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Mapping the public understanding of computational thinking education: Insights from social Q&A platform discussions

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ABSTRACT: With the growing popularity of computational thinking (CT) classes in K-12 schools, it is important to investigate public perceptions of these initiatives. Analyzing public discussions and opinions provides valuable insights that can inform future educational policies and reforms. In this paper, we collected questions and answers related to CT education on the Quora platform. Next, we applied a topic modeling approach to find out major topics in online discussions. Through analysis, we identified 6 topics in questions and 14 topics in answers. Our findings revealed that people showed great interests but also uncertainty about CT education learning outcomes. Many people asked for suggestions on CT learning tools and platforms, but they struggled to identify appropriate information to support their learning needs. Among their answers, while people held positive attitudes toward CT education, they were concerned about the difficulties their children faced in the learning process and the problem of educational equity. Moreover, since CT practices cultivate information literacy skills for children in the 21st century, the benefits of CT education might be overestimated. These findings deepen our understanding of CT education, which could inform education policies and future research directions.

Keywords: Computational Thinking, K-12 education, Public perception, Social media, Topic modeling

1. Introduction

"Computational Thinking (CT)" was first introduced by Seymour Papert (1980), who stated the importance of students' social and emotional engagement in creating a (computational) artifact (Lodi & Martini, 2021). Jannette Wing further popularized this concept and defined CT as the cognitive processes used in problem-solving, systems design, and understanding human behavior (Wing, 2006). Later on, this idea was expanded by International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA), which highlighted the importance of teaching CT in K-12 education to improve students' problem-solving skills and critical thinking abilities (ISTE & CSTA, 2011). CT has now been recognized as an integral component of digital and information literacy and is also promoted as a fundamental skill in the 21st century (Bers et al., 2022). This skill not only emphasizes the importance of understanding basic concepts of computer science but also advocates the cognitive and social dimensions of problem-solving processes across various disciplines.

Since then, an increasing number of countries have revised their education curricula to introduce CT concepts and practices to K-12 students (Kampylis et al., 2023; Mills et al., 2024; Yin et al., 2024). With the growing popularity of CT classes in K-12 schools, it is essential to understand stakeholders' perceptions. Their insights offer valuable opinions and suggestions for the implementation and improvement of educational practices. However, prior studies investigating stakeholders' attitudes and opinions heavily relied on questionnaires and interviews (Kong & Wang, 2021; Maruyama, 2019; Yu et al., 2020). Questionnaire focuses on testing hypotheses and drawing statistical generalizations without obtaining in-depth perspectives or "stories" from respondents (Cohen et al., 2018). On the other hand, interview is time-consuming, labor-intensive, and usually involves a limited number of participants (Blackstone, 2018). To address these challenges, we propose a topic modeling approach to quantify stakeholders' perceptions. This approach could perform as a triangulation method, compensating for the limitations of questionnaires and interviews observed in numerous previous studies (Isoaho et al., 2021; Jacobs & Tschötschel, 2019).

Besides, previous research investigating stakeholders' perspectives has mainly focused on researchers and educators (Kong & Wang, 2021; Maruyama, 2019; Yu et al., 2020), with none of them giving attention to public attitudes and opinions. Understanding public concerns, attitudes, and inquiries is of equal importance, as it not only reflects the degree of support and acceptance of education policies or initiatives but also highlights concerns and challenges that could provide valuable information for the development of CT education. While individuals such as office workers, writers, and artists are not direct stakeholders in CT education, their attitudes and opinions play a significant role in influencing the broader societal perspective on education. There are two reasons. First, the boundaries between computer science and other disciplines are becoming blurred. CT is considered a problem-solving approach that can be applied to different disciplines and all education levels (Shute et al., 2017). Therefore, CT education is not only valuable for computer scientists but also for individuals of different backgrounds, such as office workers and artists. Second, people from diverse backgrounds can significantly increase community engagement on educational issues (Furco, 2010). For example, office workers can provide insights into how CT education can equip students with transferable skills to improve working efficiency. Besides, if the public expresses positive attitudes and support for CT education, it signifies a general trend of educational focus. This positive sentiment can influence policymakers and educators, potentially resulting in increased investments in CT education, curriculum development, and the creation of learning resources. Therefore, there is a need to leverage social media data to gain a better understanding of public opinions toward CT education.

In the recent decade, the massive number of social media users and the conversational nature of social media posts have led to social media as an emergent approach to understanding public opinions (McGregor, 2019). Extensive prior research has utilized social media data to explore public opinion across different topics, such as politics (Skoric et al., 2020), climate change (Tandoc Jr & Eng, 2017), nuclear energy (Roh, 2017), and health information (Liu & Liu, 2021). Social media platforms create virtual communities for the public where they can engage in real-time discussion, share learning resources, and provide feedback and comments on education practices (Le et al., 2019; Yin et al., 2023). In this study, Quora (www.quora.com) was chosen as the representative platform due to its unique community-based approach to knowledge sharing, which has made it one of the most popular question-and-answer (Q&A) websites in the world (Aelieve, 2022). Quora provides an environment for users to ask questions, share opinions and experiences, and seek a wide spectrum of information. The content in Quora thus offers an opportunity for an in-depth investigation of public perceptions on specific educational topics.

This study aims to achieve two objectives. First, we summarize the themes of inquiry related to CT education that users posted on the Quora platform. Second, we investigate public perceptions, concerns, and attitudes toward CT education in response to these inquiries. Arising from these objectives, we ask two questions: RQ1) What are the themes of inquiry in questions posted online regarding CT education? RQ2) What are the themes that emerge from answers in response to these inquiries?

To address these questions, we conducted a topic modeling analysis and content analysis on both questions and answers posted on Quora. We analyzed the themes of inquiry and responses that emerged from users' posts regarding CT education. The findings provide a better understanding of public perceptions of CT education and inform future policies and practices to promote CT education at K-12 levels.

2. Literature review

2.1. CT education initiatives and the importance of CT to students

The popularizing of CT concepts and the pervasive use of computers in daily life have paved the way for the development of students' CT skills. The United Kingdom was the first country to introduce CT skills to children at all levels of K-12 education. In 2013, the UK government publicized the National Curriculum to develop digital literacy and equip students with CT skills (Department for Education, 2013). In the meantime, the United States signed "Every Student Succeeds Act" into law in 2015, giving CT education equal importance to other academic disciplines such as Mathematics, English, and Science (U.S. Department of Education, 2015).

The implementation of CT education has also been observed in Asian countries. China's Ministry of Education incorporated CT education into the curriculum from Grades 1 to 9 (Ministry of Education of the People's Republic of China, 2018). Likewise, Japan introduced CT skills in primary schools in 2020, followed by middle schools in 2021, with plans to include it in the upper secondary curriculum in 2022 (National Center on Education and the Economy, 2021). These attempts aim to equip students with the capacity to apply the foundational elements of CT in problem-solving and explore diverse approaches to problem-solving across various disciplines (Bocconi et al., 2022).

Empirical findings revealed that CT education brings multifaceted benefits to students. Children who participated in CT courses not only learned computational concepts and programming skills (Kong & Wang, 2023) but also enhanced mathematical learning (Rodríguez-Martínez et al., 2020) and language acquisition (Sun et al., 2022b). Further, CT activities cultivated children's social skills, such as communication and collaboration skills (Tran, 2019), which are crucial in facing the challenges of digital society and competitive job markets (Mørch & Kafai, 2022).

2.2. Stakeholders' perspectives on CT education

In the education context, stakeholders' perspectives enrich the teaching and learning process with a variety of comments, suggestions, and aspirations, thereby enhancing education quality and improving learning outcomes (Janmaat et al., 2016). Stakeholders include not only students, teachers, and education policymakers but also parents, professionals and experts, and educational technology companies. Multi-stakeholder perspectives provide valuable insights into how education policy translates into practice and the factors that either facilitate or hinder successful learning outcomes (Wagner et al., 2008). In addition, researchers note that curriculum development is intricately linked to internal quality work but also engages with stakeholders' perspectives in the processes (Fagrell et al., 2020).

Prior studies have investigated the perspectives of various stakeholders on CT education, including parents and teachers. At the primary school age level, parents perceived the potential benefits of CT education for their children. Through participation in CT learning activities, the children could experience fun and joy (Kong & Wang, 2021; Yu et al., 2020). A survey showed that parents of primary school children considered various benefits of CT practices, such as programming skills, creativity, problem-solving ability, and collaboration skills (Maruyama, 2019; Maruyama et al., 2017). However, they were concerned about their limited knowledge to provide sufficient support, as well as inadequate professionally-produced teaching and learning resources provided by schools (Maruyama et al., 2017). As students progress to the secondary level, parents may become more inclined to guide them toward becoming professional programmers. They held high expectations of CT education, anticipating that CT education would equip their children with greater competitiveness in future education and employment (Sun et al., 2022a).

On the whole, teachers from kindergarten (Yadav et al., 2022), primary and secondary levels (Fessakis & Prantsoudi, 2019; Wong et al., 2015), as well as the university level (Lai, 2022) have all shown positive attitudes towards CT education. However, they have also expressed similar concerns about their limited knowledge and the lack of sufficient support for professional development. For instance, teachers thought that incorporating CT activities into math classes would be enjoyable and engaging, but they reported insufficient training and unclear guidelines in the teaching materials. Specifically, they faced challenges in selecting appropriate tools or methods for teaching CT skills (Humble et al., 2020). Furthermore, while teachers recognized the benefits of introducing CT to students across all K-12 levels, they expressed a need for more support in professional training, tool evaluation, and CT assessment (Fessakis & Prantsoudi, 2019; Greifenstein et al., 2021).

2.3. Text analysis on the Quora platform

In recent years, social Q&A services have seen a dramatic increase in popularity. Among these services, Quora has emerged as one of the largest and most popular websites in the world, with millions of users worldwide seeking and sharing knowledge on a wide range of topics (Aelieve, 2022). Its extensive and contemporary interactive interface, along with its well-organized community-based discussion sections, enables the collection of data with both depth and breadth.

The majority of research has focused on health-related information shared on Quora. For example, Jang et al. (2022) analyzed the evolving public sentiment toward COVID-19 vaccination and the discourse around COVID-19 vaccination hesitancy over time. Another study conducted by Jang et al. (2023) compared anti-Asian discourse on the Quora platform before and during the COVID-19 pandemic. Moreover, Charlie et al. (2018) summarized the questions and concerns that patients have regarding breast cancer screening mammography. Several researchers have also analyzed discussions around environmental issues. For example, Jiang et al. (2018) identified the key factors influencing public preferences in climate change knowledge and opinions through an analysis of Quora answers. In educational contexts, Le et al. (2019) analyzed discussions on Quora and summarized key factors influencing university choices. Although Quora has been utilized as a data source to understand public discussions and opinions on various topics, the analysis of educational issues remains limited.

2.4. Topic modeling analysis in the education context

Topic modeling is a machine-learning technique used to cluster topics within a given corpus and calculate topic distributions (Blei, 2012). Among the various analysis models, Latent Dirichlet Allocation (LDA) has become the most frequently used method for its superior classification performance and its capacity to analyze text without pre-defined labels or categories (Jelodar et al., 2019). This method has been widely applied in social science to extract information from text data (Vayansky & Kumar, 2020).

LDA has also been used in several educational contexts, such as forum discussions, students' essays, and research papers (Maphosa et al., 2022; Shi et al., 2022). For example, Maphosa et al. (2022) identified the factors that influence students' choices and success in STEM subjects by analyzing abstracts from 179 papers. Chen et al. (2020) detected latent topics and trends in educational technologies by analyzing 3,963 articles published in Computers & Education between 1976 and 2018. Additionally, Shi et al. (2022) applied LDA to investigate gender differences in sex education discussions in an online knowledge community. Therefore, given the large volumes of text data on social media platforms and no pre-defined labels and categories within the data, LDA is an appropriate approach for the current study.

3. Methods

Our methodology involves multiple steps. We began by manually classifying posts in the dataset with labels to differentiate their roles. Next, we preprocessed the data by removing emojis, URLs, punctuation marks, numbers, stopwords, and specific tokens such as " " and "&amp". Following this, we conducted topic modeling, fine-tuning the number of topics, labeling topic names, and grouping top keywords. Finally, we performed content analysis by reviewing representative documents within each topic. This section begins by elaborating on our datasets as well as the analysis that was conducted.

3.1. Datasets

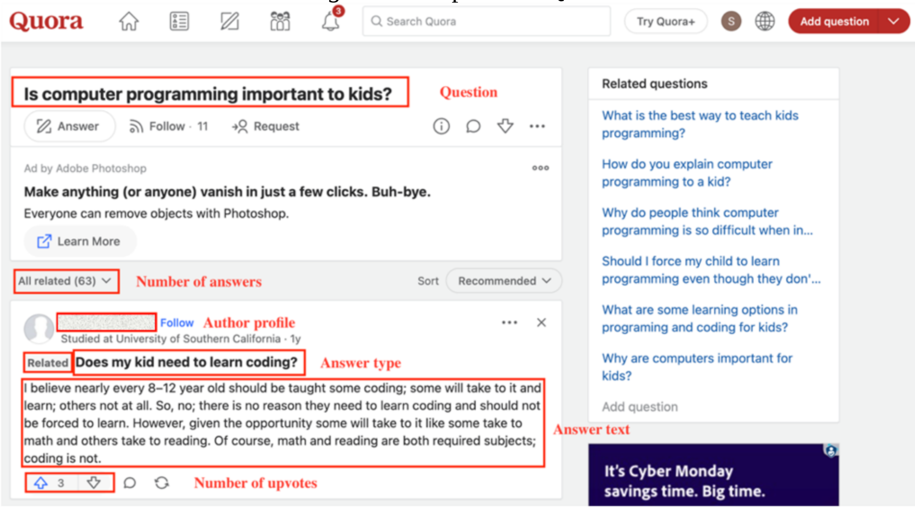
In this study, we used a Python API (Das & Semaan, 2020) to retrieve two datasets from the Quora platform between June 2010 and September 2022, covering the entire period since Quora's initial public availability on June 21, 2010. The data collection process was repeated twice by searching the below queries in questions and answers separately:

- (children or kids) AND (code OR coding OR programming OR robotics OR "computer science") AND (study OR learn)
- (children or kids) AND (code OR coding OR programming OR robotics OR "computer science") AND (teach OR instruct OR curriculum OR syllabus OR class)
- (children or kids) AND "computational thinking"

As shown in Figure 1, we extracted several types of data from the platform. For author information, we anonymized users' IDs and randomly generated a number for each user in our dataset to ensure that individual users cannot be identified. It is important to note that a question may receive multiple answers, each with varying lengths. We separated the collected questions and answers into two distinct datasets for several reasons. First, questions and answers reflect different aspects of public opinion. Questions are the initial queries posted on Quora, and analyzing them helps us identify the most frequently asked questions and the topics users are most concerned about. In contrast, answers provide further information on public responses and opinions to the questions. Second, analyzing questions and answers separately helps us to discover relationships between the two datasets. For example, we can find the similarities and differences between the topics of questions and the answers. This will reflect the public queries, the current understandings, and the gaps in CT education. By analyzing these relationships, we can gain insights into how questions and answers interact on the Quora platform.

After removing duplicates, the dataset comprised 1,369 questions and 26,964 answers. We also deleted questions and answers that did not contain keywords (i.e., "children," "kids," "coding," or "programming.") Next, we reviewed all questions and a random sample of answers to ensure their relevance and accuracy. As suggested by Jacobs and Tschötschel (2019), this step is necessary for the subjective interpretation of the content of text data. Finally, a total of 1,174 questions and 23,124 answers, written by 13,809 authors, were used for analysis.

Figure 1. Snapshot of Quora



3.2. Data analysis

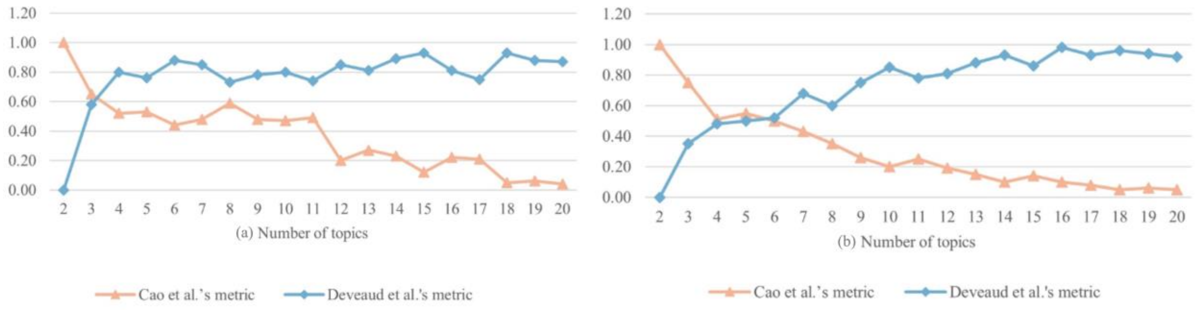
First, we classified posts in the dataset with the labels normal, related, and promoted. We observed that Quora classifies answers into 3 categories: normal, related, and promoted. Normal answers are direct replies to specific questions, related answers are similar answers recommended by the system, and promoted answers include promotional content and advertisements. Surprisingly, among the 23,124 answers associated with the 1,174 questions, only 7,543 (32.6%) were normal answers, while over 60% were related and promoted answers. These two types of answers (related answers are recommended by the system, and promoted answers are advertisements paid by Quora users for more exposure) are not directly posted in response to the specific questions (Maity et al., 2018). Instead, they appear due to the recommendation algorithm (Quora, 2023a). Therefore, to mitigate algorithm bias and ensure genuine user answers, only the 7,543 answers labeled as normal were retained for the topic modeling analysis. This subset, comprising 1,449,125 words with an average length of 182 words per answer, presents a substantial volume of textual data for gaining insights into public discussions and opinions.

Next, we removed emojis, URLs, punctuation marks, numbers, and specific tokens like “ ” and “&amp”. The terms were then singularized and converted to lowercase. Furthermore, common stopwords such as “don’t,” “‘ll,” and “‘ve” were excluded from the answer texts. To enhance interpretability and clarity, lemmatization was applied. We used the Natural Language ToolKit (NLTK) package (Bird et al., 2009) to remove inflectional endings and return the base or dictionary form of a word. For example, the words “used,” “using,” and “uses” were all converted to “use”. Following these preparatory steps, the question dataset yielded 1,284 valid English terms, while the answer dataset comprised 18,004 valid English terms. The processed corpus was then transformed into numerical vectors by using word embeddings for topic modeling analysis.

In the third step, we conducted a topic modeling analysis. In the previous work, researchers fine-tune the number of topics based on domain knowledge or statistical measures, ensuring the identified topics are meaningful and relevant (Blei, 2012). We thus applied Cao et al.’s (2009) and Deveaud et al.’s (2014) metrics to calculate the perplexity of the topic model for questions and answers separately. In Figure 2(a) and (b), the optimal number of topics was determined by the lower values of Cao et al. (2009) and higher values of Deveaud et al. (2014). Further, we calculated coherence scores to evaluate the overall interpretability of topics and assess their quality (Röder et al., 2015). In our datasets, the highest coherence scores were observed in the 6-topic model for the question dataset (0.59) and the 14-topic model for the answer dataset (0.65). Therefore, we decided to generate 6 topics for questions and 14 topics for answers in this study.

To manually assign topic names, we selected the top 10 terms for each topic based on their beta values. A beta value represents the probability of a term belonging to a given topic, with higher values indicating terms that more accurately describe the topic (Blei, 2012). We also examined representative documents within each topic to assist the labeling process. For example, in the question dataset, topic 1 contained keywords such as “age,” “start,” “benefit,” and “coding.” We interpreted this topic as relating to “when and why to learn CT skills.” Following this, we assigned labels to all identified topics. Further, we grouped similar topics into broader themes based on their assigned names and inter-topic distances. This approach of assigning topic names is consistent with recent studies (Wang & Goh, 2020).

Figure 2. Optimal number of the topic model for the (a) questions and (b) answers



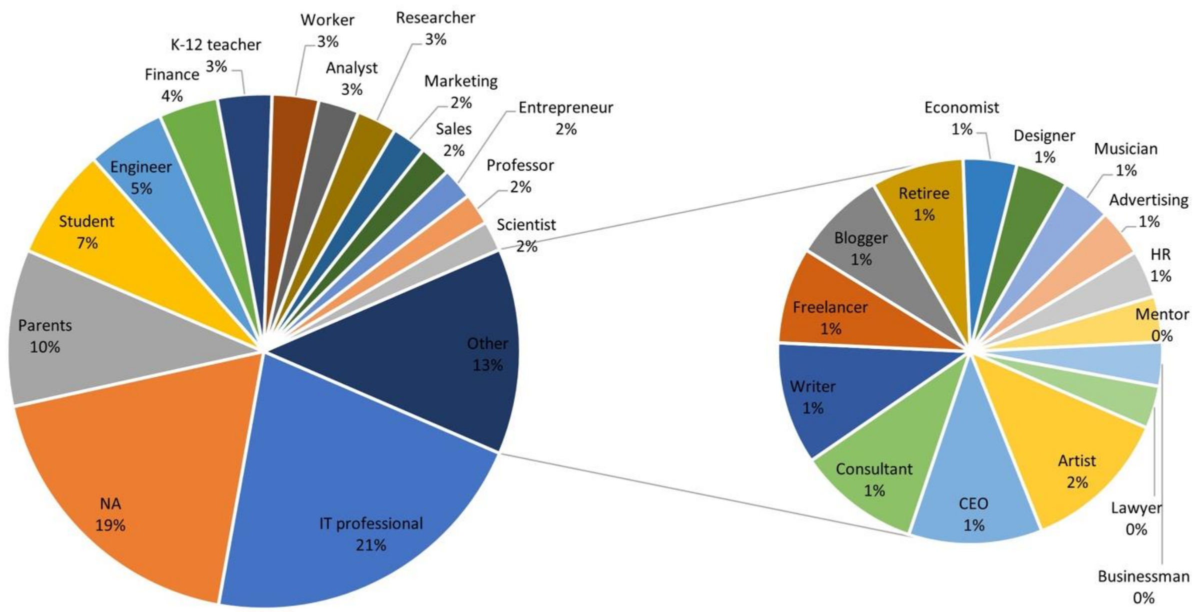
Lastly, we conducted content analysis to gain in-depth insights into the identified topics (Isoaho et al., 2021). We employed a purposive sampling approach to select representative documents from both the question and answer datasets (Kesler et al., 2022). Specifically, we extracted and manually coded 120 documents from 6 topics in the question dataset and 280 documents from 14 topics in the answer dataset based on topic relevance scores. The selected samples enabled us to validate and interpret findings for each topic, complementing the results of our topic modeling analysis.

4. Findings

4.1. Overview

A total of 7,543 answers were written by 5,642 authors from diverse backgrounds, including K-12 school teachers, university students, IT professionals, and individuals from various walks of life. Figure 3 illustrates the distribution of authors' occupations, with IT professionals being the most prominent contributors, followed by parents and university students. Interestingly, answers were also posted by individuals from other disciplines, such as musicians, writers, and lawyers, who are not experts in CT. Despite their non-expert status, their contributions provided a wide range of perspectives, and notably, these posts received hundreds of votes.

Figure 3. Distribution of authors' occupations



To visualize the LDA results, we generated the Inter-topic distance map by calculating the distances between topics and then employing multidimensional scaling techniques. Figures 4 and 5 are two-dimensional representations of the question and answer datasets, respectively. In these figures, each bubble symbolizes a different topic, with the size of the bubble reflecting the prevalence of that topic within the respective dataset.

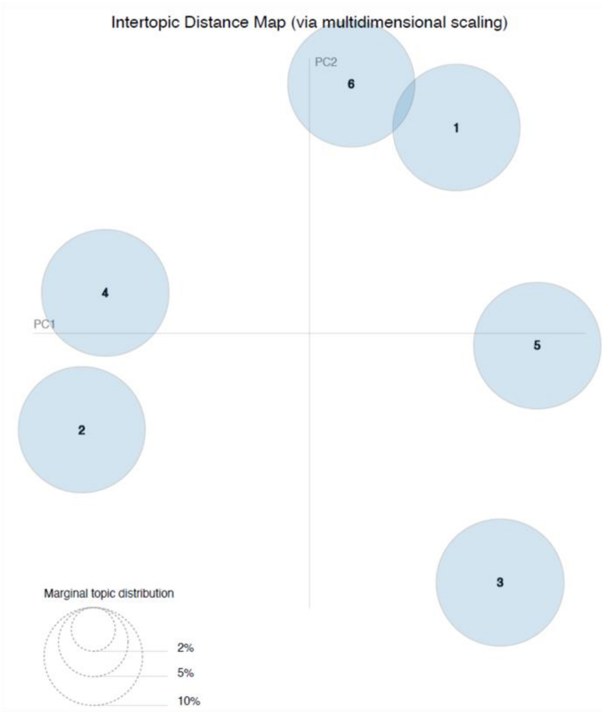
4.2. Question topics

As shown in Figure 4, 6 question topics clustered into 3 themes. The details of the analysis results can be found in Appendix Table 1. Theme 1 revealed that the public was seeking general information and suggestions on CT skills. Among 1,174 questions, nearly 30% were centered on when and why children should learn CT skills (Topic 1). People were curious about “What is the best age to learn programming?” and “What are the benefits of learning programming?” In addition, many parents realized the important role of their involvement in their children’s learning process. They were looking for guidance on how to support their children in developing CT skills (Topic 6).

In Theme 2, people asked for recommendations about the learning tools and platforms for different ages (Topic 2 and 4). For example, “What tools would you recommend for learning programming at an early age?” and “What online platforms do you think best assist kids in learning to code?” People noticed that learning resources were tailored for different age groups. They were convinced that choosing age-appropriate learning resources could support children’s learning effectively. Therefore, we found many questions contained keywords such as “kindergarten,” “primary,” and “pre-college.”

Theme 3 included questions about school curricula and CT frameworks. People asked for details about various CT curricula (Topic 5). As well they showed uncertainty about the relationship among CT education, academic choices, and future career success (Topic 3). For example, they questioned, “What is your perception of the importance of computer science in your children’s education and their future careers?” and “Is learning coding necessary to advance future careers?”

Figure 4. Six topics of the question dataset



Theme 1: Seeking general information on CT skills

Topic 1: When and why to learn CT skills?
age, start, programmer, early, game, coding, begin, benefit, interested, math

Topic 6: How could parents support children’s CT development?
young, parent, platform, make, class, find, education, skill, idea, important

Theme 2: Learning resources

Topic 2: What are the recommended learning tools?
good, program, robotic, resource, tool, scratch, begin, game, fun, introduce

Topic 4: What are the learning platforms for different ages?
year, class, online, good, free, platform, website, grade, thinking, recommend

Theme 3: CT education

Topic 3: What is the relationship between CT and college major and career choice?
computer, science, future, concept, career, degree, python, technology, job, major

Topic 5: What are CT curricula in schools?
school, language, learning, people, teaching, basic, app, student, machine, level

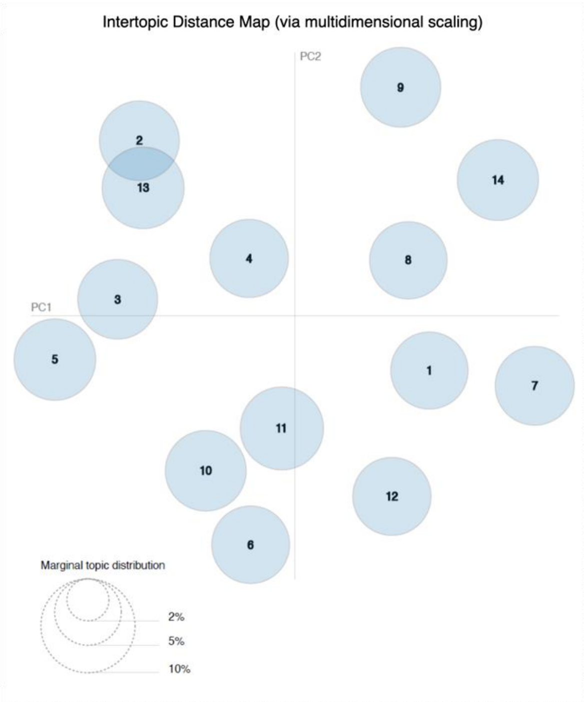
4.3. Answer topics

As shown in Figure 5, 14 answer topics are grouped into 4 themes. The details of the analysis results can be found in Appendix Table 2. Theme 1 focuses on public attitudes and concerns regarding CT education.

Generally, there is a favorable view toward CT learning among the public (Topic 13). Despite these positive views, concerns about the challenges and difficulties in the learning process were also prevalent (Topic 3). It should be noted that people shared doubts and uncertainty about the CT education initiatives in various countries. In Topic 2, people discussed the advantages and disadvantages of extending CT education to people from underdeveloped countries. Some believed that imparting CT skills to impoverished individuals could empower them to escape poverty and lead better lives with their families. However, others opposed that despite the increasing affordability of technology and widespread internet access, obstacles to learning still persisted among economically disadvantaged populations.

Theme 2 consists of people's understanding of the diverse CT knowledge being taught. As CT education gains popularity, individuals are becoming more knowledgeable about the field, sharing extensive information about their understanding of CT concepts and learning content (Topic 4, Topic 5, Topic 6, Topic 11, and Topic 10). Interestingly, while Topic 4 and Topic 5 are closer to Theme 1 in the distance map (Figure 5), after reviewing the representative documents in these topics, we decided to group Topic 4 and 5 to Theme 2. We noticed that although the answers mentioned the keywords related to difficulties and concerns in learning CT concepts and engagement in CT activities, a significant portion of texts focused on introducing the learning contents that children will learn in CT classes. This manual approach to categorizing themes is consistent with studies conducted by Chen et al. (2020) and Cutumisu and Guo (2019).

Figure 5. 14 Topics of the answer dataset



Theme 1: Attitude and concerns with CT education

Topic 2: Difficulties in implementation
reason; day; access; poor; country; demand; education; world; social; low

Topic 3: Difficulties in learning
understand, hard, difficult, question, find, answer, command, error, memory, age

Topic 13: Positive attitudes
enjoy, pretty, friend, happy, age, thing, interest, love, joy, life

Theme 2: Types of CT knowledge

Topic 4: Programming and robotics
robot, drive, function, line, step, object, move, sensor, command, control

Topic 5: CT concepts
code, write, line, type, logic, number, memory, function, read, assemble

Topic 6: Programming languages
language, python, java, programming, basic, JavaScript, web, book, project, recommend

Topic 10: Learning strategies
book, solve, practice, logic, structure, base, follow, beginner, solution, web

Topic 11: Advanced knowledge of programming
machine, learning, data, human, algorithm, model, intelligence, process, deep, train

Theme 4: Career development

Topic 8: Major choices
math, engineering, degree, field, job, college, school, education, major, university

Topic 9: Money rewards
company, job, money, competition, market, google, pay, top, hire, industry

Topic 14: Job requirements
developer, software, career, engineer, application, system, database, industry, field, programmer

Theme 3: School curriculum and CT education framework

Topic 1: Future skills
skill, technology, future, develop, world, creative, think, solve, math, logic

Topic 7: CT curricula
class, online, platform, teacher, provide, offer, curriculum, age, live, session

Topic 12: Game-based learning
game, basic, create, interest, fun, play, easy, scratch, tutorial, block

Theme 3 focused on discussions related to school curricula and CT frameworks. With the increasing integration of mandatory CT classes into school curricula, individuals have come to realize the critical role of CT practices in developing creativity, problem-solving skills, and logical thinking abilities (Topic 1). Moreover, they shared divergent views on school curricula (Topic 7) and instructional designs (Topic 12). Their discussions were not only about in-school curricula and extracurricular workshops for developing CT skills but also explored course designs offered on various online platforms.

Theme 4 discussed CT in career development. People had great expectations for CT learning, considering CT as essential for career advancement (Topic 14). For instance, they viewed CT as "An essential requirement for employment across all fields." and acknowledged that "CT education would significantly influence one's future career trajectory." Consequently, it was not surprising that individuals presumed CT skills would likely lead to greater financial rewards and enhance their prospects of securing decent jobs in the future (Topic 9). In addition, computer-related majors were believed to be more popular than other subjects (Topic 8).

4.4. Comparison between question and answer topics

The topics presented in both the question and answer datasets reveal a clear link between individuals' interest in learning CT skills and their attitudes towards CT education, as well as the expansion of knowledge regarding CT concepts, learning resources, and its potential impact on career development. Moreover, the questions and answers in both datasets highlight the need for accessible and comprehensive CT education resources, including clear frameworks and curricula and effective strategies for integrating CT skills into existing educational systems.

Table 1 summarizes the link between questions and answers. Since a single question may receive numerous answers, and these answers can vary across different topics, we first need to map out the representative topic of each answer corresponding to its question (column 1). Next, we rank the answer topics in descending order based on their frequency (column 2) and calculate the cumulative percentage of the most representative answer topics for each question topic (column 3). For example, in Question Topic 1, Answer topics 1, 8, 9, 13, and 14 collectively account for 61% of answers, while the remaining topics constitute 39%. This grouping facilitates a better analysis of the relationship between the initial inquiries and the corresponding answers.

Table 1. Commonalities and differences among the question and answer topics

Question topics	Answer topics	Accumulate percentage
Topic 1: When and why to learn CT skills?	Topic 1: Future skills Topic 8: Major choices Topic 9: Money rewards Topic 13: Positive attitudes Topic 14: Job requirements	61%
Topic 2 & 4: What are the recommended learning tools? What are the learning platforms for different ages?	Topic 4: Programming and robotics Topic 5: CT concepts Topic 6: Programming languages Topic 10: Learning strategies Topic 11: Advanced knowledge of programming	92%
Topic 3: What is the relationship between CT and college major and career choice?	Topic 8: Major choices Topic 9: Money rewards Topic 14: Job requirements	70%
Topic 5: What are CT curricula in schools?	Topic 2: Difficulties in implementation Topic 7: CT curricula Topic 12: Game-based learning	64%
Topic 6: How could parents support children's CT development?	Topic 3: Difficulties in learning Topic 7: CT curricula Topic 12: Game-based learning	67%

As demonstrated in Table 1, the topics in the question dataset indicate the high value that people place on CT skills. They sought extensive information about when and why to learn CT (Question Topic 1) and asked for recommendations on learning resources (Question Topics 2 and 4). The answer dataset contains substantial and relevant answers addressing these question topics. The answers discussed the multifaceted benefits associated with acquiring CT skills, the positive impact on students' future career development, and attitudes toward CT learning (Answer Topics 1, 8, 9, 13, and 14). Furthermore, the answer dataset reveals that users actively exchange various forms of CT knowledge (Answer Topics 4, 5, 6, 10, and 11) to offer suggestions, provide references, and share their own learning experiences within the community. These discussions indicate the widespread popularity and the growing significance of CT skills today.

Next, Question Topic 3 in the question dataset discusses the relationship between CT learning and major/career decisions. Relevant answers can be found in Answer Topics 8, 9, and 14 in the answer dataset. People discussed the positive influence of CT skills on academic performance in diverse subjects (Answer Topic 8) and underscored the significance of CT skills in the job market (Answer Topic 9 and 14). Particularly, individuals offered their perspectives on the relevance of CT skills and the salary disparities among different domains. These insights emphasize the importance of CT education for career advancement and the growing demand for CT knowledge across various job fields.

Question Topic 5 in the question dataset focuses on school curricula. In the answer dataset, 3 topics consist of discussions about CT curricula (Answer Topic 7) and the implementation of CT initiatives (Answer Topic 2). Interestingly, game-based learning (Answer Topic 12) emerges frequently in these discussions, indicating its popularity as an effective teaching approach for imparting CT skills.

Questions in Topic 6 center on seeking guidance and suggestions on parental support for children's CT development. People expressed curiosity and uncertainty about how to effectively assist their children's learning in the CT domain. However, it is noteworthy that the posts in the answer dataset only mentioned the difficulties associated with CT learning (Answer Topic 3) and school curriculum (Answer Topic 7 and 12) rather than providing specific suggestions on parental support. Nevertheless, it does highlight the prevailing challenges that individuals encounter while trying to facilitate their children's CT skill development.

Despite the inherent connection between the question and answer datasets, questions and answers convey distinct perspectives regarding public perceptions of CT education. Since questions typically serve as initial inquiries into CT education, they often only touch upon a limited number of topics of public concern. In contrast, answers offer a broader range of insights into individuals' understanding of CT education. For instance, questions may inquire about the appropriate age and purpose of learning CT skills (Question Topic 1), whereas answers not only provide information on the benefits of CT education for students (Answer Topic 1, 8, 9, and 14) but also reveal the attitudes and opinions held by individuals towards CT education (Answer Topic 13). In addition, Topics 2 and 4 in the question dataset only focus on learning resources. However, the corresponding answers not only offer valuable recommendations on learning tools and platforms (Answer Topics 4 and 10) but also delve into discussions on various CT concepts and programming languages (Answer Topics 5, 6, and 11).

The differences between questions and answers suggest that while the public may ask general questions on the platform, other users go further and are willing to share their knowledge and perspectives on specific topics related to CT education. Such communication can help individuals make informed decisions, leading to increased public engagement and a sense of community around CT education.

5. Discussion

To summarize findings from our questions and answers dataset, we created a table to illustrate public perceptions of CT education (see Table 2.). These perceptions are further discussed in the following subsections.

Table 2. Summary of public perceptions

Dataset	Public perceptions
Questions	1. People were eager to seek general information and suggestions on CT skills. 2. People recognized the importance of differentiating learning tools and platforms for different age groups 3. People held uncertainty and doubts about the relationship between CT education and future academic choice/career success, as well as school curricula.
Answers	1. People showed positive attitudes, however, they were worried about the difficulties children may face in the learning process. 2. With the increasing popularity of CT education, individuals have become more familiar with this field. 3. People acknowledged the widespread and unavoidable trend of integrating CT classes into mandatory curricula. However, they worried that school curricula and instructional designs were outdated and not engaging. 4. People had high expectations for CT education, considering CT skills essential for career advancement.

5.1. Major topics in questions

In Topics 1 and 3, people showed feelings of apprehension and uncertainty about new education initiatives. In previous research, there is a long-standing debate about whether children should learn to code and how early kids should learn to code (Hsu et al., 2018; Lye & Koh, 2014). In this study, similar results were obtained that the most commonly asked questions surrounded when and why children should learn CT skills. People sought information on "What is the best age to teach children basic concepts of computers and begin programming learning?" and "What is the benefit of learning CT skills?" On the one hand, people hoped to get positive and constructive answers to these questions, on the other hand, some individuals were also apprehensive that these skills may be limited to children aspiring to become programmers. For example, "Are there any benefits to learning how to code for kids who don't want to be programmers later on in life?" and "Do the advantages of [learning to code] outweigh the disadvantages?" These examples illustrate the uncertainty and doubts involved in the discussions of what children gain from learning programming.

In Topic 6, many people believed that parental support plays an important role in children's learning process. A large body of literature has shown the positive impact of parental involvement (PI) on students' academic success (Ma et al., 2016; Pereira et al., 2014). PI can promote a positive learning environment for children (Park et al., 2017). In addition, research findings demonstrated a strong relationship between PI and educational outcomes, including school attendance and higher grades (Boonk et al., 2018; Zellman & Waterman, 1998). In this study, there are a series of questions posted by parents related to supporting children in learning. For example, "How does a non-tech parent teach their children coding?", "What methods should parents use in order to teach their kids programming languages?" and "Where can I find a parental guide for teaching programming to kids?" Although parents assumed that their involvement in CT education could enhance their children's learning experience, improve academic performance, and extend teaching outside the classroom, they faced challenges due to the relative novelty of the subject. The limited knowledge of parents in computer science and lack of guidance from schools made it challenging for them to provide adequate support and involvement in their children's CT education.

Community users asked for suggestions on CT learning tools and platforms, but they seemed to struggle to identify appropriate information to support their learning needs (Theme 2). For example, they asked, "What are the best tools for an 11-year-old kid who wants to learn more advanced programming?" and "What tools would you recommend for kids aged 6 to 9 to learn programming?" In total, 399 (33.99%) questions were related to queries about CT learning resources. The findings indicate that a growing number of resources are available for developing CT skills. The public, however, has become more bewildered in facing an array of choices. People experienced feelings of confusion and uncertainty "I am not sure which platform would be a good choice to start with?" and "[It is] hard to find an appropriate one among online learning websites, [Does] anyone have any good suggestions?"

Surprisingly, when people raised questions on relationships among CT skills, college majors, and career development (Theme 3), they also pointed out the problems of education inequity between rich and poor. For example, they were curious about "Why do many individuals with internet access and low income not leverage coding skills to enhance their financial well-being? What additional barriers hinder their pursuit of this opportunity?" "How is it possible for poor kids in Africa to learn and earn from coding?" and "How do you feel when you see platforms like freeCodeCamp are able to help underprivileged kids learn programming?" Therefore, instead of simply advocating a promising future for CT education, people seemed to be concerned about others and wondered about how to create diverse, equal, inclusive, and sustainable education communities.

5.2. Major topics in answers

First, Quora users showed positive attitudes toward CT education (Topic 13). This aligns with prior research (Kong & Wang, 2021; Maruyama, 2019; Yu et al., 2020) that people viewed CT classes as enjoyable and engaging, particularly through hands-on activities. Additionally, CT education was acknowledged for its advantages in improving problem-solving abilities, creativity, and logical reasoning among children. For example, people posted that "CT practices promote logical thinking and enhance creativity" and "By designing games, writing code, and completing projects, CT education transforms basic coding skills into real-world experiences that are engaging and enjoyable!" Interestingly, within Topic 13, 228 out of 639 answers (35.68%) emphasized the importance of collaboration and communication skills in CT activities. This highlights a widespread belief that CT education develops children's social skills through collaborative activities. People wrote, "When children collaborate with their peers to create projects, they not only enhance their problem-solving abilities but also foster valuable skills in collaboration and communication."

Second, CT education initiatives faced many doubts, particularly in underdeveloped nations (Topic 2). Some teachers expressed concerns about potential delays in implementation and the quality of teaching, for example, "A shortage of adequately trained teachers for CT instruction, combined with teaching resource constraints, since not all schools have computer labs." Similar findings were reported in previous research that teachers perceived adequate training and guidance in combining CT activities with current teaching content (Greifenstein et al., 2021; Wong et al., 2015). However, it's important to note that previous studies were conducted in schools that were well-equipped with educational resources, including computer labs, stable networks, and well-trained teachers (Bocconi et al., 2022). In these schools, both teachers and students benefit from internet access and computer facilities, which is not typically the case in schools serving low-income households. Schools in these economically disadvantaged districts typically have larger class sizes and lower per-student expenditures. A recent survey in the United States revealed that 65% of participants with incomes below the federal poverty level reported their children were unable to participate in classes or complete schoolwork due to a lack of access to a computer or the Internet (Katz & Rideout, 2021). This study yielded similar findings, including comments like "In some countries, computer accessibility is significantly worse with ratios like 400 students per computer. I believe that in areas with income disparities, it is inevitably an unequal distribution of technology access and computer-based education." Given these findings, it is crucial to recognize that participants in previous studies did not represent all social groups, particularly those from marginalized or underprivileged communities.

Third, with the increasing number of schools revising their curricula to introduce CT to K-12 students (Bocconi et al., 2022), people shared varying opinions on school curricula and instructional design (Theme 3). Many individuals acknowledged the widespread and unavoidable trend of integrating CT classes into mandatory curricula. This shift received extensive positive support, with numerous remarks emphasizing its importance and benefits, such as "I support the initiative that students should be taught coding at a young age." They also anticipated that "Schools have competent teachers, well-structured curricula, and dedicated faculties focused on children's development." In addition, they hoped for curricula "designed to teach children real-world problems and how to solve them."

Compared to high expectations for school curricula, teachers, parents, and IT professionals argued that they were boring and outdated. For example, "Current school curricula are perceived as dull and obsolete, leading parents to seek more engaging alternatives that are practical, informative, interactive, and enjoyable." and "School curricula need to adapt to the changing landscape." Further, some critics questioned the competence of current school curricula. They believed that "Teaching and learning creativity and problem-solving skills, particularly in combining with coding, demand extensive planning, research, and engineering." These differing opinions suggest a need for ongoing evaluation and improvement of the school curricula to meet the needs and expectations of all individuals involved.

Lastly, people seemed to overestimate the importance of CT skills. A lot of answers from non-experts in CT showed high expectations that children learning programming could lead to decent job opportunities and good pay (Theme 4). Moreover, some individuals held the belief that computer engineering jobs offer superior prospects compared to other jobs. For instance, "Programmers are in high demand and typically receive higher salaries compared to other professions." and "A major in computer-related fields can lead to opportunities where, if one is diligent or exceptionally talented, they are highly sought after by many companies, well-paid, and granted a considerable degree of freedom." However, this over-optimistic expectation might pose a burden for children if their parents excessively focus on monetary outcomes. Previous research has shown that when children are burdened with excessive expectations, they may experience frustration and even depression (Ma et al., 2018). As a result, they find less joy in learning and perform worse than expected. Conversely, students who are not overly influenced by their parents' high expectations tend to derive more enjoyment from learning and can concentrate better on the learning process. Hence, parents must recognize the possible adverse effects of having excessively high expectations on their children's emotional well-being and learning experience.

5.3. Insights from questions and answers

New education policies and reforms are often faced with people's uncertainty and doubts. In this study, the most frequently asked question was, "When and why should children learn CT skills?" The answers contained uncertainty as well. Many people shared doubts regarding school curricula and the expected learning outcomes. This is probably because of risk-taking. Previous research argued that risk-taking is embedded with uncertainty in educational change and innovation (Cooke et al., 2020; Le Fevre, 2014). New education policies and curricula usually mean a significant shift from what people are used to. As a result, people may be hesitant to accept these changes. It is worth noting that individuals may view CT education as limited to computer programming.

Therefore, they were concerned that children may only focus on CS subjects and miss out on opportunities in other areas of interest. These doubts thus lead individuals to believe that the changes brought about by CT education will have a negative impact on their children's education.

Another issue faced by schools and parents is PI in children's learning. Interestingly, all the questions received several to dozens of answers except those regarding parental support in children's learning (e.g., "How to support children in learning?"). It is noteworthy that many people realized the importance of PI and attempted to seek guidance on PI in children's learning, but no respective answers were posted in the answer dataset. There are two possible reasons. First, since CT concepts and education initiatives are relatively new to the public, most people lack prior experience and knowledge of PI in CT learning, which becomes a barrier to knowledge sharing. Second, some obstacles hinder some parents from participating in their children's education. With the innovative evolution of technology and K-12 CT education initiatives, increasing numbers of children are learning via digital devices while at home. This trend raises new challenges for PI in digital spaces. Recent studies found that parents' concerns toward technology become an important factor influencing their motivation in digital learning spaces (Gonzalez-DeHass et al., 2022; Hammer et al., 2021; Papadakis et al., 2019). Further, parents' sense of digital efficacy also influences their parental efficacy in the learning process (Wong & Lee, 2017). Given that CT learning involves many practices on computers or other digital devices, some parents may be concerned about excessive screen time and addiction to digital devices. Additionally, parents may lack confidence in guiding and supporting their children's learning with digital devices and platforms. These factors potentially hinder their ability to provide effective support and be involved in their child's CT learning.

6. Conclusion

This study examined public perceptions of CT education by analyzing questions and answers on the Quora platform. The findings enhanced our understanding of public concerns and attitudes toward CT education. Applying LDA techniques, our study identified 6 topics among questions and 14 topics among answers. The findings could shape education policymaking, facilitate curriculum designs, and inform future research directions.

6.1. Implications

The findings suggest two theoretical implications. First, applying the LDA method to analyze social media data proves to be a valuable research method for investigating public perceptions of educational issues. This approach not only offers a general view of the text data but also quantifies the public attitudes and opinions towards CT education. This method also addresses limitations in traditional questionnaires and interviews in previous studies. Future research could employ this method as a triangulated research methodology to obtain a more comprehensive understanding of stakeholders' perspectives on various educational topics.

Second, the results of this study provide both qualitative and quantitative insights into public responses to education policies and practices. The major themes and distribution of posts on each topic reflected the public perspectives on CT education, including uncertainty and apprehension toward CT initiatives, the diverse types of CT knowledge, debates over the current CT curriculum, and the role of CT in career development. This study also helped to identify areas where further research and policy development may be needed to address concerns and meet the needs of diverse stakeholders. For example, future researchers may consider integrating PI as an additional means of support in fostering children's CT development and investigate its impact on children's CT skills. Additionally, game-based learning should be widely promoted as an effective approach to increase engagement and motivation within CT education.

This study also offers practical implications for educational institutions and instructors. First, schools should provide adequate guidance and training for teachers. The rapid advancement of educational technologies gave rise to a lot of learning tools in CT education. Thus, educators are now faced with a range of options to augment teaching and stimulate students' engagement in the classroom. However, a lack of professional training and guidance for integrating these tools into CT classes could potentially impact effective teaching, consequently impeding students' CT skill development. Therefore, schools should provide pedagogical training on teaching strategies, tools application, and evaluation methods. As well, teachers should have a mindset of continuous improvement.

Besides, to better facilitate CT tools application, it is recommended that educational institutions establish a database offering detailed information and clear descriptions regarding the usage of these tools, targeted age groups, and recommended assessment methods. Specifically, the database should include a wide range of plugged and unplugged tools. Each tool entry should include empirical evidence to support its effectiveness and offer guidance on how to utilize it in CT activities.

Third, schools should provide collaborative learning opportunities to address parents' concerns and anxieties. These opportunities will enhance parents' programming knowledge through hands-on experiences in programming activities with their children. For instance, schools could organize parent-child CT workshops and summer camps. These activities not only enhance children's engagement and CT performance but also improve parental involvement. Additionally, technology companies could develop more interactive and user-friendly CT tools that parents can easily use to support their children in learning.

Fourth, educational institutions could use Q&A platforms to answer academic queries from the public. Thus, students and parents will improve their understanding of education issues. In addition, these institutions could create virtual interest groups to facilitate communication among enrolled students, future students, and alumni. The information, such as learning frameworks, school curricula, and instructional design, could inform the public about key stages of CT development and provide explicit guidance on teaching and learning. These efforts could effectively reduce public uncertainty and build trust among stakeholders. Moreover, this could promote an inclusive environment that encourages the public to engage and participate in CT initiatives.

6.2. Limitations

Although the findings of this study provide valuable insights into the perceptions and concerns toward CT education, a few limitations should be noted. First, data collection was only conducted on the Quora platform. It may not fully represent all stakeholders' perspectives on CT education. Therefore, it is recommended to extend the data collection to other social media platforms to obtain a more comprehensive understanding of the topic. Further, the datasets used in this study are exclusively in English. As a result, there may be potential language and cultural biases in the findings. To mitigate this limitation, future research should consider text data in other languages for more diverse perspectives on CT education. Second, the posts on Q&A websites may change over time. Since this study did not take into account the time of posting, the dynamic trend of the public's perceptions remains unknown. Considering the ongoing evolution of CT education initiatives and curriculum reforms, understanding how public discussions on social media evolve is equally important. Third, the geographical distribution of posts in this study is mainly centered in the USA. As a result, the findings may not be generalizable to all populations around the world. To enhance the applicability and validity of the results, future studies should consider collecting data from other regions. There are many Asian countries, such as Japan, China, and Singapore, have introduced CT courses into K-12 education. The discussions from these countries would provide valuable insights into how CT education is implemented, perceived, and discussed in different cultural and educational contexts.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Six topics of the question dataset generated through LDA topic modeling

Topic label	Top 10 words	Topic rate (%)	Document counts (%)	Examples
Theme 1: Seeking general information on CT skills				
Topic 1: When and why to learn CT skills?	age, start, programmer, early, game, coding, begin, benefit, interested, math	16.60%	318 (27.09%)	"At what age can children learn simple programming?" "What are the benefits of learning programming?"
Topic 6: How could parents support children's CT development?	young, parent, platform, make, class, find, education, skill, idea, important	16.60%	114 (9.71%)	How can I help my children learn about computers?
Theme 2: Learning resources				
Topic 2: What are the recommended learning tools?	good, program, robotic, resource, tool, scratch, begin, game, fun, introduce	16.60%	218 (18.57%)	What are the resources you recommend learning to program at an early age?
Topic 4: What are the learning platforms for different ages?	year, class, online, good, free, platform, website, grade, thinking, recommend	16.70%	181 (15.42%)	Are there any better online platforms that help kids to learn to code?

Theme 3: CT education				
Topic 3: What is the relationship between CT and college major and career choice?	computer, science, future, concept, career, degree, python, technology, job, major	16.80%	195 (16.61%)	How important or unimportant do you think computer science is to your kids' education and their future careers?
Topic 5: What are CT curricula in schools?	school, language, learning, people, teaching, basic, app, student, machine, level	16.70%	148 (12.61%)	What is primary schools' curriculum to teach children how to code?

Appendix 2. 14 topics of the answer dataset generated through LDA topic modeling

Topic label	Top 10 words	Topic rate (%)	Document counts (%)	Example
Theme 1: Attitude and concerns with CT education				
Topic 2: Difficulties in implementation	reason, day, access, poor, country, demand, education, world, social, low	7.20%	523 (6.93%)	"Programming has a serious diversity problem, and the ceiling for poor people can be as hard as concrete. "
Topic 3: Difficulties in learning	understand, hard, difficult, question, find, answer, command, error, memory, age	7.10%	186 (2.46%)	"…kids should not be oriented to learn the difficult concepts of coding from a very early age."
Topic 13: Positive attitudes	enjoy, pretty, friend, happy, age, thing, interest, love, joy, life	7.50%	639 (8.47%)	"It teaches a child's fundamental skills in coding and translates them into a real-world experience that is engaging, enjoyable, and fun! "
Theme 2: Types of CT knowledge				
Topic 4: Programming and robotics	robot, drive, function, line, step, object, move, sensor, command, control	6.90%	423 (5.61%)	"You can start with robotic classes… is a great way to concretize your basics and skills over time."
Topic 5: CT concepts	code, write, line, type, logic, number, memory, function, read, assemble	6.80%	495 (6.56%)	"Programming concepts such as data type and loops or some statements etc."
Topic 6: Programming languages	language, python, java, programming, basic, JavaScript, web, book, project, recommend	7.50%	558 (7.39%)	"...once your skills progress, work your way up to JavaScript, SQL, and other more complex coding languages."
Topic 10: Learning strategies	book, solve, practice, logic, structure, base, follow, beginner, solution, web	7.30%	381 (5.05%)	"…follow a 2:1 ratio between conceptual learning and applied learning to practices…"
Topic 11: Advanced knowledge of programming	machine, learning, data, human, algorithm, model, intelligence, process, deep, train	7.80%	346 (4.58%)	"Your kids will start with core programming concepts, and they will have an excellent understanding of artificial intelligence, machine learning..."
Theme 3: School curriculum and CT education framework				
Topic 1: Future skills	skill, technology, future, develop, world, creative, think, solve, math, logic	6.70%	837 (11.09%)	"Learning to code will improve a child's abstract thinking, logic, problem-solving skills but also increases creativity and concentration."
Topic 7: CT curricula	class, online, platform, teacher, provide, offer, curriculum, age, live,	7.00%	821 (10.88%)	"...as a part of the existing classroom curriculum or as an extracurricular assignment...parents are also

	session			increasingly turning to online coding programs for their kids.”
Topic 12: Game-based learning	game, basic, create, interest, fun, play, easy, scratch, tutorial, block	6.90%	675 (8.94%)	“Your kids can use code to build their own games, animation, and apps, fundamentally changing their relationship to technology from consumer to creator.”
Theme 4: Career development				
Topic 8: Major choices	math, engineering, degree, field, job, college, school, education, major, university	6.70%	559 (7.41%)	“I want to be an engineer…I chose CS for my university major, and it helps a lot.”
Topic 9: Money rewards	company, job, money, competition, market, google, pay, top, hire, industry	7.20%	446 (5.91%)	“Working in IT is usually paid pretty well.”
Topic 14: Job requirements	developer, software, career, engineer, application, system, database, industry, field, programmer	7.40%	658 (8.72%)	“This has become a basic requirement for jobs in all fields.”