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Designs and practices using generative AI for sustainable student discourse and knowledge creation

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Abstract

Utilizing generative artificial intelligence, especially the more popularly used Generative Pre-trained Transformer (GPT) architecture, has made it possible to employ AI in ways that were previously not possible with conventional assessment and evaluation technologies for learning. As educational use cases and academic studies become increasingly prevalent, it is critical for education stakeholders to discuss design considerations and ideals that are key in supporting and augmenting learning via quality classroom discourse that sets the climate for student learning and thinking, and teachers' transmission of expectations. In this paper, we seek to address how emergent technological advancements such as GPT, can be considered and utilized in designs that are consistent with the ideals of sustainable student discourse and knowledge creation. We showcase contemporary exemplars of possible designs and practices that are based on the pedagogy of knowledge building, with recent illustrations of how GPT may be utilized to sustain students' knowledge building discourse. We also examine the potential effects and repercussions of technological utilization and misuse, along with insights into GPT's role in supporting and enhancing knowledge building practices. We anticipate that the findings, through our exploration of designs and practices for knowledge creation, will be able to resonate with a broader audience and instigate meaningful change on issues of teaching and learning within smart learning environments.

Keywords: Generative artificial intelligence, Generative pre-trained transformers, Sustainable student discourse, Knowledge building, Knowledge creation

Introduction

The development and implementation of Artificial Intelligence (AI) has significantly evolved in the past few decades, from a fledgling concept of human intelligence emulation, into a peak global interest that pervades all walks of life, with capabilities to disrupt and potentially mold new ways of living. This phenomenon has become widespread and is undeniably impactful on education, with possibilities that are promising, but can also be potentially overhyped (Holmes, 2019). We can learn from the history of AI development, particularly the AI winter in the 1980s, when AI research and development suffered a loss in interest and funding, following the unfulfilled ambitions and unrealistic

promises of AI abilities by scientists and companies (Hendler, 2008). Hence, even with untapped potential to create impacts by augmenting human intelligence with machine intelligence for educational research and purposes (Yang, 2021), there is also growing unease at how AI can sustainably do so (Vinuesa et al., 2020) without repeating the history of bringing AI into another winter. There remains a critical need to investigate how AI can be responsibly designed, implemented, and evaluated in a sustainable manner, especially in the education of the next generation of students who will eventually bring forward a new wave of designs and developments for AI-enabled learning.

In the field of education, the quality of classroom discourse is considered a prominent focus in discussion of school reform (Cazden & Beck, 2003) and remains an important area of study, with multi-perspective research that investigates the quality of productive student discourse (e.g., van Boxtel & Roelofs, 2001) and more recent studies that tap on emergent technologies to discern quality of ideas (e.g., Lee, 2021) and to achieve better student learning gains (e.g., Grenander et al., 2021). Other significant challenges have since emerged, predominantly centered around the search for feasible designs to sustain students' pursuit of inquiries and reflections during discourse (Yang et al., 2020), and the infrastructures and frameworks required for sustaining innovations in student discourse (Kashi et al., 2023). Most of these efforts are banking on combinations of emerging technologies including AI to bridge the mentioned gaps and it is inevitable that future research will build on and have increasing reliance on related developments.

However, the use of AI-related approaches and methods within educational studies also brings about its own set of affordances and challenges, in the midst of researchers' efforts in developing smart learning environments not just for learners, but other stakeholders including teachers and administrators. There remains the need for a collective and better understanding of such technological advancements in the learning spaces. Hence, even though the emergence of generative AI (GAI) is not a newly discovered piece of technology or invention, the surge of interest in the wide-ranging affordances and capabilities of GAI does bring about great concern about how this development, which is still undergoing heavy research and experimentations, can potentially impact and sustain learning through discourse. What is more concerning will be how GAI synthesizes content—be it summaries, connections, suggestions, or recommendations—and does so in a way that is very similar to a human and at times superseding what a human can create (LaGrandeur, 2021), and leading to blurred lines between authentic students' outputs, intentional plagiarism, and AI-generated content.

A popular application of generative AI is ChatGPT (OpenAI, 2022), which has enjoyed a sudden surge in popularity with its share of fans and critics, while also creating heated debates concerning whether it should be banned or harnessed for education. In a general learning context, generative AI can serve a variety of functions and purposes, including the creation of personalized content for individual learners, the generation of engaging and realistic simulations or appealing virtual environments for learning, and assisting with creative tasks in the fields of science, technology, engineering, arts, and mathematics (STEAM). On the flip side, there are already growing concerns about the ethical use of generative AI, particularly concerning the possibility for the technology to create misleading, false, and damaging mistruths, or act as nontraditional shortcuts for students to complete assigned tasks.

Hence, there is a need to adhere to overarching principles and approaches that are theory-based and evidence-driven, to form the basis for how we think about the usage of GAI for teaching and learning, and not be distracted by the technology but to be focused on the process and outcomes that we want to achieve in class and with the students. We seek to answer these questions: “Can generative AI be beneficial for sustaining student discourse and knowledge building?” and “How do we envision and imagine this to be conducted in the classrooms?” This paper focuses on how generative AI can be used to support these efforts and processes in the context of idea-centric student discourse and learning in authentic smart learning environments.

Background

In this section, we highlight the origins, implementations, and implications of generative AI, followed by the importance of supporting and sustaining student discourse via knowledge building, and an overview of existing efforts and the associations between GAI, sustenance of student discourse and knowledge building.

Generative AI and emerging applications in education

Exemplars of generative AI in the form of chatbots have been around since the 1960s but in the past decade, it has been growing in prominence due to the introduction of generative adversarial networks (GANs) in 2014 by Ian Goodfellow and his colleagues (Goodfellow et al., 2020). GANs have huge capacity and enormous potential in replicating and mimicking distributions of data, and they can also be taught to produce real-world-like objects and artifacts across a wide range of domains and subject matter. This development is viewed to be very disruptive to the current landscape. For instance, it is currently very challenging to tell the difference between genuine events and content that have been digitally manufactured, due to synthesized material such as deepfakes videos (Westerlund, 2019).

Among the underlying rationale and reasons why generative AI has garnered so much traction in recent years, several explanations (Dwivedi et al., 2023; Baidoo-Anu & Owusu Asnah, 2023) have pointed out that users sought innovation and novelty that can dramatically speed up task completion. However, there remain some detrimental factors in how incorrect information can be synthesized and the prevalence of inherent bias and ethical concerns from trained datasets. These limitations however do not deter most users from wanting to generate copious amount of content and material at a whim and with almost human-like similarity and accuracy. Without going too deep into technical details, generative AI as a category of AI algorithms generates new outputs based on the data they have been trained on, unlike traditional AI algorithms that are limited to pattern recognition and prediction of results. Generative AI can create new content in the form of videos and imageries, textual and audio information, via a variety of applications of image synthesis, semantic image editing, classification and so on (Creswell et al, 2018).

Recent developments and advancements in deep learning and extant literature have also led to the emergence of another family of neural network models that use the transformer architecture, Generative Pre-trained Transformer (GPT; Brown et al., 2020), which uses a large amount of publicly available digital data with Natural Language

Processing (NLP) to read and produce human-like language on almost any topics. From initial use cases ranging from game settings as part of ad-hoc conversations with non-playing characters (NPCs) to customer-service chatbots for commercial transactions, a more sophisticated GPT-3 was developed (Brown et al., 2020); it became the family of neural network models behind the application ChatGPT that attracted worldwide attention with a myriad of applications across various contexts. As technology advances, newer versions of GPT such as GPT-4 have been launched and improved by OpenAI, the company behind the ChatGPT application, with the proclamation that future versions of GPT will be trained with more parameters and become substantially more powerful to process and produce more accurate and fluent content that even includes multimedia.

Within the education landscape, the ability to create synthetic media has long been sought after, since there is great potential and benefits from creating tools and content that benefit student learning and teaching practices (Sykes et al., 2008), although these can also be a threat to society if they are used in unethical and unregulated manners. Considering that generated content will be based on large language models that the algorithms are trained on, which inherently consist of content from global and diverse sources, this feature of generative AI highlights the potential benefit of augmenting knowledge building discourse by providing an alternative source of ideas for authentic problems that are naturally diverse due to the varying sources of content (Scardamalia, 2002). As a result of such usage, most knowledge builders will then be able to readily relate the application of ChatGPT with key knowledge building principles (Scardamalia, 2002) and align them to the affordances of this particular AI feature. In this paper, we use ChatGPT as a platform to test our design considerations and proposed scenarios for potential use cases in supporting knowledge building due to the surge in usage and growing prominence of ChatGPT as a leading application that is being used worldwide (Baidoo-Anu & Owusu Asnah, 2023). Other generative AI rivals are anticipated to eventually be able to perform similarly with our design considerations and scenarios.

Importance of studying student discourse and sustaining it

From preschool through K-12 education to higher education, there are evidence of growing emphasis on classroom interactions and collaborations (Blumenfeld et al., 1996; Dillenbourg, 1999; Ligorio et al., 2005). The discussions by students that take place in the classroom, also known as student discourse, are undoubtedly critical to learning and the quality of classroom discourse is important in setting an optimal climate for learning and communication of teachers' expectations for student learning (Nystrand et al., 1997). Because student discourse is so fundamental to teaching and learning activities, not only is it more rigorous and purposeful, the interactions that take place are also highly complex, and thus student discourse has become a frequently studied topic in the field of the learning sciences.

Existing student discourse and related practices can, however, be improved in terms of allowing discourse to be more pervasive, encouraging all stakeholders (teachers and students) in the classroom to play co-contributory, active and diverse roles in discourse (Chuy et al., 2011), and engage discourse practices to be sustainable within and beyond the classroom. With the inclusion and integration of emergent technologies for education, the alignment of classroom-based digital technologies with a dialogic pedagogy can

potentially bring about transformative learning (Major et al., 2018). Further, as discourse expands into the public realm and students become influenced by exposure afforded by social media, it is timely to get students to adopt information critically and constructively from the internet into classrooms (Chan et al., 2019). With the pervasive integration of inquiry-based learning, project-based learning, and integration of collaborative technology into current classroom environments, teachers and students will be able to engage in rich, open, and self-directed conversations that are also sustainable for the long run without compromising the rigor of knowledge work.

Role of knowledge building in supporting and sustaining student discourse

In moving away from the prevalent teacher-centric learning patterns and encouraging students' agency in initiating and sustaining discourse, knowledge building (Scardamalia, 2002) is an appropriate approach and pedagogy that is principle-based, with practices which consist of dialogue moves that participants can use to theorize, question, ideate, and build on each other to create newer knowledge or improve ideas, as part of collective efforts to advance community knowledge. The suite of principles, practices, and recommendations generated through knowledge building research (Scardamalia & Bereiter, 2014) are able to answer the call by the Organization for Economic Co-operation and Development (OECD) to allow learners to create new value as they question the status quo, collaborate with others, and think outside the box as they learn to navigate by themselves through unfamiliar contexts (OECD, 2019). In essence, working within the paradigm of knowledge creation in education requires one to demand from its contributors the ability to generate, critique, improve upon, and synthesize ideas.

The traditional method of knowledge builders' generation of ideas and content originated from verbal sharings and written discussions in a pen-and-paper fashion; it evolved into knowledge building on digital platforms such as Computer Supported Intentional Learning Environments (CSILE) and a later current version known as the Knowledge Forum (Scardamalia, 2004), with both online discourse platforms supporting knowledge building. Knowledge builders on the Knowledge Forum write online posts (thereafter known as Knowledge Forum *notes*) to introduce, share, discuss and debate about a concerned topic, in a non-exhaustive list of claims, thoughts, shared information, ideas, and even methods and strategies to resolve problems and issues. Two key characteristics of knowledge building discourse stand out from other approaches and we postulate these can facilitate and sustain student discourse in the longer term.

Firstly, the implementation of the knowledge building approach focuses less on arguing and more on finding out what is a better understanding of a line of inquiry, usually in response to uncertainties in discussions, which play the key roles in moving shared knowledge forward. For example, in encouraging knowledge building discourse that is idea-centric in nature, it becomes paramount to bring about a design mode discourse (Bereiter & Scardamalia, 2003) in classrooms to support and reflect the value of fairness, equity, and respect for all when evaluating and building on peers' responses. When students are able to make themselves heard and acknowledge theirs and others' ideas that can be presented on the same stage with fair treatment, they undertake greater responsibility for their own work and exhibit greater agency in wanting to pursue better ideas

and improve their work. These knowledge creation and building processes take considerable time and effort and consequently help sustain the student discourse.

Secondly, knowledge building environments and discourse allow students to work on real ideas and authentic problems that are relevant and not easily answerable from classroom experiences. When students draw on external assistance to understand, newer ideas to inspire, and better information to reason, they realize the relevance, importance, and possible impact that their work can have on possibly shaping the society that they are living in and classrooms of the future. The tasks and assignments that students seek to complete no longer remain short-term tasks solely for assessment purposes, but rather important steps that everyone in the same community have to be part of in order to achieve long-term goals.

Current efforts and potential in using GAI for knowledge building and sustaining student discourse

Works related to generative pretrained transformer (GPT) for educational purposes are already existent in the years prior to the nascent rise and surge of GPT-related attention in recent times. However, these works (e.g., Li et al., 2022; Phillips et al., 2022) are mostly evaluative or functional for the studies' purposes and often demonstrate what GPT is already known for, that is, summarization and synthesis of information not found in the original source text. These phenomena are present because in most prior research studies, there is either limited relevant data for training models or research groups are unable to scale due to safety or ethical compromises. The other elephant in the room for a functional and publicly accessible large language model (LLM) is associated with daily running costs. Hence, when OpenAI's large language models (LLM) in the form of GPT3 and GPT4 were introduced with large financial backings, researchers and end-users were able to gain access to state-of-the-art LLMs with minimal setup and accessibility costs and are henceforth able to start working on new AI-enabled solutions that were previously unfeasible or not yet established.

With easier access to LLMs and based on the affordances from GAI, it has become more feasible for education stakeholders to address the common patterns of classroom talk, which are often dominated by closed and short answer questions that usually end with factual and procedural knowledge, and teacher-centered Initiate-Response-Explain discussions (Kwek, 2020). By tapping on GAI to generate a range of new and realistic artifacts, students will no longer be limited to prior references or older materials, but instead become more exposed to a wider and novel range of non-repeated information that can aid their thinking and improvement of ideas, and therefore contribute to the sustenance of student interests and ensuing discourse.

With better expert advice guided by GAI and for teachers to utilize, GAI can be harnessed to support collaborative learning via the automation of achieving learning outcomes, such as desired collective performance of students and selected content of student discourse (Lee & Tan, 2017b), and also by supporting the social interaction processes including discourse patterns and moves, learners' sentiments and emotions, and learners' behaviours (Tan et al., 2022a). For example, Chen and Tsao (2021) were able to facilitate Grade 11 students' learning by comparing students' perspectives in a discussion on social scientific issues, helping them to visualize other learners' similar

perspectives and individual perspectives among the class. This application was found to have significantly improved students' effectiveness in taking multiple perspectives. By building on the characteristics of existing training data and AI anchored on knowledge building principles, it is possible for GAI to even extend help towards knowledge builders who need language support (e.g., explaining the word meanings, checking of grammar, rewriting of sentences) and aid them in reflections on social collaboration processes (Johnson & Johnson, 2009), among the many possible use cases in a knowledge building environment.

Design considerations and proposed moves

To answer how technologies like GPT and ensuing similar technological advancements can be integrated and utilized in designs for sustainable student discourse, we align the use of GAI with knowledge building as an idea-centric pedagogy (Lee & Tan, 2017a; Hong & Sullivan, 2009) to conduct ideational analysis in knowledge building (Tan et al., 2022b). During knowledge building, it is crucial for a teacher to ask questions to elicit student ideas for a particular line of inquiry, track the development of students' ideas, and elevate students' ideas to a higher level (Zhang et al., 2011). Among a list of 12 knowledge building principles (Scardamalia, 2002), we propose six of the principles to be used for guiding teachers, with four principles pertaining to idea-centric pedagogy and two principles pertaining to fulfilment of student needs. The principles are explained below with descriptions.

Pertaining to idea-centric pedagogy:

- *Real ideas, authentic problems*—Knowledge problems often stem from efforts to understand the world, with ideas as real as things touched and felt that can be instinctively used to address real-life issues and authentic problems.
- *Idea diversity*—The diversity and contrast of ideas is critical for stimulating further discussions and to create a collaborative environment for different ideas to evolve and develop.
- *Improvable ideas*—All ideas are viewed to be improvable and given a psychologically-safe environment where students are comfortable to take risks, continuous work can be conducted to improve quality, coherence, and utility of ideas.
- *Rise above*—By working towards more inclusive principles, integrated ideas, and higher-level formulation of problems, elevated planes of understanding can be achieved after transcending trivialities and oversimplification.

Pertinent to fulfilment of student needs:

- *Constructive use of authoritative sources*—Students can be assisted during discourse with the productive use of trustworthy sources of knowledge and information, which is closely related to students' idea-centric discussion; specifically, how students could critically evaluate and employ reliable published knowledge sources to address their knowledge gaps during group inquiry. These resources also support the objectives of students' inquiry and help them attain a deeper comprehension of the pertinent material by interpreting and making sense of the resources.

- *Embedded, concurrent & transformative assessment*—In consideration of students being able to potentially achieve in-depth critical thinking and idea improvement, embedded and transformative assessment needs to occur within learning activities to advance knowledge; that is, students could be empowered to conduct rigorous self-assessment with high standards of criteria in a concurrent and consistent manner.

With reference to the above knowledge building principles and considerations, generative AI (i.e., GPT) can be designed and used as a learning companion for knowledge building and sustaining of student discourse. A list of the above-mentioned principles along with respective design considerations and moves are summarized in Table 1. The ways in which these designs are translated into actions are explicated through the pilot study in “[Pilot study](#)” section.

Pilot study

Setting and participants

To examine the potential of using GPT to deepen and sustain knowledge building discourse, we used ChatGPT to examine an online student discourse hosted on the Knowledge Forum. The student discourse in the form of textual data was extracted from a student Knowledge Building Design Studio (sKBDS; Teo et al., 2022, Yuan et al., 2023) that was held virtually in June 2022, spanning over three days and involving 22 students and six teachers from primary and secondary schools across Singapore, along with

Table 1 Supporting knowledge building principles with generative AI

Knowledge building principles	Proposed moves that generative AI can conduct as a learning companion
Real ideas, authentic problems	Generative AI can be used to (a) Identify and explain existing or new authentic problems that the students intend to work on (b) Summarize the existing pool of ideas generated by student discourse
Idea diversity	Generative AI can (a) Synthesize new ideas, perspectives, or issues from current discourse to stimulate further discussions (b) Prompt students to consider diverse perspectives and help them appreciate the value of varying viewpoints that are essential for collaborative knowledge building
Improvable ideas	Generative AI can (a) Identify relevant ideas from the discourse that have the potential for improvement (b) Recommend how ideas can be further developed and improved
Rise above	Generative AI can enable students to relate ideas and discourse with content beyond existing environments, to connect to other peers’ work, theories, or principles
Constructive use of authoritative sources	Generative AI can suggest novel ways for students to explore related ideas while pursuing similar lines of inquiry that are drawn from established sources (including other discourse external to the learning context)
Embedded, concurrent & transformative assessment	Generative AI can synchronously prompt students during discourse to reflect on their ideas and suggest criteria to evaluate peers’ ideas and discourse

researchers from tertiary institutions. The sKBDS was designed as an authentic blended learning space where teachers, students, researchers, and international experts come together to build their knowledge on big ideas (e.g., sustainability), working together to tackle real-life problems and produce novel solutions, via the production and sharing of innovative ideas to advance community knowledge. Student participants can continuously improve their ideas via collaborative discourse on the online Knowledge Forum and breakout sessions. Because most of the teacher and student participants were new to the context of sKBDS and the use of the Knowledge Forum, all participants were invited to an orientation session before the main sKBDS event, to familiarize with details and platforms that will be used during the sKBDS for knowledge building.

Apart from using the sKBDS as a space for students to communicate and discuss wide-ranging ideas, another goal was for students to share and collaborate their ideas with other learning peers from different environments and cultures, while giving them opportunities to acquaint themselves with field experts and researchers from different walks of life to improve their ideas on sustainability-themed issues. These conversations and discussions are not limited to the online space that were provided on the Knowledge Forum (Fig. 1), but it will also be beneficial for students to record their ideas as knowledge artifacts within the online space, so that they can refer to the ideas and build on them in the future. On the Knowledge Forum, students may click on the relevant links to access information resources, while teachers can use the teachers' lounge to discuss with each other. In essence, the collective goal of the sKBDS was facilitate the advancement of community knowledge.

Discourse data collection and method

To kickstart the discourse in the sKBDS, student participants will access designated discussion spaces, also known as views (Fig. 2) on the Knowledge Forum, to share their ideas that they want to pursue and engage each other by writing and posting notes or building on one another's notes. The responses were then recorded and pinned in a spatial manner within the student community space for other learners to visualize and build on, as shown in Fig. 2. An alternative but more traditional view of the notes can also be viewed in a hierarchical and ordinal manner (Fig. 3). Although

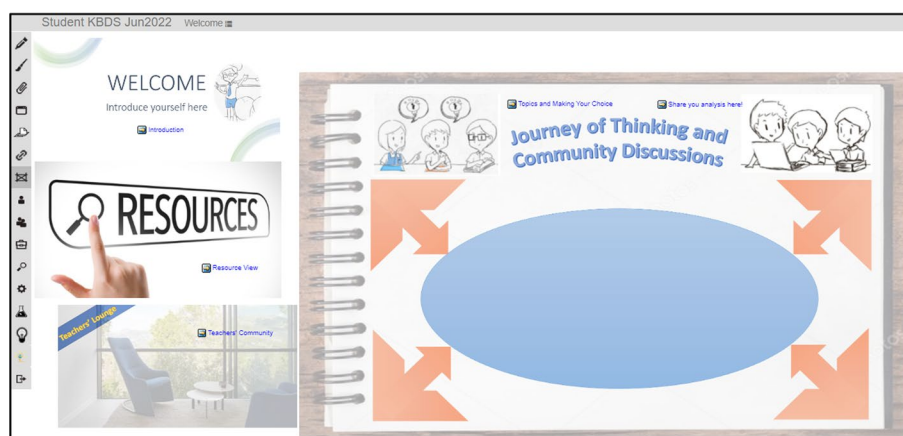


Fig. 1 The Knowledge Forum as an online space for discussions with links to different resources

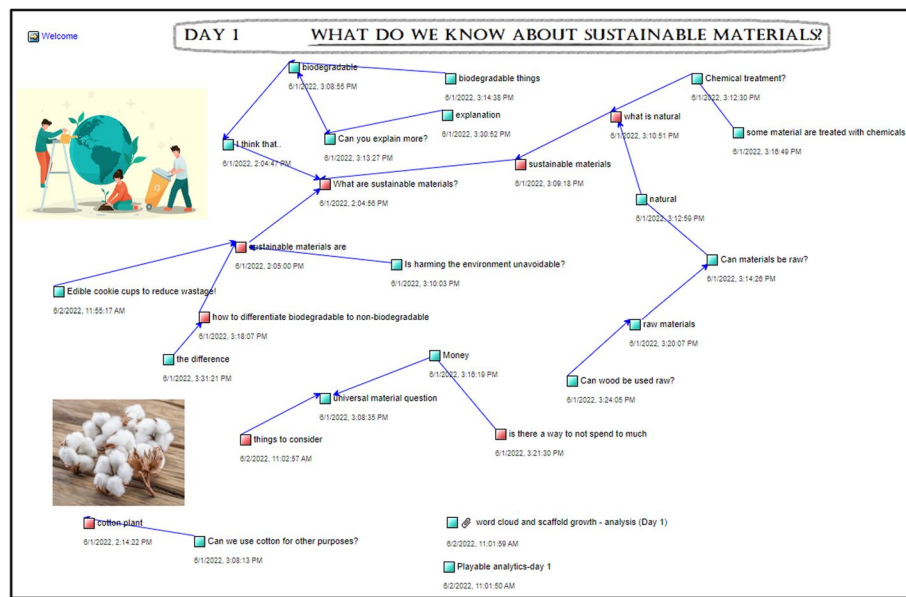


Fig. 2 Students share ideas using notes (nodes) and build on (arrows) other notes in the view, alongside read notes (in red) and unread notes (in blue)

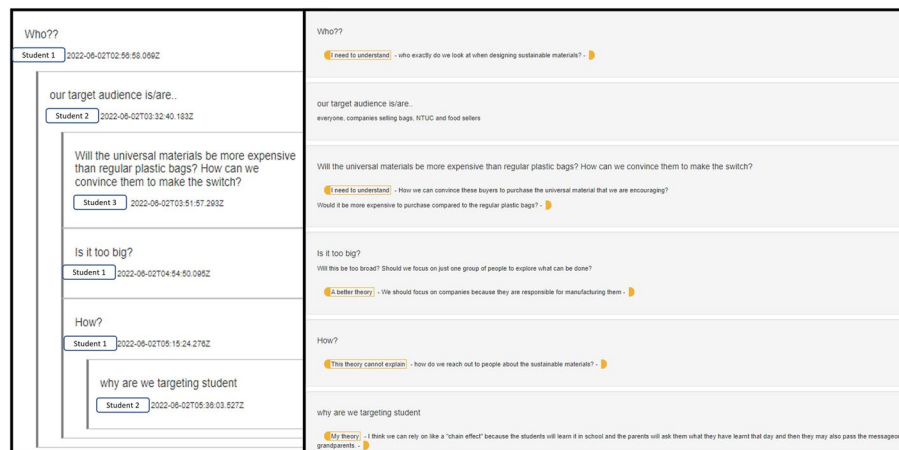


Fig. 3 The same set of students' notes can be alternatively represented with the posting sequence

the latter methods are considered traditional ways of extracting textual data from online discourse, these methods are also part of a more feasible and programmatic approach for obtaining data from student textual discourse for subsequent processing and analysis using ChatGPT.

Based on the programmatic approach, we first used a custom API for the Knowledge Forum, coded in the Python language, to extract the textual discourse data in the format shown in Fig. 3 and to also preserve the data structure and integrity of student discourse, such as maintaining the order of build-on and the chronological nature of discourse that took place during the sKBDS. Thereafter, we checked the alignment of the extracted discourse data against the knowledge building principles and possible

moves in Table 1, before storing the discourse data in a repository. The collected discourse data comprise of student-written notes on the Knowledge Forum and for analytical purposes, selected notes of interest were then split into individual samples of about 500 words, due to additional prompt engineering and also for the resulting prompt to remain under the token limit of 4096 tokens (token-to-words conversion is estimated and dependent on type of text and nature of sentences being used) for each call on ChatGPT during this study. The resulting prompt consisting the necessary prompts and the student discourse data was then sent to ChatGPT to conduct some of the mentioned moves (Table 1) and for ChatGPT to act as a learning companion.

By combining the use of ChatGPT with knowledge building principles and moves, we show how generative AI can function similarly to a human knowledge builder, with the potential to sustain student discourse in existent manners and possibly display novel ways beyond current methods that encourage greater student agency in improving ideas and sustaining knowledge building discourse. We therefore designed several scenarios (explicated in next “[Application scenarios](#)” section) in which ChatGPT was inputted with the engineered prompts to act on the given student discourse data, and the subsequent outputs from ChatGPT were reported with a descriptive analysis that also illustrates the affordances of generative AI for knowledge building and sustenance of student discourse. These were then qualitatively compared with the original student discourse data, if applicable and available due to students’ capacity and abilities, and discussions of the findings and limitations are reported in Sect. “[Discussions and limitations](#)” section.

The following list of three scenarios demonstrate the capabilities and potential of ChatGPT in becoming a learning companion for sustaining student discourse: (1) summarizing key points from student discourse; (2) synthesizing new information and ideas from external sources or discourses; and (3) generating recommendations and strategies to improve ideas and advance knowledge.

Application scenarios

For a start, ChatGPT was tasked to “summarize 10 key ideas” from provided student discourse samples. We showcase an example result in Table 2 from a chosen discourse sample titled ‘Sustainable materials & energy 1’, which has students discussing

Table 2 ChatGPT’s summary of key points from one of the provided student discourse sample

Key Ideas
1. Sustainable materials are those that do not deplete resources and can easily break down
2. Biodegradable materials can decompose quickly without harming the environment
3. Edible cups made from natural materials are an example of sustainable products
4. Raw materials like wood and plants can be used directly to create sustainable items
5. Some materials are treated with chemicals to enhance their properties or prevent decay
6. Cotton can be used for various purposes, including clothing, shopping, and food containers
7. The message of sustainability should be directed towards companies, parents, and children
8. Engaging and appealing presentations, such as videos and cartoons, can help convey the sustainability message
9. Rice and corn husks are potential alternatives to tree-based materials, but they may require chemical treatment
10. Raising awareness and promoting sustainable materials can be done through presentations, online messages, and targeting both adults and children

sustainable materials and energy and is the first of many groups from the sKBDS to select this topic. The ordering is only for identification purposes and does not affect the analysis. When compared to the original discourse sample, it is apparent that ChatGPT was able to provide an accurate list of key ideas within seconds. This is an expected capability of ChatGPT and shows that a previously tedious task that students or teachers take significant time to execute can now be completed in seconds.

Subsequently, ChatGPT was tasked to “synthesize new information and ideas from external sources or discourses”, using the same topic and not mentioned in the provided discourse sample. It was able to successfully list three issues (Table 3) that were not previously discussed in Table 2, with further highlights on how these additional issues highlight the broader challenges and considerations related to sustainable materials and energy beyond the initial list of key ideas provided by the students in the discourse sample.

When ChatGPT was further prompted to “provide authoritative and relevant sources related to its suggestions within the local contexts in Singapore”, references and sources for each additional issue were suggested but these were not valid resources (refer to Table 4). Some of the information was also outdated, such as the naming of the Ministry of the Environment and Water Resources (MEWR) Singapore, which has already been renamed to the Ministry of Sustainability and the Environment in 2020, indicating that ChatGPT may be using even older versions of archived data (earlier than the proclaimed update in 2021) for synthesizing certain information.

In terms of evaluating ideas for embedded assessment, ChatGPT was tasked to “provide three recommendations to improve the list of ideas”, of which the results are shown in Table 5.

Building onto the recommendations and in terms of supporting the idea creation process, ChatGPT was lastly tasked to “suggest what should one do during a group discussion, if the discussed ideas are found to be shallow?”. ChatGPT proceeded to provide the following advice as shown in Table 6.

Table 3 ChatGPT was able to synthesize three additional issues related to sustainable materials and energy

Three additional issues related to sustainable materials and energy
1. E-waste management: With the increasing use of electronic devices, there is a growing concern about the proper disposal and recycling of electronic waste (e-waste). E-waste contains hazardous materials that can harm the environment and human health if not handled properly. Developing efficient e-waste management systems and promoting electronic recycling are crucial for reducing the environmental impact of electronic devices
2. Energy-efficient buildings: Buildings are major consumers of energy and significant contributors to greenhouse gas emissions. Designing and constructing energy-efficient buildings can help minimize energy consumption, reduce carbon footprint, and promote sustainable practices. This includes incorporating renewable energy sources, improving insulation, optimizing heating and cooling systems, and implementing smart technologies for energy management
3. Circular economy: The concept of a circular economy focuses on reducing waste and maximizing resource efficiency. Instead of the traditional linear "take-make-dispose" model, a circular economy aims to keep materials in use for as long as possible through recycling, reusing, and repairing. Implementing circular economy principles can minimize resource extraction, reduce waste generation, and promote sustainable production and consumption patterns

Table 4 ChatGPT provided invalid sources and references related to the three synthesized additional issues**Sources and references**

1. E-waste management:

Authoritative Source: National Environment Agency (NEA) Singapore. *Singapore's Approach Towards E-Waste Management*. <https://www.nea.gov.sg/our-services/waste-management/waste-management-infrastructure/e-waste-management>

Relevant Source: Ministry of the Environment and Water Resources (MEWR) Singapore. *Managing Electronic Waste in Singapore*. <https://www.mewr.gov.sg/insider/managing-electronic-waste-in-singapore>

2. Energy-efficient buildings:

Authoritative Source: Building and Construction Authority (BCA) Singapore. *Green Mark for Buildings*. <https://www.bca.gov.sg/GreenMark/others/GreenMarkBuildings.html>

Relevant Source: Urban Redevelopment Authority (URA) Singapore. *Sustainable Buildings in Singapore*. <https://www.ura.gov.sg/Corporate/Guidelines/Sustainable-Buildings>

3. Circular economy:

Authoritative Source: National Environment Agency (NEA) Singapore. *Towards a Zero Waste Nation: Singapore's Journey*. <https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/towards-a-zero-waste-nation>

Relevant Source: National Environment Agency (NEA) Singapore. *Singapore's Circular Economy Approach*. <https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/circular-economy>

Table 5 ChatGPT evaluated the ideas and suggested ways of improving the discussed ideas**Three recommendations to improve discussed ideas**

1. Conduct feasibility studies: Before implementing any idea, it is important to conduct thorough feasibility studies to assess the viability and potential impact of each solution. This includes evaluating factors such as cost-effectiveness, scalability, environmental impact, and compatibility with existing infrastructure. Feasibility studies can provide valuable insights to prioritize and refine the ideas, ensuring their successful implementation
2. Foster cross-sector collaboration: To tackle complex sustainability challenges, it is crucial to foster collaboration among different sectors, including government agencies, businesses, research institutions, and civil society organizations. Encourage platforms for dialogue and collaboration, such as sustainability forums, working groups, and public-private partnerships. This collaborative approach promotes knowledge sharing, resource pooling, and collective action towards sustainable materials and energy solutions
3. Promote public education and awareness: Raise public awareness about sustainable materials and energy through targeted education campaigns. Develop educational programs, workshops, and awareness campaigns that highlight the importance of sustainable choices and their impact on the environment. Engage schools, community centers, and media platforms to disseminate information and encourage behavior change. Empowering individuals with knowledge can drive demand for sustainable alternatives and promote their adoption in daily life

Table 6 ChatGPT provided advice on the idea creation and improvement process**Suggestions on what one can do about shallow ideas**

1. Encourage deeper exploration: Facilitate a deeper exploration of the topic by asking open-ended questions that encourage critical thinking and analysis. Prompt the group to delve further into the underlying causes, implications, and potential solutions related to the topic. Encourage participants to share their perspectives and challenge each other's assumptions, fostering a more comprehensive understanding of the issue
2. Broaden the discussion: If the ideas being discussed seem shallow, it could be helpful to broaden the discussion to include a wider range of perspectives and expertise. Invite individuals from different backgrounds or disciplines who can provide unique insights and alternative viewpoints. This diversity of perspectives can enrich the conversation and lead to the generation of more thoughtful and innovative ideas
3. Facilitate brainstorming techniques: Utilize brainstorming techniques to stimulate creativity and generate a wider array of ideas. Encourage participants to think outside the box and suspend judgment during the brainstorming process. Techniques such as mind mapping, role-playing, or the "six thinking hats" method can help stimulate new ideas and encourage deeper exploration of the topic

Discussions and limitations

In the described and explored scenarios, we identified several ways in which generative AI has the potential to perform as a learning companion and address common problems that are prevalent in collaborative learning and knowledge building classrooms. These problems are, namely, how students often unknowingly engage in repetitive ideas, commit build-on to ideas in a shallow manner that consists of simple agreements or disagreements, and inbreed ideas without thoughtful consideration of new information and knowledge from authoritative sources. Before the emergence and surge in popularity of GPT-based technologies and applications, teachers are often the main initiator of learning and knowledge building moves that can now be conducted with generative AI, some of which were demonstrated by ChatGPT in the above scenarios—quick and precise summarization of textual content, selective exemplification and expansion of current content, improvement and connection of ideas—essentially what a teacher might enact during different stages of a knowledge building process while trying to sustain student discourse in an actual classroom (Lee et al., 2022).

On the one hand, we view the emergence of generative AI and ChatGPT as a boon for educators, because many teachers unknowingly wrest control of higher-order thinking opportunities from the students, by attempting to interpret and summarize ideas on behalf of the students. As a result, these moves inevitably reveal teachers' preferred line of inquiry and are generally peppered with bias. Further, through teachers' moves, many lessons and issues may be quickly completed and solved, but the possible routes towards eventual solutions are resultingly narrowed and repetitive with the shallow understanding that reduces students' agency in inquiry. More importantly, students are unlikely to have the opportunity to develop critical knowledge building competencies and may revert to just waiting for the teacher's instructions that indicate the next step forward. By implementing generative AI to assist the teacher in executing similar tasks, it is envisioned that bias can be minimalized and this option can be initiated based on needs, with teachers' time diverted to knowledge co-construction with students.

On the other hand, from the evidence that was observed in the pilot study, the use of generative AI ChatGPT is not a bed of roses, as shown by how invalid references were synthesized and partially correct, which unfortunately still seem reasonable to students who may not do their due diligence in checking the authenticity and can potentially contribute to a cascading chain of mistruths if blindly used. Hence, without peer evaluation or other authoritative sources such as teachers to monitor such processes, it is likely that the use case of generative AI for learning should still require checking mechanisms in terms of peer-checking and mentoring to sift out mistruths or inaccurate information that construe fake news or information.

With respect to the use of generative AI in knowledge building processes, it is also key for students and especially novices, to be knowledge builders that use ChatGPT with discretion and sieve out potential untruths that can mislead the community towards unverified knowledge. Moving into the near future where AI plays a larger role not just in education but in many other aspects of life, the quality of discourse can be strengthened, and the balance of agency may shift towards students who are keen to explore knowledge and seek better understanding. Assuming that once students are accustomed and supported in the original complex processes of summarization, expansion,

improvement and connection of ideas, it is then possible for students to take on a higher plane of reflection and begin asking questions such as, “Whether the AI has been summarizing ideas fairly?” when replacing intentions and words with other synonyms that may not truly reflect one’s views; and, “What does undistilled content look like without AI’s involvement, and consequences if one does not agree with the ideas selected by the AI?”.

Analogous to the use of the calculator that has taken over rudimentary mathematical calculations and left students to focus on higher order mathematical problem solving, generative AI has the potential to support students who are not satisfied with their current questionings and wonderments, and generative AI can be used to advance their inquiries, thereby allowing student discourse to be sustained with lesser overheads. With suitable designs of scaffolds and supports, students can continue to create and advance knowledge while taking into consideration of AI-enabled interactions.

Perhaps, in this early stage of a possible nascent age of usable and implementable AI, students’ cognitive responsibilities and epistemic agency can be guided to include the necessary knowledge and skills for the appropriate use of generative AI. We suggest users of AI consider the use of Know-Build-Critique, or KBC as an acronym for the following three ways that may help education stakeholders to navigate the use of generative AI for knowledge building and sustaining student discourse:

1. Know (K): Undertake research and develop knowledge of how generative AI works, including the strengths, feasibility, and limitations
2. Build (B): Build on and harness the strengths of generative AI, such as using information from other authoritative sources of knowledge to enhance the quality of one’s ideas or viewpoint
3. Critique (C): Acquire know-how in adopting a critical lens for evaluating information from generative AI and consideration of ethical use in work

Conclusion

Some may ask, is there then truly a limit to what generative AI cannot achieve? Essentially, knowledge building processes encompass more than just idea generation, improvement, and connection, as shown in this study. Parallel to these developments is the dynamic formation of structures that are “socially organized and sustained through co-constructing collective inquiry structures as the work proceeds in response to emergent inquiry directions and needs” (Zhang et al., 2018, p. 395), also called “reflective structuration” (Zhang et al., 2018). It can also be referred to as a dual-layer of co-construction that evolves—structure to shape the collective idea improvement and structure for emergent social configuration—henceforth, the knowledge building DNA (Tan, 2023). These are some components that are yet to be fully augmented and replicated via the use of GPT and are still critical elements of what helps to drive and sustain student discourse.

All things considered, we have showcased how generative AI like GPT can be considered and utilized in designs that are consistent with sustainable student discourse and knowledge building. Examples were used to illustrate the use of generative AI to support idea-centric knowledge building and the potential ways to develop students’ capacity for

productive AI usage. The findings and effects were discussed with thoughts on misuse and current limitations on how student discourse can be sustained in a viable manner. While the support of the emergent and dynamic reflective structuration of knowledge building may seem challenging at this point in time, the speed at which AI developments are advancing may give us a better and clearer answer sooner than later.

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AVYL, SCT, and TCL made equal contributions to the design and conceptualization of the work, data collection, analysis, and interpretation. AVYL drafted the work, SCT and TCL revised it, and AVYL completed the submission.

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Declarations

Consent for publication

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