Challenges and Opportunities in NYC School Sustainability During the COVID-19 Pandemic: Structural Topic Model Analysis

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Introduction

Declared as a pandemic on March 11th, 2020 by the World Health Organization, the Coronavirus Disease 2019 (COVID-19) was notorious for its speed and scale of transmission. The pandemic has caused serious and far-reaching consequences. In terms of school education, the pandemic hindered children's access to education and exacerbated education inequalities. Research showed that schools were closed completely in 2020 for an average of 4 months and 6.5 months with partial closures included in the world (UNESCO, 2021b). There were more than 1 billion children deprived of their education in the pandemic due to school closures (UNICEF, 2022b) and 24 million students at risk of not returning to schools due to the economic burden caused by the pandemic (UNESCO, 2021b). There was an increasing rate of mental health problems among children as well as parents, the latter had to take more responsibilities to take care of their children during the school closure (Hoofman & Secord, 2021).

Nevertheless, the pandemic also created opportunities to reflect on the environmental issues and enhanced a willingness among people to take action. For years, environmental experts feared that a global pandemic caused by overdeveloping natural resources and ignoring climate change may occur (Gorji & Gorji, 2021). The pandemic proved the rationality of such fears. Therefore, some news and research linked the pandemic with climate change as a consequence of human activities and called for people to pay more attention to protecting the environment (Beasy and Gonzalez, 2021). The shutdown of national boundaries and the restriction of movement contributed to less consumed energy, better air and water quality, and better ecology (Miklos, 2022). Lessons learned from the pandemic encouraged people to use more eco-friendly products and traffic ways. All of this made environmental and sustainable education (ESE) unprecedentedly important.

However, the real challenges and opportunities of school ESE in the pandemic were still unknown. Although it appears in key documents of international conferences and national policies, it is usually in a peripheral position compared with other economic indexes (Beasy & Gonzalez, 2021). Even in schools required to deliver ESE, it still may give way to subjects crucial for high-stake tests. Moreover, the implementation of ESE is largely dependent upon the educators' beliefs and knowledge since there are limited, immature textbooks or training programs for teachers (Beasy & Gonzalez, 2021).

The article will focus on three research questions:

RQ 1: What challenges and opportunities of NYC school sustainability did Sustainability Coordinators encounter during the pandemic?

RQ 2: To what extent can Sustainability Coordinators' characteristics predict different topics? **RQ 3**: Which technology integration level did they belong to?

In the following article, there will be five parts to answer the research question. It starts from a literature review. It then describes the theoretical framework: replacement, amplification and transformation (RAT). Next, it presents the methodology. After that, it shows the results of the data analysis: topics of challenges and opportunities of school sustainability, and the relationship between topics and variables. Lastly, it provides a discussion of the results.

Literature Review

Over the past half a century, there has been an increasing interest in advocating ESE worldwide (UNESCO, 2021a). ESE has been recognized as the integral element of quality education and the key enabler of other SDGs.

The pandemic brought both unprecedented challenges and opportunities to ESE. The closure of schools and social isolation requirements made in-person activities hard to be implemented, which was a great loss to ESE since it is about interactions between individuals, groups and environment from an ecological point of view (Tidball & Krasny, 2011). Assaf & Gan (2021) found that the lack of physical interaction in outdoor environment made it difficult to teach ESE. The sudden transfer from in-person class to hybrid or online class was overwhelming but teachers and students were not well prepared for it. Research showed that there were 65 per cent of households with children doing online learning during

pandemic while only 5.7 per cent schools offered a majority of all courses online before the pandemic (US Census Bureau, 2020).

Nevertheless, research also showed that the pandemic is beneficial for the development of ESE. The news about the COVID-19 outbreak often linked the pandemic with environmental degradation, which facilitated people to reflect on climate change issues and enhanced a willingness to take action (Beasy and Gonzalez, 2021). Servant-Miklos (2022) proposed that the pandemic has warned us to prepare for more and longer disruptions due to human impact on environment. Assaf & Gan (2021) applied social-ecological system to explore the teaching methods that environmental educators used in the pandemic in Israel. Findings showed that main challenges, like the lack of physical interaction in outdoor environment, and opportunities, like access to online learning and sharing teaching materials nationwide, facilitated the development of diverse teaching methods for ESE. Since climate change and the COVID-19 outbreak are so similar, similar measures can be applied to both, such as making global efforts, identifying online misinformation, taking care of mental health, etc. (UNICEF, 2022a). Moreover, the lockdown policies in many countries led to a drastic reduction in pollution and greenhouse gases emission, better air and water quality, strengthened ecological equilibrium (Khan et al., 2020). Lessons learned from this encourages people to use a more efficient public transport system and more eco-friendly products, which makes ESE unprecedentedly important to ensure long-term sustainable development.

However, the actual challenges and opportunities of ESE that schools had during the pandemic were still unknown. Although the ESE is in a central position of SDGs, only few countries, such as Finland, Australia, Scotland, have set it as the core course (Assaf & Gan, 2021). ESE is usually peripheral in the policy practice, in which high-stake exams and subjects with higher output-input ratios are always the priority (Beasy & Gonzalez, 2021). Only schools and teachers with special interests teach ESE although it is required to be incorporated into all subjects officially (Assaf & Gan, 2021). Therefore, how the ESE was provided was largely dependent on the educators' beliefs and knowledge of relevant topics (Beasy & Gonzalez, 2021). This missing information enlightened the author to explore it.

As one of the biggest cities in the world, NYC took the lead in bettering the environment and promoting sustainable development (Pizmony-Levy et al., 2021). NYC DOE is the department that manages the public schools in NYC. First published in 2009 and edited in 2013, the *Chancellor's Regulation A-850* is the key document calling for sustainability efforts in schools in the City (NYC DOE, 2009, 2013). The updated *Chancellor's Regulation A-850* required each principal to designate a Sustainability Coordinator for that individual school and they are both responsible for completing an annual site-specific school sustainability plan, report and survey (NYC DOE, 2008). To learn the feedback from the Sustainability Coordinators, an Annual Sustainability Survey is conducted in the format of multiple choices and open questions, which includes basic personal information questions like gender, race, years of teaching, and in-depth questions, like providing examples of teaching climate change. The questions are updated annually to follow the current trend and issues. The 2021 Sustainability Survey was aimed to analyze schools' performance in the preceding July 1st through June 30th and was completed by June 30th, 2021.

Theoretical Framework

Due to the spread of the pandemic, in July 2020, NYC DOE announced the *School Building Re-opening Preliminary Plan* to guide schools to implement hybrid class, which aimed to provide in-person instruction to at least 33% of students for the 2020 fall semester (NYC DOE, 2020). Although many teachers may never have online teaching experience, technology integration became the necessity since they need to teach in-person and online students synchronously. Here, technology integration means "the incorporation of technology resources and technology-based practices into the daily routines, work, and management of schools" (US DOE, 2002, Ch. 7, para. 3).

Proposed by Joan Hughes (2006), the replacement, amplification and transformation (RAT) is a theory to assess preservice and inservice teachers' technology integration level in K-12 education. RAT focuses on the effects that technology brings in teaching and learning rather than the types of software that teachers use (Hughes, 2006). It therefore can be applied to any teaching scenarios that involve technology (Kimmons et al., 2015).

To decide which technology level teachers are in, three themes are considered: instructional method, student learning processes, and curriculum goals (Hughes, 2006). Regarding the three levels, the replacement means that technology is used to replace traditional teaching tools without changing learning

goals, process, or instruction (Hughes, 2006). The amplification stresses that technology "amplifies" teaching goals, process, and instruction, making teaching more efficient and productive (Hughes, 2006). The transformation represents a fundamental change of learning goals, process, or instruction using technology, which closely relates to teachers' beliefs (Hughes, 2006). In this case, technology enables teachers to teach in a way that cannot be achieved in the traditional classrooms. Teachers who have already redefined the traditional teaching methods and are able to apply different technology to diverse teaching scenarios are doing transformation (Kimmons et al., 2015).

Therefore, this paper uses RAT as the theoretical framework to explore the technology integration level from the topics of challenges and opportunities.

Data and Methods

Data Collection

This study is based on secondary data analysis of the 2021 Annual Sustainability Survey conducted by the Office of Sustainability at the NYC DOE using STM. Completion of the survey is schools' obligation to *Chancellor's Regulation A-850* for school sustainability (NYC DOE, 2013). The survey has been conducted annually since 2010 to collect feedback from schools' Sustainability Coordinators (NYC DOE, 2008). Survey items might be changed annually to match the policy changes. In 2021, the dataset included common variables such as gender, race, years of teaching, and some new questions about the influence of the pandemic. To better understand the influence of the COVID-19 on ESE, two open questions were added in the survey, "Thinking about how things have been going since the beginning of the coronavirus outbreak, in what ways, if any, have things been difficult or challenging for your school's engagement with sustainability" and "Thinking about how things have been going since the beginning of the coronavirus outbreak, what, if anything, have been some positive aspects of the situation for your school's engagement with sustainability". The survey was completed by June 30, 2021. The dataset is not public and I obtained permission to use it for one-time, non-exclusive use for this research project. There were 1139 observations with valid answers for challenges and 970 observations for opportunities.

STM

As the Internet popularizes and the technology develops, computational algorithms are evolved to extract useful information from huge text data, which is called text mining (Fan et al., 2006; Schmiedel et al., 2019). Topic modeling, a type of text mining method, enables researchers to find recurring topics from a text corpus by automated algorithms (Schmiedel et al., 2019). It applies an unsupervised machine learning method to find out the proportions of topics in documents and the proportions of terms in each topic. Each document is a mixture of topics and each topic is a distribution of terms (Hill, 2020). The idea behind topic modeling is that the co-occurrence of words is relational and can define the topics (DiMaggio et al., 2013).

The Latent Dirichlet Allocation (LDA) is the most basic topic model introduced by Blei et al. (2003). The Correlated Topic Model (CTM) extends the LDA and enables the exploration of a deeper understanding of relationships among topics. The STM, developed by Roberts et al. (2016), allows the analyze of the relationships between topics and other variables by incorporating covariates and metadata in the content analysis (Roberts et al., 2019). It can be applied to the models including linear models, interaction effects, nonlinear relationships, etc. (Roberts et al., 2019). Since the relationships between variables and topics are usually the focus of study in social science, the STM is very useful to provide this information. The stm package in R (Roberts et al., 2019) is used to create the STM.

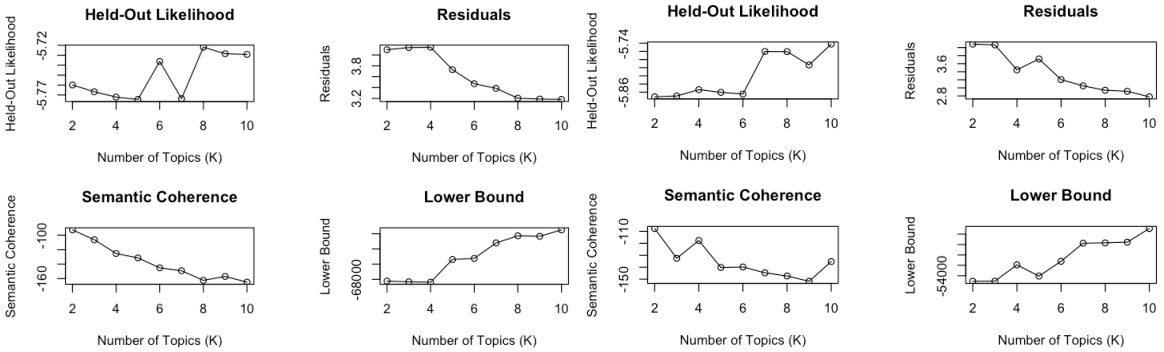
The application of topic modeling to education is diverse but limited, especially in the field of education (Bowers et al., 2015; Wang et al., 2017). To narrow down this gap, this study uses STM to analyze topics of challenges and opportunities in NYC school sustainability during the pandemic.

Results

Optimal Number of Topics

To build a STM, the number of topics is not automatically created by R but is decided by users in advance. Determining an optimal number of topics is a tradeoff process and there is no right answer (Roberts et al., 2019). Some diagnostic measures can help make the decision: held-out likelihood, semantic coherence, lower bound, and residuals. The rule is: the higher held-out likelihood, semantic coherence, and lower bound, the better meaning of topics; the smaller residuals, the higher density of meaning (Hill, 2020). The Figure 1 and 2 show diagnostic values by number of topics for challenges and opportunities. Therefore, I decided to set six topics of challenges and four topics of opportunities in the following STM.

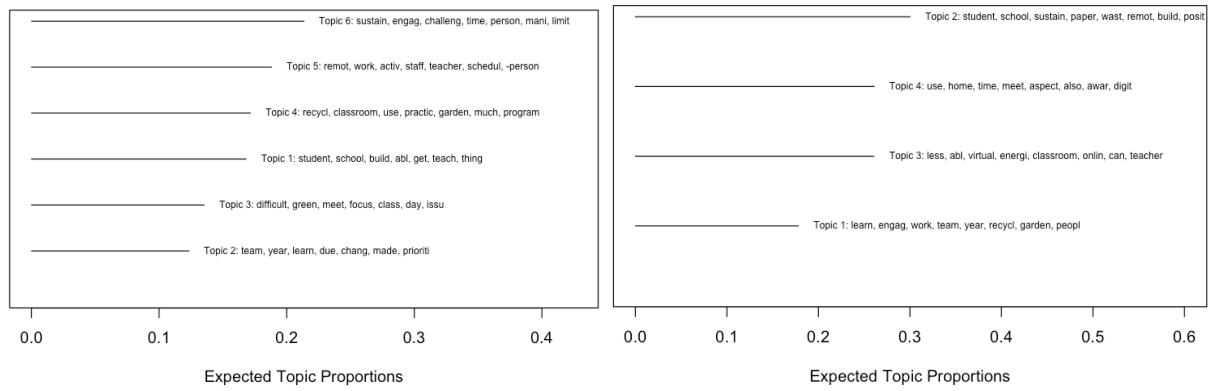
Figure 1. Diagnostic Values by Number of Topics of Challenges & Opportunities



Identification of Topics

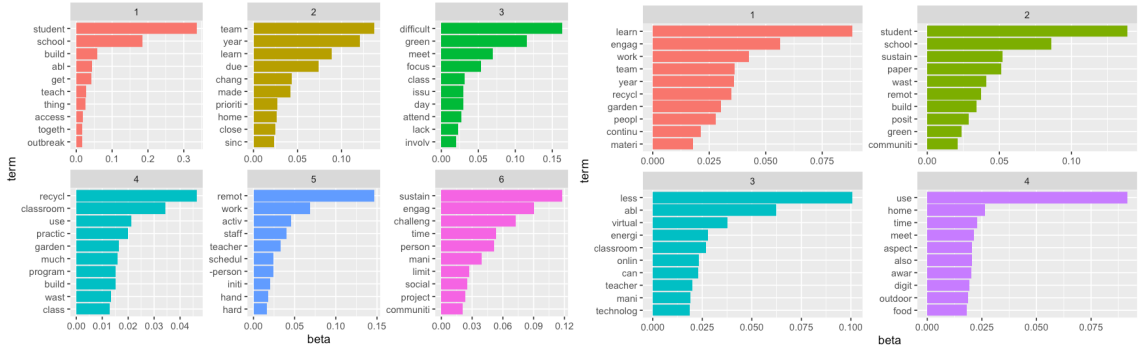
The Figure 3 and Figure 4 show the expected topic proportions of challenges and opportunities with the seven most frequent keywords for each topic.

Figure 3. Expected Topic Proportions of Challenges and Opportunities



The expected proportion of each term in each topic of challenge and opportunity can be seen in Figure 5 and Figure 6. Under each topic, the proportions of relevant terms are ordered from the highest to the lowest. It should be noticed that the scale of the x-axis for each topic is different.

Figure 5. Expected Term Proportions of Topics of Challenges and Opportunities



Based on the estimated topics, I can order all the documents in R by the proportion for each topic. After reading the high proportion documents for each topic, I generated labels for each topic as Table 1 and Table 2 shows.

Table 1. Structural Topic Model Outcome of Challenges with Topic Labels, Keywords, and Exemplary Text

Topic Labels	Keywords	Examplary Texts
Topic 1 Fewer Students in the Building	student, school, build, abl, get, teach, thing	#269 “Hardly any students were in the building to work on projects, which is what excited students.”

Topic 2 Difficult to Create Student Teams	team, year, learn, due, chang, made, prioriti	#437 "It was a challenge to try to organize a student council or any other student team."
Topic 3 Focused on Something Else	difficult, green, meet, focus, class, day, issu	#356 "It fell off the priority list."
Topic 4 The Routines of Sustainability Stopped	recycl, classroom, use, practic, garden, much, program	#136 "Since we were out of the building for most of the year, the routines of sustainability we might usually have done were not."
Topic 5 Frequently Changed Schedule	remot, work, activ, staff, teacher, schedul, -person	#675 "One difficulty was finding an appropriate time to meet as a Green Team. It was a struggle with so many changes."
Topic 6 Limited Engagement in Sustainability	sustain, engag, challeng, time, person, mani, limit	#957 "The students spent so (much) time on screen remote learning that it was difficult to get anyone to engage anymore time."

Table 2. Structural Topic Model Outcome of Opportunities with Topic Labels, Keywords, and Exemplary Text

Topic Labels	Keywords	Examplary Texts
Topic 1 Engaged in Online Learning	learn, engag, work, team, year, recycl, garden	#822 "How to learn about important topics virtually and the ways we can engage online with one another."
Topic 2 Used Less Paper	student, school, sustain, paper, wast, remot, build	#526 "We use more digital resources and less paper."
Topic 3 Consumed Less Energy	less, abl, virtual, energi, classroom, onlin, can	#14 "We didn't produce much waste in the school and certainly didn't consume as much energy."
Topic 4 Recycled at Home	use, home, time, meet, aspect, also, awar	#209 "We encouraged the students to do recycling at home and it seemed we had some positive effects."

Relationships between Topics and Selected Variables

Compared with LDA and CTM, the biggest advantage of STM is that it allows to explore the relationship between topics and covariates. In this research, the different proportions of topics may be influenced by different backgrounds of respondents, like gender, race, years of teaching, etc. The stm package in R enables to build a logistic regression model to check if the proportions of topics are influenced by other variables. To further explore their relationships, an estimation model was fitted:

$$Prevalence_{ij} \sim \beta_0 + \beta_1 * Female_i + \beta_2 * White_i + \beta_3 * YearsofTeaching_i + \beta_4 * Volunteer_i + \beta_5 * Teacher_i + \varepsilon_i$$

In the model, the *i* indexes the *i*th document and the *j* indexes the *j*th topic. The $Prevalence_{ij}$ is the matrix of topic prevalence values derived from the STM. The β_0 is the intercept. The $Female_i$ is a dummy variable of gender, representing the gender of each document's responder. The β_1 is its coefficient. The $White_i$ is a dummy variable of race, representing whether the responder is white or not. The β_2 is its coefficient. The $YearsofTeaching_i$ is an ordered variable, representing the years of teaching of each responder. Here, it is transferred to three dummy variables and $YearsofTeaching_{i\,l} = 2$ (between 3 and 7 years) is set as the reference group so that we can explore how less years ($YearsofTeaching_i = 1$, representing 2 years or fewer) or more years ($YearsofTeaching_i = 3$, representing 8 years or more) is different from the middle one ($YearsofTeaching_i = 2$ represents between 3 and 7 years). The β_3 is its coefficient. The $Volunteer_i$ is a dummy variable of being a volunteer, representing whether the responder volunteered to be a Sustainability Coordinator. The β_4 is its coefficient. The $Teacher_i$ is a dummy variable of being a teacher, representing whether the responder was a teacher. The β_5 is its coefficient. The ε_i is the error that the model failing to cover.

The Table 3 and 4 provide the descriptive statistics for the variables included in the models.

Table 3. Definitions and Descriptive Statistics of Variables for Challenges (n=1,139)

Variables	Definition and Metrics	Mean	SD
Dependent Variables			
Topic 1 Fewer Students in the Building	No = 0, Yes = 1	.17	-
Topic 2 Difficult to Create Student Teams	No = 0, Yes = 1	.12	-
Topic 3 Focused on Something Else	No = 0, Yes = 1	.13	-
Topic 4 The Routines of Sustainability Stopped	No = 0, Yes = 1	.18	-
Topic 5 Frequently Changed Schedule	No = 0, Yes = 1	.19	-

Topic 6 Limited Engagement in Sustainability	No = 0, Yes = 1	.21	-
Independent Variables			
Female	Male =0, Female = 1	.70	-
White	Non-white = 0, White = 1	.49	-
Years of Teaching 1: 2 years or fewer 2: between 3 and 7 years 3: 8 years or more	Time duration that teachers have been teaching	2.51	.62
Volunteer	Non-volunteer = 0, Volunteer = 1	.32	-
Teacher	Non-teacher =0, Teacher = 1	.47	-

Source: Annual Sustainability Survey 2021

Table 4. Definitions and Descriptive Statistics of Variables for Opportunities (n=970)

Variables	Definition and Metrics	Mean	SD
Dependent Variables			
Topic 1 Engaged in Online Learning	No = 0, Yes = 1	.18	-
Topic 2 Used Less Paper	No = 0, Yes = 1	.30	-
Topic 3 Consumed Less Energy	No = 0, Yes = 1	.26	-
Topic 4 Recycled at Home	No = 0, Yes = 1	.26	-
Independent Variables			
Female	Male =0, Female = 1	.71	-
White	Non-white = 0, White = 1	.49	-
Years of Teaching 1: 2 years or fewer 2: between 3 and 7 years 3: 8 years or more	Time duration that teachers have been teaching	2.51	.61
Volunteer	Non-volunteer = 0, Volunteer = 1	.32	-
Teacher	Non-teacher =0, Teacher = 1	.44	-

Source: Annual Sustainability Survey 2021

For each topic, a logistic regression model was completed to check the relationship between the topic and variables. Table 5 and 6 consists of the output of all the topics of challenges and opportunities.

Table 5. Estimates on the Relation Between Topics of Challenges and Some Variables

	Topic1 Fewer Students in the Building	Topic2 Difficult to Create Student Teams	Topic3 Focused on Something Else	Topic4 The Routines of Sustainability Stopped	Topic5 Frequently Changed Schedule	Topic6 Limited Engagement in Sustainability
Female	-.01***	.02***	-.01	.04**	-.04***	-.01
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
White	.00	-.01	.01	.05***	-.06***	.01
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
Years of Teaching==1	.01***	-.01	.00	.01	-.02	.01
	(.00)	(.01)	(.01)	(.03)	(.01)	(.02)
Years of Teaching==3	-.01**	.00	-.01	.01	.01	-.01
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
Volunteer	-.02***	-.01	-.01	.05***	.01	-.03**
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
Teacher	-.01**	.00	-.01	.05***	-.03**	-.01
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
Intercept	.18***	.11***	.15***	.08***	.25***	.23***
	(.00)	(.01)	(.01)	(.02)	(.01)	(.01)

Standard errors in parentheses

*p < .01, **p < .001, ***p < .0001

Table 6. Estimates on the Relation Between Topics of Opportunities and Some Variables

	Topic1 Engaged in Online Learning	Topic2 Used Less Paper	Topic3 Consumed Less Energy	Topic4 Recycled at Home
Female	.01	.01	-.03***	.02**
	(.01)	(.00)	(.01)	(.01)

White	.01 (.01)	.00 (.00)	-.01* (.01)	.00 (.01)
Years of Teaching==1	.00 (.01)	.02* (.01)	.00 (.01)	-.02 (.01)
Years of Teaching==3	.00 (.01)	-.02*** (.00)	.00 (.01)	.02*** (.00)
Volunteer	.00 (.01)	-.02*** (.00)	-.01 (.01)	.03*** (.01)
Teacher	.01 (.01)	.00 (.00)	-.01 (.01)	.00 (.00)
Intercept	.17*** (.01)	.31*** (.01)	.30*** (.01)	.23*** (.01)

Standard errors in parentheses
*p < .01, **p < .001, ***p < .0001

Discussion

In this study, I explored the topics of challenges and opportunities of ESE in NYC schools, to what extent Sustainability Coordinators' characteristics can predict different topics and in which technology integration level they belong to.

As noted in previous research, ESE has gained more and more attention in the past few decades. As one of the biggest education systems in the world, NYC DOE established OOS to promote ESE and conducted an Annual Sustainability Survey to learn the feedback from schools' Sustainability Coordinators. In the 2021 Annual Sustainability Survey (NYC DOE, 2021), two open questions about challenges and opportunities were added in the survey. Using STM in R, topics of challenges and opportunities were identified.

To sum up the text mining results, there are mainly six topics of challenges and four topics of opportunities. The six topics of challenges are: Topic 1 Fewer Students in the Building, Topic 2 Difficult to Create Student Teams, Topic 3 Focused on Something Else, Topic 4 The Routines of Sustainability Stopped, Topic 5 Frequently Changed Schedule, and Topic 6 Limited Engagement in Sustainability. The four topics of opportunities are: Topic 1 Engaged in Online Learning, Topic 2 Used Less Paper, Topic 3 Consumed Less Energy, and Topic 4 Recycled at Home. These results answered the first research question. Estimation models were built to further explore to what extent Sustainability Coordinators' characteristics can predict different topics of challenges and opportunities.

Reviewing all topics of challenges and opportunities, it is clear that the technology integration level for NYC public schools was in the initial stage of amplification. Teachers replaced the traditional tools with technology to fulfill the demand of hybrid class between in-person and remote students, and partially changed the teaching processes, goals, and instruction accordingly.

To further improve teachers' technology integration ability, previous research showed that there are two key points. First, support teachers' knowledge development. Teachers who teach ESE may not necessarily come from the related field of study, and may not be trained to teach ESE in hybrid class or online class. In this unprecedented situation, the government and schools should hold more professional trainings for on-site teachers and offer them more resources (Ertmer, 1999). Second, improve teachers' self-efficacy. Increased self-efficacy is thought to be closely linked to intentions of using technology in teaching and better technology integration ability (Amalfitano, 2017; Ertmer, 1999). As Bandura's theory suggested, what happens in one's mind is what one actually does (Bandura, 1986). Increased computer self-efficacy is as or more valuable to the transformation changes than having all external resources (Amalfitano, 2017).

The unique contribution of this study is in two ways. First, it is the first time to use STM in the field of ESE. The previous study has applied STM in diverse subjects: topics of research literature of educational leadership (Wang et al., 2017), finance bond election proposals (Bowers et al., 2015), American politics (Roberts et al., 2019), mask-wearing issues in the pandemic (Lee et al., 2021), organizational culture (Schmiedel et al., 2019), etc. However, there has been very limited application in the field of education and none for the ESE. Therefore, this paper is the first one to apply STM into ESE. Moreover, STM enables to explore the relationship between different topics and variables. By doing this, we can better

predict topics with Sustainability Coordinators' characteristics. Second, it helps fill in the gaps of challenges and opportunities of ESE during the pandemic. Although there were lots of research about challenges and opportunities in general education during the pandemic (UNESCO, 2021b; UNICEF, 2022b; Hoofman & Secord, 2021; L. La Velle et al., 2020), little research studied challenges and opportunities in ESE during the pandemic. The fact that this paper uses STM to identify topics of challenges and opportunities in ESE helps update the development of ESE in the COVID-19 scenario in NYC public schools and called for more attention and improvement in this field during the emergency.

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