

Empowering Learners for a Sustainable Future: Categorizing Educational Resources for SDG Competence

Chi-Un Lei, Senior Lecturer, The University of Hong Kong

culei@hku.hk

(852) 3917 – 4758

University of Hong Kong

Pokfulam Road, Hong Kong

1. Introduction

Seventeen Sustainable Development Goals (SDGs) were proposed by the United Nations in 2015, intending to attain them by 2030 (United Nations General Assembly, 2015). SDGs cover a wide range of global issues that have to be resolved, including reducing poverty (SDG 1), providing quality education (SDG 4), and reducing inequality (SDG 10). To cultivate good talent in resolving global issues, SDG 4.7 states that by 2030 all learners should acquire the knowledge and skills needed to promote sustainable development (Giangrande et al., 2019).

Numerous educational initiatives in K12 schools and universities have contributed to achieving SDG 4.7. For instance, university ranking authorities integrate sustainable education as a criterion for their sustainability and general university rankings. University College London (UCL) in the United Kingdom categorised over 6,000 course modules by SDGs in 2021 (Mitchell et al., 2021). Meanwhile, the Global Schools Program (GSP) is a flagship program of the Sustainable Development Solutions Network focused on K12 education to support the achievement of SDGs (Tibbitts et al., 2023). These initiatives help educate students to become informed and responsible citizens who can contribute to a more sustainable future. However, SDG experts are often insufficient in creating and localising enough educational materials for K12 and university education, hindering effective SDG education.

Besides K12 schools and universities, SDG education should also upskill current knowledge workers (Hamburg, 2020). Achieving SDGs requires collective action from various stakeholders, including governments, businesses, civil society, and individuals. Therefore, everyone should understand the interconnections between different SDGs and work collaboratively to achieve all SDGs. Additionally, people need to keep themselves updated with the latest developments and progress towards these goals, especially since progress can be affected by various global and local factors. Unfortunately, there is limited research on how knowledge workers can learn SDG knowledge after their university studies and what resources are freely available to the public for learning SDG knowledge. This makes the public not be informed about sustainable development.

This study proposes utilising machine learning and open data to examine the current state of SDG integration within education, specifically in K12 public curricula (pre-university), university, and OER/MOOC communities (post-university). The inquiry focuses on classifying educational resources based on their relevance to SDGs, using open datasets, and illustrating various cases on the SDG identification of educational resources. For instance, the study analyses the curriculum structures of the Faculty of Science in a university to show how SDG knowledge is currently being taught holistically. By harnessing machine learning, the community can improve the accessibility of resources for SDG education, and stakeholders can monitor and evaluate progress to ensure SDG 4.7 is being achieved. Ultimately, this study aims to facilitate the incorporation of SDGs

into all learning processes, ensuring the achievement of all SDGs by 2030.

2. SDG Classifications of Educational Resources

To understand SDG education comprehensively and plan for its implementation across age groups, we have analysed various educational resources. Our training dataset for machine learning is sourced from the OSDG Community dataset (OSDG, 2021), which is based on United Nations reports and policy documents that are publicly available and already labelled with SDGs. In 2021, the OSDG dataset contains around 32,120 records of text consisting of 3 to 6 sentences. Basic analysis codes can be found in the dataset.

2.1. Case 1: K12 Public Curriculum

This study examines the presence of SDGs in common subjects taught in high schools (K10 - K12) in Hong Kong, where foundational knowledge and skills are often developed. Specifically, we analysed the curriculum of the Hong Kong Diploma of Secondary Education (HKDSE) to identify how SDGs have been integrated into five technology-related subjects in the first stage of the study (Lei, 2022). In the second stage, we expanded the analysis to 13 general subjects (Lei and Tang, 2023). Our analysis at the module, subject, and curriculum levels has revealed the details of subjects covering SDGs. We also interviewed school teachers to gather their feedback on our findings.

2.2. Case 2: University Common Core and General Curriculum

We used the Common Core curriculum of a large public university in Hong Kong to tag existing courses with SDGs and align students' learning with SDGs. Our team analysed around 170 courses using course overviews, reading lists, and topic lists to identify the SDGs covered in each course (Lei et al., 2022; Lei and Wang, 2023). The analysis of SDGs for all Common Core courses can help students choose which courses to take if they want to study in-depth on an SDG. We shared our classification results with teachers of the 170 courses. Their feedback highlights the need to improve the classification performance of the algorithm and the uneven distribution of awareness of SDGs and sustainability development among teachers in the Common Core Curriculum (and other subjects). Our investigation further expanded to label over 12,000 courses spanning seven public universities in Hong Kong. This inquiry aims to discover additional resources for regional-level SDG education. It underscores the importance of a consensus among stakeholders on the definitions of sustainability education and their relevance to education.

2.3. Case 3: Open Educational Resources from Professional Parties

Open Educational Resources (OERs) that connect the public with SDGs currently need to be more tagged and be widely used for promoting SDG education. Therefore, we proposed using AutoGluon as the classification algorithm for better classification performance of OERs (Yao et al., 2023). Our proposed classification employs detailed metadata for classification, amalgamating the outcomes of multiple classification models to enhance accuracy. We used OERs in the SDG Academy as a validation benchmark for comparison with extant approaches. Our model demonstrates competitive performance across different performance metrics and allows assigning multiple SDGs to OERs, which is naturally expected in SDG-related corpus. Besides classifying resources of SDG Academy, we also classified resources of IEEE TryEngineering to support their climate change education.

2.4. Case 4: MOOC Resources

Although Massive Open Online Courses (MOOCs) have the potential to become a convenient channel for learning SDGs, there are only scattered studies exploring the

adoption of SDG content in MOOCs. Our investigation analysed how SDGs have been taught in 2818 MOOCs on the Coursera platform (Wang et al., 2022). We provided an overview of the proportion of different SDGs in different universities and offered a good reference for communities to plan for future MOOCs involving SDGs. For example, almost no relevant courses or only a few courses, including SDGs 1, 2, and 6, are considered the most priority SDGs. Our ongoing investigation involves analysing MOOCs and MOOC-based micro-credentials on edX, Coursera, and FutureLearn, for a comprehensive analysis of how MOOCs can be used for continuous education and professional education of SDG knowledge (Liu et al., 2023).

3. Analysis of SDG Education in University Science Curricula

Instead of analysing a single course, we analysed a coherent set of courses in university curricula for a more holistic understanding of SDG education. By taking multiple courses that cover various aspects of the same SDG, students can develop generic skills while gaining a deeper understanding of the complex issues and challenges associated with the SDGs. Additionally, employers from international companies are increasingly seeking employees who deeply understand global issues, making professional SDG education valuable for career preparation.

The studied university, the University of Hong Kong, is ranked No. 4 in Asia and No. 26 worldwide, according to Quacquarelli Symonds University Rankings (2023). There are 21 curricula in the Faculty of Science, including seven intensive curricula accredited by international and professional bodies. Each curriculum's distribution of introductory, advanced, and capstone courses varies significantly. For example, Food & Nutritional Science has more introductory courses (15) than other curricula, which may contribute to its higher coverage of SDGs. In contrast, Earth System Science and Ecology & Biodiversity have fewer introductory courses (8 each) but may cover many SDGs due to their focus on environmental issues.

To support the classification, subject content is extracted from the faculty curricula website with approval from the Faculty Associate Dean of Teaching and Learning. Contents on "Course Objectives" and "Course Contents & Topics" are used for identifications. OSDG Community dataset is used as the training data for model learning. Model training was conducted on the Google Colab Pro+ program using a Tesla T4 GPU with AutoGluon version 0.6.0. Currently, SDGs 1 to 16 can be classified through the code. We decided to have a conservative classification for high precision and fewer false positive cases.

Overall, about 23.5% of courses in the Faculty of Science have been classified to at least one SDG, with 25.3% of courses in intensive curricula and 23.6% of courses in normal curricula classified to at least one SDG. The proportion is generally lower than the university average. This indicates the Science curricula focus more on the fundamental sciences and less on applied science (which could be under the Engineering curriculum).

The findings suggest that incorporating SDGs into curricula depends on the subject and its focus. For simplicity, only the Normal Curricula were considered for the following analyses. The results reveal the following insights:

- Curricula in Chemistry, Biochemistry, Earth System Science, Geology, and Risk Management have covered more SDGs than other curricula, indicating a broader focus on sustainable development.

Table 1. *Total number of SDGs Classified in Science Curricula: Overview*

Curriculum	A	B	C	D	E
Biochemistry	10	17	3	30	5
Biological Sciences	9	22	3	34	12
Chemistry	8	21	5	34	3
Decision Analytics	8	18	4	30	11
Earth System Science	8	16	1	25	6
Ecology & Biodiversity	8	19	1	28	12
Environmental Science	12	24	3	39	10
Food & Nutritional Science	15	22	4	41	17
Geology	7	19	1	27	5
Mathematics	8	39	5	52	14
Molecular Biology & Biotechnology	9	13	3	25	7
Physics	11	31	3	45	5
Risk Management	7	14	4	25	5
Statistics	7	16	4	27	5

A: The number of introductory courses in the curriculum

B: The number of advanced courses in the curriculum

C: The number of capstone courses in the curriculum

D: The total number of courses in the curriculum

E: The number of SDGs classified in courses

Table 2. *Total number of SDGs Classified in Science Curricula: Breakdown*

Curriculum	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
Biochemistry	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	1
Biological Sciences	0	3	2	0	0	0	0	0	1	0	0	0	0	1	3	2
Chemistry	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
Decision Analytics	0	0	0	1	0	0	0	0	9	0	0	0	0	0	0	1
Earth System Science	0	0	0	0	0	1	0	0	1	0	0	0	2	1	0	1
Ecology & Biodiversity	0	0	0	0	0	0	0	0	1	0	1	0	0	4	4	2
Environmental Science	0	0	0	0	0	0	1	0	1	0	1	1	2	1	2	1
Food & Nutritional Science	0	10	3	0	0	0	0	0	2	0	0	1	0	0	0	1
Geology	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	1
Mathematics	0	0	0	5	0	0	0	1	6	0	0	0	0	0	0	2
Molecular Biology & Biotechnology	0	1	2	0	0	0	0	0	2	0	0	0	0	0	1	1
Physics	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	2
Risk Management	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	1
Statistics	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	1

- Decision Analytics, Mathematics, and Statistics curricula strongly focus on SDG 4 (Quality Education), providing the quantitative and analytical tools for analysis (SDG 4.6). Decision Analytics and Mathematics curricula also focus on SDG 9.
- The Food & Nutritional Science curriculum strongly focuses on SDG 2, which aims to address a specific global issue (zero hunger). This is unsurprising as the subject is closely related to food production, safety, and nutrition, which are central to these SDGs.
- Compared to other curricula, more courses in Ecology & Biodiversity curriculum have taught about SDGs, with at least one SDG (including SDGs 14 and 15) classified in approximately 42.86% of the courses.
- Courses in Chemistry and Physics curricula have relatively low coverage of SDGs, with only 8.82% and 11.11% of the courses, respectively, covering something related to SDGs. This could be attributed to the fundamental nature of these disciplines, which may not directly address specific SDGs. However, it is worth noting that these subjects are indirectly relevant to sustainable development. For example, chemistry is crucial in developing environmentally friendly materials for effective chemical processes.

From the SDG perspective, SDGs 9 and 16 have been widely covered in courses in the Faculty of Science (33 courses and 18 courses). This indicates that illustrating cutting-edge knowledge and promoting peaceful and inclusive societies is a common theme across various science disciplines. Meanwhile, among 15 courses that taught SDG 2, most courses are from the Food & Nutritional Science curricula (10 courses). This indicates a focus on addressing food security and sustainable agriculture issues.

4. Conclusions and Future Work

Incorporating Sustainable Development Goals (SDGs) into education is essential for cultivating informed and responsible global citizens who can contribute to a more sustainable future. This study used machine learning techniques to investigate the integration of SDGs into various educational resources, including K12 public curricula, university courses, Open Educational Resources, and MOOCs. Our findings revealed that the presence of SDGs in educational resources varies significantly depending on the subject, its focus, and the level of education. For example, incorporating SDGs into university science curricula is highly dependent on the discipline, with some subjects having higher coverage of SDGs than others. Our study contributes to the understanding of the current state of SDG integration within education. It highlights the need for a consensus among stakeholders on the definitions of sustainability education and its relevance to various educational resources. By harnessing machine learning, we can improve the accessibility of resources for SDG education and allow stakeholders to monitor and evaluate progress to ensure SDG 4.7 is achieved by 2030.

The study can be further extended based on the following dimensions:

1. Feedback from teachers and students on the analysed curricula should be collected. For example, it would be valuable to discuss the steps that can be taken to ensure that graduates are prepared to address the global challenges outlined in the SDGs.
2. It is worthwhile exploring the depth or extent to which these courses cover SDG-related content. For example, are these courses providing a fundamental understanding or delving into potential solutions related to global issues?
3. The study is based on the curricula of a single university, which might not be representative of all universities. Therefore, it is worthwhile to conduct a cross-university curricula analysis.

Remarks

ChatGPT has been used for the synthesis of the conclusion (Section 4) of the manuscript, with further editing by the author. ChatGPT has also been used for polishing the writing of the manuscript.

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