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An analysis of Hong Kong high school curriculum with implications for United Nations sustainable development goals

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Abstract

The United Nations Sustainable Development Goals (SDGs) Target 4.7 stated that by 2030, all learners should acquire the knowledge and skills needed to promote sustainable development. However, only scattered studies outline how SDG knowledge has been taught in public K12 curricula. This study aims to identify SDG topics in 13 subjects in the Hong Kong Diploma of Secondary Education curriculum and the perceptions of teachers in relation to SDG education. Data were collected through a machine learning approach and semi-structured interviews. Analysis of the module, subject, and curriculum level was conducted. By examining how teachers perceive in relation to the results of SDG classification and implementation of SDG education, the findings showed that teachers and administrators have adopted positive attitudes towards SDG classification, and supportive government can positively influence teachers and administrators in implementing SDG education. Such findings can be useful for policymakers to develop strategies to facilitate SDG education.

Keywords: Sustainable Development Goals, Curriculum analysis, K12, Machine learning

Introduction

In 2015, the United Nations established 17 sustainable development goals (SDGs) on sustainable economic growth and social development (United Nations General Assembly, 2015). Target 4.7 stated that by 2030, all learners should acquire the knowledge and skills needed to promote sustainable development. SDGs play an essential role in human development, which can contribute to the improvement of education for sustainable development (ESD) and enable students to make good judgements, take responsibility and come up with effective solutions to maintain environmental integrity, economic growth and social fairness, whereby students can acquire skills including self-regulated learning, critical thinking, problem-solving and future-related skills (Kwee, 2021).

Strategies are needed for the advancement of SDG education. Martin and Ho (2009) explored how schools in Singapore developed outdoor education to seek sustainability. Eames et al. (2010) evaluated three Education for Sustainability (EfS) professional development programmes from New Zealand at the school level and demonstrated their

impacts on school education. Walshe (2017) explored how an interdisciplinary approach to SDG education in England developed one class of 16- and 17-year-old geography students' understandings of sustainability. Kwee (2021) made an attempt to incorporate SDGs in English teaching. Hurd and Ormsby (2020) studied how teachers in four US K12 schools taught SDGs at the lesson level. Meanwhile, Zguir et al. (2021) illustrated how governments in countries designed K12 sustainability education at the policy level. However, only scattered studies outline how SDGs have been taught and assessed in the regional or national public K12 curricula. In other words, no mechanisms or protocols have been proposed to analyze how much SDG knowledge K12 students have learned in the curriculum.

Measuring the proportion of students who have studied SDGs or sustainability topics during their K12 learning is not easy. For example, Gallwey (2016) discussed challenges in holistically measuring how SDGs have been taught. Furthermore, the curriculum analysis could be challenging to match SDGs with public curricula in practice. Subject teachers also may have difficulties holistically understanding all 17 SDGs. Karaarslan and Teksöz (2016) revealed that science teachers' competencies do not cover systems thinking skills together with affective aspects in terms of Integrating Sustainable Development Concepts into science education programs. Kwee (2021) also summarized the challenges of implementing SDGs in K12 education from school teachers' perspectives.

In our preliminary study, a machine learning approach has been used to identify SDG topics in five technology-related subjects in the 2023 Hong Kong Diploma of Secondary Education (HKDSE, equivalent to K10–K12) curriculum (Lei, 2022). The conducted module-/subject-/curriculum-level analysis indicates the strengths and weaknesses of these subjects in covering SDGs in their curriculum. For example, we identified that the high school curriculum focuses more on the foundations of subjects, and universities concentrate more on teaching cutting-edge and frontier topics.

In this manuscript, the study aimed to expand the pilot study on a wider spectrum of 2023 HKDSE curriculum, covering the analysis of 13 foundational "science" subjects and "personal, social, humanities education" subjects. The 13 subjects were selected based on the Curriculum and Assessment Guide, including core subjects and elective subjects from the Education Bureau. The details can be seen on the bureau's website. This manuscript also includes new examples and a detailed analysis. Furthermore, school teachers and administrators were interviewed to understand how they think about the outcome of the SDG classification and how the SDG can be taught in the high school curriculum. The research questions are:

(1) How can topics in high school subjects be classified through machine learning according to SDGs?
(2) How do school teachers and administrators perceive the outcome of the machine learning-based SDG classification and the development of SDG education in the high school curriculum?

Section "Literature review" illustrates how SDG has been currently taught in K12, secondary school or high school curriculum. Section "SDG classifications of subjects based on machine learning" explains how machine learning classification has been used to

analyze 13 courses in the HKDSE curriculum. Section "Research results" investigates the perception of school teachers and administrators in relation to the results of SDG classification and implementation of SDG education.

Literature review

Most of the current studies focused on the implementation of SDGs at the higher education level by the analysis of relating the course content to SDGs (Fındık et al., 2021). There is little research on implementing SDGs in K12 education (Bezeljak et al., 2020; Eli et al., 2020; Hoang et al., 2020). Among the current studies related to K12 education, some focused on curriculum and teaching practices (Hoang, 2020) and an interdisciplinary approach to ESD (Eli et al., 2020), while some focused on sciences or social science subjects (Nguyen, 2018). There is limited research on the implementation of SDGs in different subjects as a whole or the reorientation of a curriculum in ESD.

The active engagement of teachers in SDG education provides practical solutions to such problems (Summers et al., 2005; Winter, 2007). Teachers play a key role in SDG education, as it is necessary for them to change the traditional segmented approaches to holistic and interdisciplinary approaches (Kwee, 2021). However, transcendence can be challenging. For example, English teachers lacked previous experience and much knowledge of sustainable development and experienced difficulties in gaining a complete understanding of sustainable development, thereby excluding the possibility of the incorporation of sustainable development into their language instruction (Fındık et al., 2021; Kwee, 2021). In terms of implementing SDG education, teachers suggested that the meaning of the interdisciplinary approach was not very specific, so they did not have a clear understanding of the strong relationships between these approaches to sustainability (Eli et al., 2020; Kwee, 2021). During implementation, teachers also found that the interdisciplinary activities were insufficient, as there was no clear boundary between these subjects, making cooperation and the synthesis of the related instructional materials and activities difficult (Kwee, 2021).

School support is also a key to successful SDG education (Kalsoom & Khanam, 2017). However, very few schools incorporated all SDGS in their curricula, while some of the schools focused on some SDGs related to the environment or education (Eli et al., 2020). According to the above research, this article aims to break the boundary between different subjects and help teachers and schools have a holistic understanding of how K12 students in Hong Kong have learned SDGs through the public curriculum. Furthermore, in order to investigate how the curriculum can be effectively aligned with SDGs, feedback from the principal and subject teachers has been collected.

SDG classifications of subjects based on machine learning

Research design

This study analyzes the contents of SDGs in 13 subjects provided by high schools (K10–K12) in Hong Kong. These scopes of these subjects are defined in the curriculum of the 2023 Hong Kong Diploma of Secondary Education (HKDSE) by the Hong Kong Examinations and Assessment Authority (HKEAA). DSE subjects analyzed in this manuscript are shown in Table 1.

Table 1 Subjects analyzed in this study

Technology subjects	Foundational science subjects	Personal, social, humanities education and other subjects
Design and applied technology (DAT)	Biology (BIO)	Economics (ECO)
Health management and social care (HMSC)	Chemistry (CHE)	Geography (GEO)
Information and communication technology (ICT)	Physics (PHY)	Liberal studies (LS)
Business, accounting and financial studies (BAFS)	Integrated science (IS)	Physical education (PE)
Technology and living (TL)		

Every subject has several major modules, and the estimated lesson time for each subject is around 250 h. These subjects have their own instructional strategies. Thus, they do not share an aligned structure of the syllabus. In general, the module introduction, "topics to be learned", and "descriptions of the module" are used as the test set in the classification process. The subject syllabus can be found on the HKEAA website.

We hardly find a complete set of curriculum syllabi that have been manually classified based on SDGs. Therefore, we adopted the OSDG Community dataset (OSDG, 2021) as the training dataset. The dataset is mainly based on reports and documents from the United Nations. These documents are publicly available and often already have SDG labels associated with them. The OSDG community decomposed these documents into records. In 2021, there were around 32,000 records of short text comprised of 3–6 sentences. More than 1000 community volunteers then validated the records on the relevance to originally tagged SDGs. To be specific, each volunteer is presented with a single simple question that asks if the suggested label is relevant to the given short text. Texts are labelled by multiple volunteers to ensure a high degree of quality. The dataset only includes SDG 1 to SDG 15 because SDGs 16 and 17 are overarching goals that might pop up in almost all kinds of texts.

The classification procedure that has been used to analyze a university's general education curriculum (Lei et al., 2022) and the DSE curriculum in the pilot study (Lei, 2022). In the machine learning process, the first step was preprocessing the text data, which involved tokenization, stemming/lemmatization, as well as retaining only nouns, verbs, and adjectives. Then, the term frequency-inverse document frequency (TF-IDF) was used in the feature weighting to convert the text into numerical vectors, which emphasize the importance of specific terms in the dataset. A multinomial logistic regression algorithm from the Python scikit-learn library was used for the classification, with L2 regularization and balanced class weights. The model was trained using the OSDG Community dataset. The model has been cross-validated to the OSDG dataset. The accuracy and (weighted) F1 score both stand at 0.86, and the top 2 and 3 k accuracy is 0.94 and 0.97, accordingly (OSDG, 2021). This indicates the good performance of the mechanism for classifying policy documents. Once the model was trained, it was applied to the university's curriculum data to obtain relative SDG relevance scores across SDGs 1–15 for every module of subjects. The relative

SDG relevance score of an SDG indicates how much content according to that SDG has been taught and does not indicate how that SDG has been advocated.

To calculate the SDG relevance scores for each module, we first obtained the predicted probabilities from the logistic regression model for each SDG category. These probabilities represent the likelihood that a module is relevant to a particular SDG. The relative relevance scores for each module sum to 1. The threshold of 0.09 was chosen based on experimentation, allowing for a balanced representation of SDGs across the modules. In other words, if the relative relevance score of an SDG is larger than 0.09, that SDG will be claimed to be taught in that module. Therefore, multiple SDGs can be classified in some subject modules, and sometimes no SDGs can be classified in any modules.

Classification results

Module level analysis

Generally, in most modules, only one major SDG can be classified. In other words, by studying these modules, students can have a better understanding of topics of the classified SDGs. Figure 1 shows the classified SDGs of two modules in two subjects. Based on Fig. 1 (Top), the module "Industrial Chemistry" in the CHEM focuses on production-related SDGs, including SDGs 7, 9 and 12. This module discusses

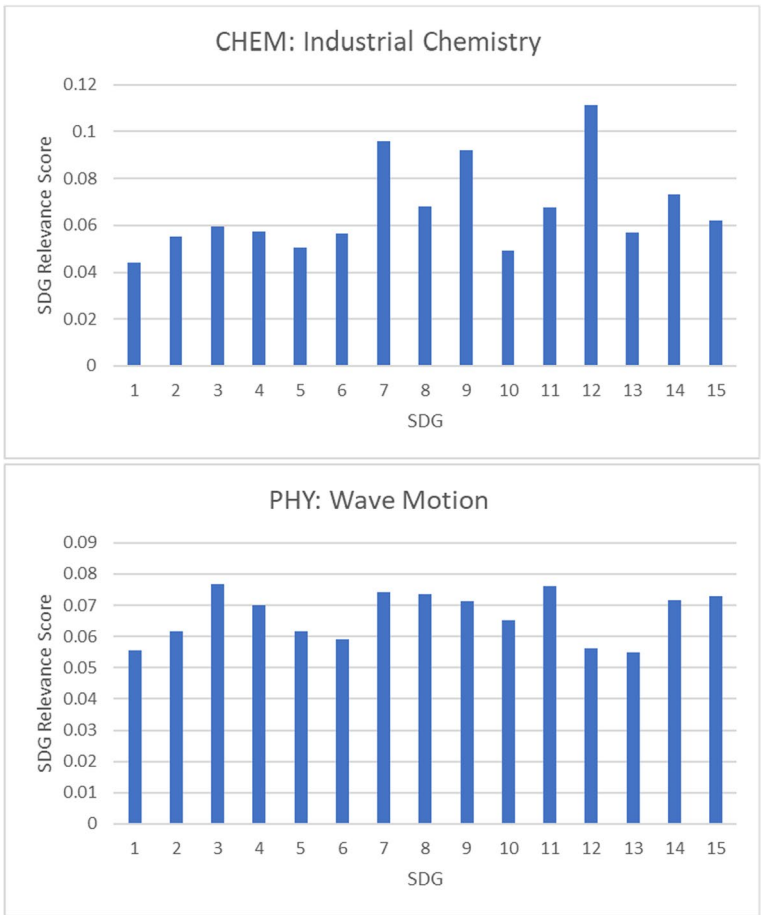

Fig. 1 Relative SDG relevance scores in two modules in CHEM (Top) and PHY (Bottom)

industrial processes such as the Haber process, the chloroalkali process and the methanol manufacturing process. Furthermore, in the module, students learn how to optimize chemical processes and understand the impact of petrochemistry and industrial processes on our environment. Discussions of the module can help students have a better understanding of SDG Targets 7.3, 9.4, 12.2, 12.4 and 12.a. On the other hand, as shown in Fig. 1 (Bottom), the module "Wave Motion" in PHY does not have a particular focus on any SDGs, indicating the course may not cover topics related to SDGs. Through reading the syllabus, the module is about the properties of waves, sound waves and electromagnetic waves, including propagation, reflection and refraction, diffraction and interference of waves. The module also talks about audible frequency range and noise pollution. The discussion is less focused on topics in SDGs.

The mapping of curriculum description and SDGs can be further explained by providing the example of the Geography (GEO) curriculum. In the curriculum content of the compulsory modules, there is one module called “Managing River and Coastal Environments: A Continuing Challenge”. The module covers the hydrological cycle, drainage basins, and fluvial processes, which are essential aspects of understanding and managing water resources (SDG 6). The module also covers coastal landforms as well as human activities in river and coastal environments, which are directly related to the sustainability of marine ecosystems (SDG 14). Fluvial and coastal environments are also crucial for terrestrial ecosystems and biodiversity (SDG 15). Therefore, the module examines the impact of human activities on these environments (SDG 6), including erosion, mass wasting, and damage to ecosystems. Based on this description, the machine learning methods have identified SDGs 6,14 and 15 on the curriculum.

Subject level analysis

As mentioned in the DSE document, GEO can help students examine the inter-relationships among people, places and the environment: “It offers a systematic framework for enquiry into questions about the world that surrounds us.” GEO covers eight SDGs. Discussion of food and water (SDGs 2 and 6) is the core of GEO. Being a highly urbanized region, the subject has a focus on the development of sustainable cities and communities (SDG 11), including transport, and industries (SDG 9). The course also covers SDGs related to the planet (SDGs 13, 14, 15), including climate change. There is also a module on "Rational" that explains why this subject is needed, making the module related to SDG 4. More details of classifications can be found in Table 2.

BIO, CHE and PHY are subjects designed to provide a concrete foundation for each corresponding discipline. Meanwhile, IS is for students who want to equip core scientific literacy of three science subjects and widen their horizons by taking other subjects. The analysis revealed that knowledge taught in IS, in terms of SDGs, is partially proportional to the combined BIO, CHI and PHY. For example, a similar proportion of topics has covered SDGs 2, 3, 6, 9, and 12. SDGs 4, 11, 13 and 14 have not been covered in IS, but have been covered in three other science subjects. Meanwhile, SDG 7 has been relatively more well discussed, compared to the other three subjects.

Table 2 Number of SDGs classified in modules in GEO

Module	Related SDGs
Rational—Course background	SDG4, SDG11
Opportunities and Risks—Is it rational to live in hazard-prone areas?	SDG11, SDG13, SDG15
Managing River and Coastal Environments: A continuing challenge	SDG06, SDG14
Changing Industrial Location—How and why does it change over space and time?	SDG09
Building a Sustainable City—Are environmental conservation and urban development mutually exclusive?	SDG11
Combating Famine—Is technology a panacea for food shortage?	SDG2
Disappearing Green Canopy—Who should pay for the massive deforestation in rainforest regions?	SDG15
Climate Change—Long-term fluctuation or irreversible trend?	SDG13
Dynamic Earth: The building of Hong Kong	SDG11, SDG15
Weather and Climate	SDG13
Transport Development, Planning and Management	SDG11
Regional Study of Zhujiang (Pearl River) Delta	SDG11

Table 3 Number of SDGs classified in subject modules (#: Number of modules in the subject; ^: Number of topics in the subject): Total number of SDGs classified

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	#	^
DAT		2		4			1	1	19		2	8		3	1	27	90
HMSC	1	1	22	1	4	1		1	1						1	22	25
ICT			3						7							7	24
TL		7	4		2		1	1	2			4			1	14	28
BAFS				1	1		2	5	3		1	3		2		11	49
BIO		2	2			2			1					1	1	6	8
CHEM			1	1		1	2		1			6		1		15	16
PHY			1	1			5						1			8	10
IS		1	2			1	5		1		1	2			1	10	11
ECO	1	6		1			4	7	3	5		2				11	15
GEO		1		1		2			1		5		2	2	3	12	12
LS			4		4		1	1	1		2	1			1	6	12
PE			4	4			1	1							1	10	10

Curriculum level analysis

Table 3 shows how SDGs have been taught in the DSE curriculum. In general, most technology and science courses often have a major focus on an SDG, indicating that these courses aim to resolve one particular issue in society. Other subjects have a wider spectrum of SDGs covered. For example, 70% of modules in ICT are related to SDG 9. Similar patterns can be found in HMSC (SDG 3; 67%) and PHY (SDG 7; 63%). In particular, every module in HMSC is related to SDG 3. On the other hand, BIO, GEO, ECO and BAFS cover a wide spectrum of SDGs in their subject modules. For example, BIO talks about nutrition (SDG 2), health (SDG 3), water (SDG 7), animals (SDGs 14 and 15) and plants (SDGs 15). However, no SDGs can be classified in three out of eight (37.5%) modules in BIO. In TL, seven modules strongly focus on SDG 2 since these modules mainly focus on nutrition and cooking. Meanwhile, discussions of another seven modules in TL are on textiles and clothing.

Compared to curricula in universities (Lei et al., 2022), the K12 DSE curriculum is found to be less focused on SDG 9 (Except ICT). This may be because the high school curriculum focuses more on the foundations of subjects, while universities concentrate more on teaching cutting-edge and frontier topics. Topics in SDGs 1, 10 and 13 are not well discussed in the DSE curriculum since only a few courses slightly discussed these issues.

Teacher's perceptions on the SDG classification and the SDG education

Research design

This section is guided by the research question: How do school teachers and administrators perceive the outcome of the machine learning-based SDG classification and the development of SDG education in the high school curriculum? To answer the research question, a qualitative case study design was selected in order to examine school teachers' and principals' perceptions of SDGs classification and SDGs implementation.

Data collection

The primary data source was in-depth semi-structured interviews with one geography teacher, one school assistant principal (who is an English teacher) and one school vice-principal (who is a geography teacher) from two public secondary schools in Hong Kong. The interview questions focused on (1) the school Principal's and subject teachers' perception of the machine learning classification; (2) the impacts of the SDGs classification on subject teachers' instruction. (3) students' way of SDGs learning and support for SDG education in high school. All the interviews have obtained participants' consent. Each interview lasted for around 30 min. They were recorded and later transcribed. In order to protect the participants' identities, the researchers used T1, T2 and T3 to represent the English teacher (school assistant principal), geography teacher and school vice-principal, respectively. A general inductive approach was used to narrow down and reduce the large chunk of data into meaningful themes and subthemes.

Findings and discussion

To answer the research question, the researchers categorized the findings into three themes and six subthemes. Table 4 summarized the themes and subthemes of the study.

Table 4 Themes and subthemes of the interview

	Themes and subthemes
4.3.1	Personal perception of machine learning classification
4.3.1.1	Strengths of SDGs classification
4.3.1.2	Limitations of SDGs classification
4.3.2	Impact of SDGs classification on instruction
4.3.2.1	Creating a holistic view of education
4.3.2.2	Challenges affecting SDGs implementation
4.3.3	Students' way of SDGs learning and support
4.3.3.1	School activities
4.3.3.2	Government support

Personal perceptions of machine learning classification

This study showed that all participants had a positive attitude towards machine learning SDG classification. T1 said, *"I think it basically matches my expectations for certain areas in SDGs"*. This was supported by other participants. They said,

> *"We think the results are similar and what we focus about SDGs is aligned with what you have found in the curriculum."*

Strengths of SDGs classification

The study indicated that machine learning classification has distinct advantages in terms of SDG classification. For example, T1 said,

> *"I totally agree with the classification result in terms of the course related to technology and living. When trying to expand to the other subjects, for instance, for geography, I think the focus will be similar. And then obviously they include climate, landscape, and weather. And I think it is aligned with the course outline for the subject". I think for biology, chemistry, physics they are all expected, because it's all about theories and scientific findings."*

T2 added,

> *"For geography we mostly focus on all the SDGs inside the planet. That means SDG 6, SDG13, SDG14, and SDG15 will be included. This is aligned with what you have found out in the curriculum. We also agree that the good health is not really covered in our subject as well as gender inequality, because it is not the main focus on the curriculum."*

Limitations of SDGs classification

In this study, machine learning classification also showed its limitations with respect to SDGs classification. T1 said,

> *"I am surprised that economics only cover a few sections because the curriculum is so wide and I expect more than just these areas, And I think for economics, maybe they could have been more topics that can be covered. Basically, they talk a lot about supply and demand. In my school, the economic teachers will also promote fair trade. This content may not be in the formal curriculum, but basically it is one of the areas that teachers do cover."*

Another teacher also said,

> *"In terms of geography, we actually think that there are still some minor topics that can be related to poverty. for example, in terms of famine combatting, there are some details on the curriculum talking about how to tackle poverty." For SDG7 and SDG8, we think that there are still some topics that can relate to affordable and clean energy. For example, when you talk about climate change, we also have a chapter mentioning about clean energy and their functions."*

Impact of SDGs classification on instruction

The findings of this study showed different impacts on teachers' SDG education. This section has two parts which are about the positive impact on teaching and factors affecting the SDGs implementation.

Creating a holistic view of education

Previous studies showed that curriculum analysis provided teachers and schools with some guidance on education for sustainable development and helped them move towards a more holistic and cross-curricular perspective of education for sustainable development where economic, environmental and social factors are not considered separate entities (Jóhannesson et al., 2011). This study also showed the same results. T2 and T3 said,

> *"It provides us with clear directions to have students understanding more about the sustainability environment because in the past we always mentioned one point. we need to combine economic, environmental, and social factors together".*

As the results indicated, teachers and administrators did not develop a holistic conception of sustainable development, which was consistent with the study (Kwee, 2021). The curriculum analysis helped them create a holistic view of education. In terms of reasons for teachers' lack of a holistic conception of sustainable development, the school assistant principal (who is an English teacher) and the school vice-principal (who is a geography teacher) revealed that they followed the formal curriculum in their teaching practice, but the formal curriculum did not intentionally cover the SDG topics.

Challenges affecting SDGs implementation

Previous studies suggested the lack of school management support hampered teachers from implementing sustainable development in their teaching (Eli et al., 2020). This study showed a positive relationship between teachers' personal commitment towards SDGs and school management support, which is aligned with the previous studies. T1 said,

> *"It would be difficult to expand these topics within the curriculum because of the teaching hours and we need more teaching hours for all electives. Considering the nature of examination-oriented education, I think it is not conducive to the whole development of the subject because of the lesson times."*

As the results indicated, the limited teaching time can be a barrier to SDGs implementation, which aligned with the study indicating that the crowded curriculum did not enable teachers to implement new approaches in the classroom (Tibbitts et al., 2023). The findings also suggested that school support is also a key to successful SDG education (Kalsoom & Khanam, 2017).

Students' way of SDGs learning and school support for SDGs implementation.

Previous studies have suggested different ways for students to learn SDGs (Martin & Ho, 2009; Walshe, 2016; Hurd & Ormsby, 2020). In this study, the findings provide other different ways of SDG learning in the lesson level.

School activities

Subject teachers have suggested different ways of SDG learning. For example, T2 said,

> *"There are many SDGs ideas already incorporated inside our original curriculum. Other than the lesson time for the curriculum. We also designed some of the geography activities for the students and would take the students out of the classroom for a few trips such as local field trips."*

The vice-principal also added,

> *"We also have geography channel, which is school-based channel for students to make videos to talk about some recent issues, and their impacts on the daily life of the students and people around them. By understanding all these topics, students may have a better idea of all these sustainable goals."*

In terms of SDG implementation, the school vice-principal (who is a geography teacher) and another geography teacher indicated that while the school curriculum did not include SDG topics, the course contents did cover SDG topics such as SDG 7. During the lecture time, teachers paid more attention to the effect of SDGs topics, such as climate change impacts and provided solutions to tackle climate change. Other than lesson time, the teachers also adopted a case-based learning approach and designed some activities, such as fieldwork, to help students gain a better understanding of global issues.

Previous studies have indicated the lack of implementation of SDGs in languages (Kwee, 2021). Due to this fact, T1 said,

> *"I think the better way we can learn SDGs from the extracurricular activities due to limited teaching hours. In addition, basically right now, from secondary school's perspective, a lot of focus is now put on STEM, students can learn from STEM education."*

The school assistant principal (who is an English teacher) also confirmed that while the formal curriculum did not provide SDG topics, the course materials of some subjects did include SDG topics. In terms of English class, the school assistant principal revealed that due to limited teaching hours, it was better to learn SDGs from extracurricular activities. The English teacher provided students with learning opportunities for SDGs by encouraging students to write essays on SDGs topics, such as the topic related to how to tackle poverty and hunger around the world. In addition, the school assistant principal added that the school developed theme-based activities called "Global Week" and made use of different courses, including history lessons and liberal study lessons, to introduce different SDG topics.

Government support

Government Support plays an essential role in promoting SDGs education in Hong Kong. T1 said,

"The implementation of SDG education is closely related to the education system. SDGs is already embedded in the most updated curriculum guideline. However, it depends on what the government wants to promote. If there's a clear guideline provided by the government, which includes SDGs in the overall objectives. Then I think a lot of schools will follow the guideline."

T2 also said,

"There has been collaboration between universities and schools in the implementation of SDG education. We actually know some of the sustainable development. If the government can encourage more collaboration between the University and the secondary school and provide support, maybe some of the new academic ideas can also promote low-level education."

According to the results, their teaching practice is based on the formal curriculum. However, the school curriculum does not cover SDG topics. Promoting curriculum on ESD topics is considered to be a key pillar of ESD integration (UNESCO, 2017). However, the main challenge is that it might take decades to complete national-level curriculum revisions, and the revised curriculum often needs a long time to reach the classrooms. Instead of relying on national-level curriculum overhaul, policymakers can work closely with OECD and build on existing curriculum to scale up ESD efforts, which can increase the speed of integration and help ground ESD interventions in local contexts, thereby potentially maximizing their relevance and suitability for local actors (Tibbitts et al., 2023). In addition, considering teachers' lack of holistic view of sustainable development, the training programs, including the encouragement of the collaboration between the university and secondary school on campus, can be provided to help teachers and students to develop a better understanding of SDGs topics.

Conclusion

This study is unique in adopting a machine learning approach to identify SDG topics in 13 subjects and probing into teachers' and administrators' perceptions of incorporating SDGs in their teaching. It provides a holistic view of how 13 courses in the 2023 HKDSE curriculum are related to SDGS and how teachers and administrators perceive SDG classification and implementation of SDG education. The findings can provide insights for institutes providing professional development courses, school management and educators to implement SDG education effectively at K12 schools to promote sustainable development in different subjects. This study also aimed to identify and possibly establish connections (Cohen et al., 2010; Jóhannesson et al., 2011) between subject areas for education for sustainable development. Making the connection also means that although the difference between these subjects can hamper schools from developing education for sustainability, it offers a possibility of reorienting education based on what we found in curriculum analysis (Jóhannesson et al., 2011).

Although this study identified SDG topics in 13 subjects and perceptions of teachers and administrators in relation to SDG education, it shows some limitations. There is a lack of a dataset of curriculum syllabi that have been manually classified based on SDGs, thereby, the results of SDGs classification may not be complete. This study also shows a limitation in its few participants, which has reduced the generalizability (Queirós et al., 2017). In addition,

the study was conducted in Hong Kong educational contexts and these findings can be generalized to other curricula in similar educational contexts. However, compared with the previous study, which used different methods, including text analysis to conduct curriculum mapping and policy review and develop a new curriculum (Tibbitts et al., 2023), our study provided another method (machine learning) to conduct curriculum analysis, which can be applied to different educational environments such as MOOCs (Wang et al., 2022) and university curricula (Lei et al., 2022). This manuscript also captured detailed information, such as the attitudes and motivations of teachers and administrators in implementing SDG education in depth. It offers an opportunity to reflect on current SDG education in Hong Kong high schools and provide insights on how the curriculum can be effectively aligned with SDGs. To improve the accuracy of the study, future study aims to conduct a human verification of the results of the classifications based on machine learning.

Abbreviations

BIO	Biology
BAFS	Business, accounting and financial studies
CHE	Chemistry
DAT	Design and applied technology
ESD	Education for sustainable development
EfS	Education for sustainability
ECO	Economics
GEO	Geography
HMSC	Health management and social care
HKEAA	Hong Kong Examinations and Assessment Authority
HKDSE	Hong Kong Diploma of Secondary Education
ICT	Information and communication technology
IS	Integrated science
LS	Liberal studies
PHY	Physics
PE	Physical education
SDGs	United Nations Sustainable Development Goals
TL	Technology and living

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Availability of data and materials
The OSDG datasets analysed during the current study are available in the OSDG repository https://doi.org/10.5281/zenodo.7136826. Other datasets generated during the current study are available in our GitHub repository, https://github.com/HKU-SDG-Classification/. Scripts of interviews can be provided upon request.

Declarations

Competing interests
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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