ii) Attitude: Attitude is defined as the permanent positive or negative feeling about a person, object or issue (Bell 1998). Attitude refers to self-reflection and appreciation of the importance of social, environmental and economic aspects.
(iii) Behavior: Behavior represents the intention to protect the environment and resources that consider the needs of future generations and at the same time meet current needs.

Various studies involving different fields have analyzed the importance of knowledge and the effects of lack of knowledge in decision-making. Bell (1998) states that the attitude and behavior of an individual are influenced by the level of knowledge. According to Laroche et al. (2001), changes in attitudes and behaviors among students are personal and are usually a slow process. In addition, students' daily lives are found to be closely related to their social environment, personal values, attitudes, interests and motivations. In general, the relationship between attitude and sustainable behavior is complex.

In addition, some studies also suggest that there is a correlation between attitude and behavior, but there are also studies that do not find any relationship between the two variables (Dwyer et al. 1993). Behavior is a case of situations in which it differs from the social environment (Yin et al. 2002). The attitude and behavior of an individual are a state of constant change caused by the process of learning, prioritization and perception. Therefore, it is important to introduce sustainability issues in long-term teaching in all school subjects (Juntunen and Aksela 2014).

More recently, various fields of academic interest have begun to focus on sustainability issues where emphasis is placed on teaching and learning approaches. Many experienced and new teachers are working hard to implement ideas of sustainable development through curriculum due to various challenges. To overcome these challenges, a general

framework as proposed is intended to be applied to all subjects related to science, technology, engineering and mathematics that integrate sustainable development concepts into the teaching and learning processes. However, associating the dimensions of sustainable development with the chemistry curriculum is an important issue whereby this shows that the three dimensions are of equal importance. Therefore, having a deep understanding of these three dimensions through chemistry education is expected to lead to significant changes in knowledge, attitudes and behaviors that will be useful in developing an individual's ethics and actions toward sustainable development. Although these three dimensions are important, the three dimensions of sustainable development concepts are not required to be integrated into each chemistry teaching and learning session but teachers are encouraged to have a deep understanding of the relationships between these three dimensions for each topic in the chemistry subject to facilitate the teaching and learning processes.

5 Case Study: Chemistry Curriculum in a Pre-university Program

The purpose of science in the context of sustainability is to understand and explain the dynamics necessary to prevent humans as individuals and collectively, physically, socially, economically, culturally and psychologically from destroying the environment (Anon 2018). Although there is a general desire to integrate ESD into science education, studies have shown that learning about sustainability issues is relatively low in secondary education, including chemistry education (Burmeister et al. 2012). Therefore, it is suggested that the national curriculum and publications in science education should strive to strengthen ESD in science education (Osborne and Dillon 2008; Rocard et al. 2007).

The subject of chemical sciences is defined as the foundation of modern life and society (Bradley 2005). Therefore, chemistry education has a special responsibility to contribute to ESD through formal and informal education (Burmeister et al. 2012). Existing chemistry teaching materials focus primarily on the technological or environmental aspects, without reflecting the full ecological, economic and social impact. Additionally, there are discussions on whether to add environmental issues or the basics of chemical technology related to sustainability in chemistry content or contexts. To address this issue, a chemistry curriculum that includes the practice of the Green Chemistry concept, socio-scientific chemistry education and the integration of sustainable development concepts into chemistry education strategies have been proposed (Burmeister et al. 2012).

According to Karpudewan et al. (2012), general knowledge and domain-specific knowledge and skills need to be developed to enable an individual to evaluate new chemical-based products and technologies in their own lives and in the society in which they live and work and respond accordingly. Students also need to develop the same skills regardless of whether they are going to start a career in science and technology. The current generation is the future leaders and needs the ability to move forward to engage in social discussions and make decisions on sustainable development issues. To achieve the ESD goals for all students in chemistry, a variety of different suggestions for integrating sustainability concepts in secondary chemistry teaching have been suggested. This proposal covers changes in content (Eissen 2012) to the overall curriculum change with emphasis on chemistry learning (Burmeister and Eilks 2012).

In addition, chemistry education can also help students to actively understand and participate in social discourse and to make decisions on socio-scientific issues related to chemistry and a variety of other applications (Hofstein et al. 2011). In addition, the preparation of a chemistry syllabus toward developing competencies for students' understanding and allowing them to engage in social discussions on chemistry applications and technologies can make chemistry education more relevant to ESD. To achieve this goal, students must have strong chemistry knowledge in the context of socio-scientific or sustainability issues. The mere attitude of students to acquire knowledge based on chemistry content alone is not sufficient to achieve ESD through the subject of chemistry (Sjostrom and Stenborg 2014).

In this case study, the pre-university chemistry curriculum at the PERMATApintar™ National Gifted Center, Malaysia, is selected because the students are given exposure to view the knowledge links obtained from various subjects with real-life situations (Yassin et al. 2012). In addition, the center emphasizes not only the academic excellence of the students, but also the holistic development of the students as outlined by the National Education Blueprint (Bakar 2017). In addition, Malaysia's recognition of sustainable development through the 11th Malaysia Plan reflects the importance given to the country on sustainable development. The concept of sustainable development highlighted in the context of chemistry above is a guide for chemistry educators who want to collaborate on embedding the concept of sustainable development as part of student life and this initiative is a proof that chemistry education has the potential to contribute to sustainable development.

The center emphasizes student holistic development which includes physical, emotional, spiritual, intellectual and social aspects. Students participating in the program are offered advanced courses in biology, chemistry, physics, mathematics and statistics, which resemble first-year courses at the university level. In addition, students can also conduct research in the field of interest. One of the main goals of the program is to produce the younger generation in line with Malaysia's need for an industrialized nation by 2020 (Pusat

PERMATApintar™ Negara 2018). Therefore, the findings from this case study are expected to yield results that will benefit other pre-university students.

6 Enculturing Sustainable Development Concept Through Chemistry Curriculum

The transition toward the integration of sustainable development concepts through chemistry subjects is an important and serious consideration for a pre-university program at the PERMATApintar™ National Gifted Center. However, the integration of sustainable development concepts with chemistry subject cannot be accomplished by simply incorporating them into the syllabus of chemistry subject. In light of this, a framework for integrating sustainable development concepts through the subject of chemistry (Fig. 4) is developed based on the concept as shown in Fig. 3, whereby this case study suggests that there are six aspects that are closely related to each other that need to be focused on to effectively integrate sustainable development concepts through the subject of chemistry, namely (1) education policy; (2) awareness; (3) resources; (4) curriculum orientation; (5) pedagogical approaches; and (6) stakeholder engagement. This framework clearly describes the things that need to be considered at every level before beginning to integrate the concept of sustainable development through the subject of chemistry.

Generally, the integration of sustainable development concepts through chemistry subject depends on education policy at the government and institutional levels whereby the policy is to pave the way toward in achieving the goal of integrating sustainable development concepts through chemistry subject. Without a policy that emphasizes on the concept of sustainable development, any plan to integrate the concept of sustainable development through the subject of chemistry cannot be effectively implemented.

The integration of the concept of sustainable development through the subject of chemistry begins with the awareness of stakeholders, whether external or internal stakeholders within an institution. With awareness, a basic understanding of the concept of sustainable development and an appreciation of the benefits of integrating sustainable development concepts through the subject of chemistry can be enhanced among teachers. However, this can only be done with the help of training resources. In addition, in order to gain an appreciation of the benefits of integrating sustainable development concepts through chemistry subject, pedagogical approach and curriculum orientation need to be emphasized. Throughout this process, aspects of pedagogy and curriculum also need to be focused on deepening the knowledge of how and where to integrate sustainable development concepts through the subject of chemistry. In the meantime, in order to create an ongoing appreciation for the integration of sustainable development concepts in the teaching of chemistry subject and their involvement in teaching the concept of sustainable development in the classroom, teachers need to be provided with resources and time. The six aspects outlined in this framework are important to consider when integrating sustainable development concepts through chemistry subject at school or institution level across the country. This indirectly encourages and engages teachers in integrating sustainable development concepts through the subject of chemistry.

Overall, the implementation of this framework involves the involvement of internal and external stakeholders within an institution. The external stakeholders identified in this framework are the government, the Ministry of Education and non-governmental organizations. For the integration of sustainable development concepts through chemistry subject, the government is directly involved in the formulation of ESD-related policies, while non-governmental organizations are directly involved in assisting the government in implementing ESD-related programs at the institution level. At the institutional level, the involvement of key stakeholders, including administrators, teachers, parents and students, should be emphasized in order to successfully integrate sustainable development concepts through the subject of chemistry. With the help of this framework, specific aspects that need attention can be researched and used as a guide to the process of integrating sustainable development concepts through chemistry subject at schools or institutions nationwide and this indirectly encourages and engages teachers in conducting sustainable chemistry education.

7 Conclusions

ESD is a learning process that aims to equip students, teachers and the school system with the new knowledge and thinking needed to achieve economic well-being and act as responsible citizens and restore the environment in which living organisms depend on The Cloud Institute for Sustainability Education (2019). However, the diversity of issues within the ESD invites the involvement of various stakeholders in the implementation of ESD, namely the government, non-governmental organizations and the media. The roles and responsibilities of the various parties vary according to needs; however, the cooperation of all these parties is necessary to leverage the synergy.

Recent developments in Malaysia show a deep interest by the Malaysian government in STEM education. In Malaysian Education Blueprint 2013–2025, Ministry of Education

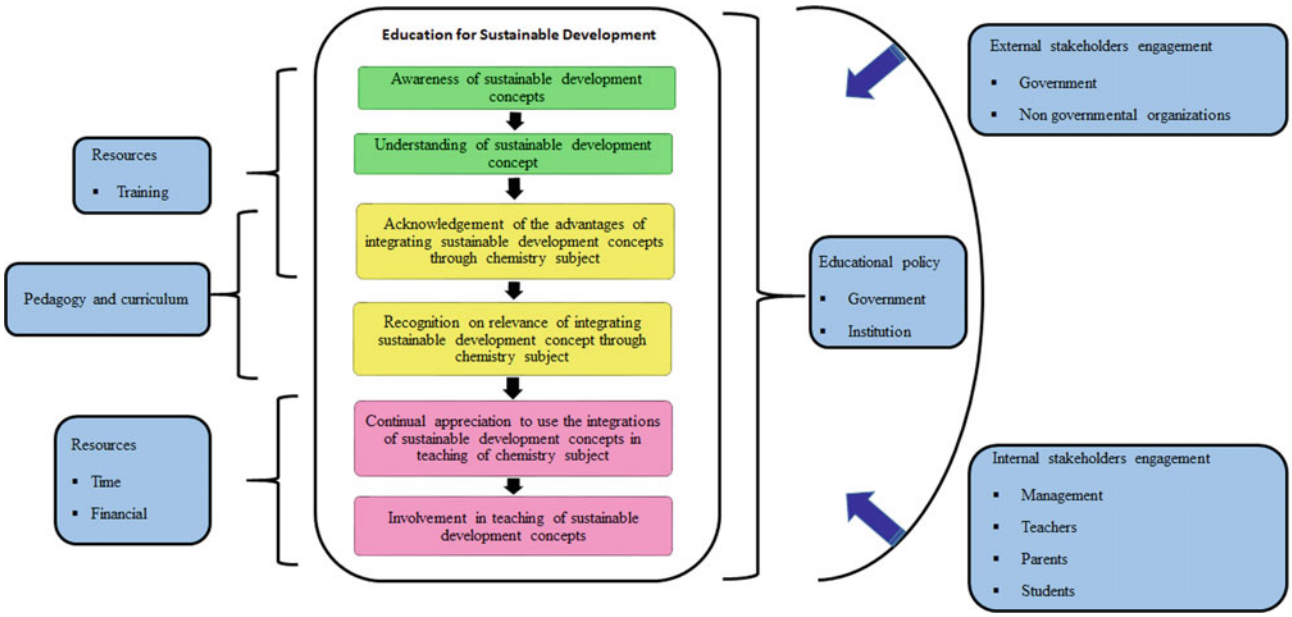

Fig. 4 Framework for integration of sustainable development concepts through chemistry subject

Malaysia (2013) stated that the government intends to ensure that students are equipped with the skills needed to meet the changing world with the application of Science, Technology, Engineering and Mathematics (STEM). In addition, ESD was introduced to recognize the need to promote sustainable development through integration in the curriculum for the benefit of future generations. However, in Malaysia, the emphasis on integrating sustainable development concepts in STEM education, especially focusing on chemistry, is lacking.

This issue has raised several questions that need to be addressed in relation to the integration of the concept of sustainable development through the subject of chemistry. This case study addresses the integration of sustainable development concepts in the Malaysian education system, particularly in the field of STEM as well as the chemistry subject of pre-university program at the PERMATApintar^{TM} National Gifted Center. Furthermore, these issues also raise questions about the levels of knowledge, attitudes and behaviors of sustainable development concepts in chemistry subject, factors that influence the integration of sustainable development concepts in chemistry subject as well as the planning needed to integrate sustainable development concepts into the subject matter of the pre-university curriculum at the PERMATApintar^{TM} National Gifted Center.

A framework for integrating sustainable development concepts through the subject matter of the pre-university program at the PERMATApintar^{TM} National Gifted Center is developed. The framework suggests that to effectively integrate the concept of sustainable development through the subject of chemistry, there are six main areas that need attention, namely education policy, awareness, resources, curriculum orientation, pedagogical approach and stakeholder's engagement. Two aspects of policy need to be considered are government and institutional policies. Meanwhile, the aspect of awareness is concerned with understanding the concept and relevance of the concept of sustainable development through the subject of chemistry. In addition, the types of training, finance and time have been identified as aspects of resources that need to be considered in integrating sustainable development concepts through chemistry subject. The integration of sustainable development concepts in syllabus and the contextualization of chemistry content as aspects that should be considered in the curriculum. In the curriculum, learning outcomes need to be revised to facilitate the process of integrating sustainable development concepts through chemistry subjects. Pedagogical approach needs to be considered and this includes pedagogical types, learning approaches and pedagogical techniques. Subsequently, stakeholders include government,

experts in the field of ESD, administrators and chemistry teachers are identified to be directly involved in promoting the integration of sustainable development concepts through chemistry subject. Meanwhile, parents and students are found to be indirectly involved in the practice of sustainable development in daily life.

In the past, most of the proposed frameworks or models of ESD in Malaysia do not focus on the process of integrating sustainable development concepts. As such, the framework developed in this case study is intended to serve as a guide for the government and institutions to enculture sustainable development concepts through STEM education. In addition, the framework is developed based on the inputs by various stakeholders. Therefore, the framework will be instrumental for administrators and teachers to develop a sustainable chemistry teaching toward achieving ESD.

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