

# Youth as Designers of Artificial Intelligence and Machine Learning Technologies: What Do We Know About the Opportunities and Challenges of K-12 Students Creating Their Own Applications?

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**Abstract:** Over the past decade there has been exponential growth in artificial intelligence and machine learning (AI/ML) applications moving out of the lab and into the world, impacting everyday lives. To date, most AI/ML and learning research efforts have centered learners as recipients of instruction from, or collaborators with, AI agents. This symposium brings together a group of scholars who will discuss how learners and teachers can engage with AI/ML technologies as creative resources, or CreateAI. CreateAI refers to the use of AI tools and methods for creative expression, that is, involving students not just in using AI for pre-determined productive ends, but also as creators who can design and build projects with AI/ML.

## Overview

We are participating in exponential growth in artificial intelligence and machine learning (hereafter: AI/ML) applications, using them, or being data subjects of them, as they move out of the lab into the world, impacting everyday lives. Consequently, there has also been increased attention to algorithmic bias and harm enacted by AI applications (Benjamin, 2021). There is now a growing call for AI literacy (e.g., Long & Magerko, 2021; Touretzky et al., 2018) and for all K-12 students and teachers to be prepared to understand, use and critique AI applications. However, to date, most AI in education efforts have concentrated on what has been called artificial-teachers, artificial-tutors, and artificial co-learners, positioning learners as recipients of instruction from AI agents or collaborators with AI agents (Ouyang & Jiao, 2021). In current discussions, one perspective has received much less attention: how learners create, train, test and research AI applications. Like Touretzky, Gardner McClune & Seahorn (2022), we see the construction of computational artifacts of AI/ML-based applications as a premier

opportunity for students to see themselves as “not just programmers, but AI application developers.” (p.10). While K-12 computing education research (CER) has recognized youth potential for consequential computational action with a variety of curricular activities and programmable tools, much less is known about what this means in the context of developing applications involving AI/ML.

In this symposium, we bring together an international group of presenters who will address different dimensions of what learners can gain from designing AI/ML applications, examine in which ways critical agency can be developed, and what kind of challenges they observed. The presentations in this symposium will focus on a set of intersecting ideas:

- *Tools*: What kind of tools already exist or need to be designed to support creative AI design activities? What are the design features that support students in different grade bands and with different motivations to work in Creative AI?
- *Ethics*: What are critical issues in Creative AI? How best to engage students in discussions around algorithmic justice and fairness when creating AI applications?
- *Learning*: How do we define this approach of Creative AI? In which ways do current discussions about generative AI add/contrast/extend the possibilities of Creative AI? What do we need to know about students' prior understanding at different age levels? What might students learn about AI, CS, and other disciplines through Creative AI? What are the intersections of practices and concepts in Creative AI vs CS framed by current CS standards?
- *Teaching*: What are promising pedagogies for teaching Creative AI in K-12 schools and informal settings? What frameworks are in development or already in place? How can AI/ML be integrated into current computing education pedagogies and frameworks? What are appropriate activities that are accessible and feasible for K-12 students and their potential teachers? and
- *Assessment*: How can teachers assess student learning of AI key concepts and practices in creating AI applications? Our goal is to develop a better understanding of the opportunities and challenges associated with creative AI/ML applications and how we can prepare students and teachers for a world in which AI-based solutions to problems in health, energy, and the environment will be a ubiquitous part of their 21st-century education experience.

The symposium is organized in four sections: (1) the chairs will introduce the topic; (2) each of the panelists will have six minutes to share their approach, (3) followed by our two invited discussants, and (4) a Q&A with the audience and presenters.

## Making AI-Based Apps Strengthens Children's Data Agency and Understanding of AI

Matti Tedre, Henriikka Vartiainen

This socioculturally informed study introduces a pedagogical framework, design principles, and a cross-boundary co-design process involving teachers and researchers to co-develop new educational practices, curriculum materials, and technology for teaching AI in Finnish basic education. In a multidisciplinary, design-based research project, 213 students in 4th and 7th grades explored the basics of AI by co-designing and creating their own AI-driven applications while considering AI's impact and ethics. Grounded in design-oriented pedagogy, the aim was to position children as designers and knowledge creators in AI (Kahila et al., 2024). The intervention started by introducing learners to uses of classifiers in contexts familiar to them. Following that, our meta-design approach used open-ended tasks and scaffolding to engage students in collaboratively exploring key classifier concepts through their own interests and app ideas. Using our own AI app development studio that does not require programming, children followed the basic epistemic functions related to ML workflows and connect their design ideas and evolving understanding to real-world contexts (Pope et al., 2024). Fig. 1 presents classroom photos from different stages of the co-design process. At the end of the project, children reflected on the potential risks and harms of AI through their own app-design process and explored algorithmic bias using generative AI (Vartiainen et al., 2024).

Qualitative content analysis of pre-and post tests, children's design ideas, and reflections of the app design process revealed that co-design provided promising entry points for children to develop conceptual understanding of AI principles, workflows, and its role in everyday life. Taking on agentic, central roles in personally meaningful, scaffolded AI design projects cultivated children's data agency and ownership of their learning process. Children's pre-and post tests showed that their data-driven explanations of algorithmic bias improved significantly, indicating a more critical understanding of how AI-based systems should be designed or

redesigned (Vartiainen et al., 2024). The study's theoretical and pedagogical insights, alongside its empirically validated framework for scaffolding data-driven design, offer research-based guidance for advancing culturally relevant, equitable, and inclusive AI education. We suggest that such AI education will help children build their data agency: their ability and volition to be active, contributing members and critical makers of the data-driven society.

**Figure 1**  
*4th and 7th Graders Explore AI in their Everyday Life*



## Empowering students to shape the future: Understanding AI/ML learning difficulties in K-12 education

Franz Jetzinger, Tilman Michaeli

To prepare students for their future, it is crucial that (computing) education not only enables them to understand the digital world surrounding them but to actively shape this world. Given the immense impact of AI/ML systems on our daily lives, this includes empowering students to creatively design and develop such systems themselves. To this end, relevant AI/ML-related competencies are being discussed and introduced in K-12 computer science curricula around the world (e.g., Touretzky et al., 2019; Tedre et al., 2021; Michaeli et al., 2023). Also, a plethora of educational resources and approaches has been developed in recent years (Morales-Navarro et al., 2024). However, we still lack an understanding of problems teachers and students face in the classroom, in particular when designing AI/ML systems.

To address this gap, we conducted an action research project with the goal of developing theories about learning and teaching processes in the field of AI/ML in order to improve teaching on an empirical basis. In our national context (Bavaria, Germany), AI was introduced within a mandatory computer science subject for all high school students in year 11 (Jetzinger et al., 2024). Within the curriculum, in about 16 lessons, the students learn about basic ideas of AI methods, specific algorithms (such as decision tree learning and artificial neural networks), discuss challenges for our society, and train their own AI/ML models. In our first action research cycle, we particularly focused on students' (AI-specific) learning difficulties. To this end, the 10 computer science teachers who participated in the project reported their lesson plans and brief reflections on each lesson. After teaching the entire AI sequence, the students' learning progress was assessed through a test. Furthermore, we conducted semi-structured interviews with the teachers. The data was analyzed qualitatively using an inductive approach in line with grounded theory, triangulating the different data sources.

In addition to general barriers in line with existing literature, such as issues with mathematical and programming skills, we identified several AI/ML-specific learning difficulties. First, our results suggest that students have difficulties in evaluating whether certain AI/ML methods can be applied to a given problem. One reason for this may be a more general problem with assessing the capabilities of AI: on the one hand, students overestimated the capabilities of AI systems. On the other hand, they generally assumed that AI/ML methods can only be used for very complex tasks. Furthermore, the teachers reported difficulties in training AI/ML models with unknown datasets. In contrast to the small and generally "well-prepared" data sets that are commonly used within AI education, students face various difficulties in preparing the data (e.g., splitting into a training and test data set), applying a particular ML algorithm and especially evaluating a trained model with the purpose of improving it. These findings align with the more general difficulty we found in our data of bridging the gap between pedagogically reduced and real-world examples to apply AI-related concepts from the classroom to AI/ML systems that students use in their everyday lives. Additionally, our results show that working with authentic tools that allow for solving "real-world problems" poses a lot of challenges for students and teachers alike. Similar to other areas of computing education, this raises the question of design principles for adequate tool support that foster students' creativity and agency.

The next step in the first action research cycle is to discuss these difficulties with the participating teachers in order to co-design strategies and approaches to address them for the second cycle. In this way, the results of our study contribute to the identification of learning difficulties in K-12 classrooms and provide valuable insights for improving AI education on an empirical basis - laying the foundation for empowering students to shape their future.

## Critical, ethical, empowering design of AI/ML systems for social good

Netta Ilvari

Children are living in a world dramatically transformed by emerging AI/ML systems. Moreover, their everyday life is transformed by numerous crises, pandemic, on-going wars and climate change as notable examples. All this is causing anxiety, sorrow and fear among children, concerning their future as well as the future of the globe and humankind. Now, more than ever, we need to engage children as changemakers for a better – more equal, just, sustainable – future. Computing education, on its part, should foster children's agency regarding their (digitalized) futures. We should invite children to approach computing and its consequences critically and to shape the trajectories of computing of the future. Moreover, we should invite children to view the world and the crises within with a critical yet constructive stance, trying to make the world a better place for us all. Naturally, computing alone can never solve complex societal problems, but it can contribute on its part.

We report on a design research project in which we explored critical, ethical and empowering design methods together with children. The methods, in different ways, invite critique of the status quo with injustice, inequality and oppression; and taking action to transform it (Iivari et al. 2022). We particularly derived inspiration from the Scandinavian political Participatory Design tradition which prioritizes empowerment and the right to have a voice and a say in design (Iivari et al. 2022). We also relied on speculative and critical design traditions that invite critically probing, questioning and dreaming about (alternative) futures, using design as a form of critique or a political tool (Iivari et al. 2022). Such approaches enable both critique and action taking for a better world. They entail ethical consideration of right and wrong and foster empowerment – of individuals and collectives, in relational and motivational senses (Iivari et al. 2022).

In the project, children designed diverse AI/ML systems with advanced surveillance, sensing, reasoning and adaptation abilities to tackle a wicked societal problem of bullying. Based on our explorations, we recommend four methods for critical, ethical, and empowering design of AI/ML systems: (1) Miracle method (Iivari et al. 2024a) invited children to imagine a bullying-free futures, revealing rich insights into the oppressive status quo but also desirable futures to design for (Iivari et al. 2024a).; (2) Critical reflection on underlying assumptions, values and best- and worst-case consequences of design invited children to critically consider their own role and responsibility as designers shaping the future, and the consequences of AI/ML systems on people's lives (Iivari et al. 2024b); (3) Theatre of the Oppressed method (Iivari et al. 2024a) invited children to discuss their designs within their school community and to mobilize the community for collective action taking against bullying, fostering empathy towards and the necessity to work on behalf of the bullying victims.; and (4) Design activism (Iivari et al. 2024a), finally, invited children to engage their school community through activism campaigns and anti-bullying designs to mobilize everyone to take action against this vicious problem, making visible personal responsibility to do so.

Criticality in the sense of critique and radical change picture in these methods, as well as reflections on right and wrong, desirable and undesirable futures – including with AI/ML systems. Relational and motivational empowerment of child-designers and bullying victims picture strong in the design, but also collective empowerment of entire school communities. Our insights enable renewing children's computing research and practice in several respects. We will continue tackling wicked societal problems of interest to children, collaboratively with them exploring the potential of AI/ML systems for social good.

## Empowering teachers as users and creators of specialized AI tools for diverse classrooms

Safinah Ali

Current AIML curricula are primarily designed for STEM classrooms with AI concepts, practical applications and ethical implications as the primary goal (Casal-Otero, et al., 2023). However, AI literacy today is relevant to

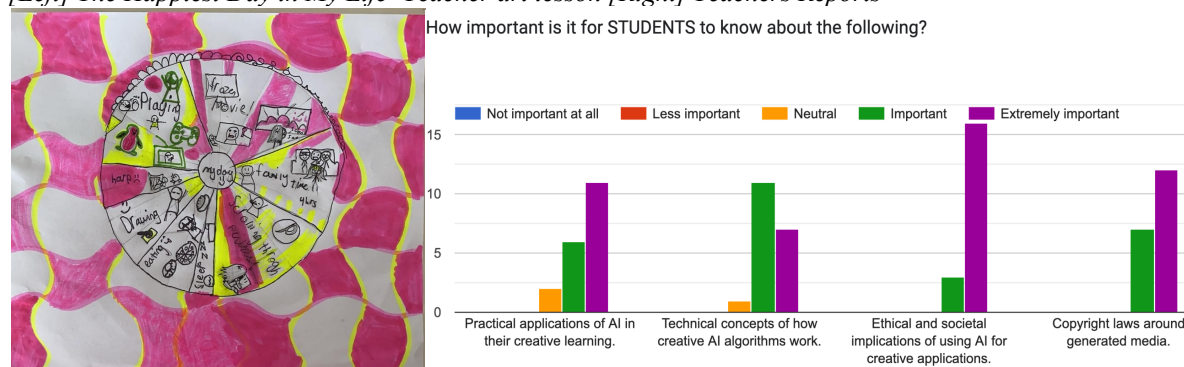


non-technical classrooms, and is not just a technical skill, but a socio-technical skill (Ali et al., 2021). Diverse fields of work such as art, law, education, policy, and sports are all impacted by AI. To make AI learning accessible within these contexts, AI pedagogy must be adapted to non-technical classrooms, and be designed with educators from diverse classrooms. We situate the current work in the context of art classrooms, where we integrate AI learning materials and tools in art learning. We exploit multiple ways of knowing about technology - epistemological pluralism - as a framework to understand art making as a way to learn with and about AI.

In this work, we co-designed AI and Art learning materials and tools with 21 creative educators in four languages. Teachers gained foundational AI knowledge, practical experience with AI tools, and AI prototyping skills. Teachers described AI and art learning objectives for their students, developed lessons to use AI tools in creative learning, designed AI tools for supporting art learning in their classrooms, and reflected on the usage of AI in creative classrooms. We utilized the use-modify-create framework (Lee, et al., 2011), where teachers gained experience with AI skills, and used them to create their own AI tools and lessons. Teachers demonstrated higher confidence in teaching with, explaining and making with AI. For instance, teachers used the AI Art Explorer tool that helps creative learners reflect on the artwork and gain personalized feedback during art creation, and develop lesson plans around using AI Art Explorer in their own classrooms. Teacher-defined learning objectives ranged from using AI for personalized art feedback, investigating students' own art style (4 teachers), evolving own art style (4 teachers), expressing emotions through art (3 teachers), creative ideation (3 teachers), gaining knowledge in art history (3 teachers), identifying emotions in art (2 teachers), and art for social justice (2 teachers). Teachers designed tools tailored for their classrooms, such as, a socio-emotional learning tool, a language learning through AI character personality design, and a social justice art reflection tool to promote creative inquiry. A thematic analysis of pedagogical practices emerging in teachers' lessons revealed the use of reflective practice, inquiry-based learning, iterative learning, representation of self, project-based learning, ethical reflection in art making, aesthetic and emotional management (see Figure 2).

**Figure 2**

*[Left] The Happiest Day in My Life -Teacher art lesson [Right] Teachers Reports*



While discussing implications of AI tools in the classroom, teachers were most concerned about the over-reliance on AI and impact on students' critical thinking, data privacy, and were most hopeful for AI's ability to offer personalized learning and student support, support students' creativity and innovation, and their skill development for the future. In this work we suggest a three stage approach - learning about AI, using AI tools in lessons, and developing AI tools for their own classrooms, that involves educators as key stakeholders in designing learning materials and tools, and empowers them to be informed users, creators and educators in an AI-driven future. Meaningfully including educators is an effective medium of making AI learning accessible to non-technical classrooms and adapt to diverse pedagogies.

## Understanding and creating with AI: Tools and strategies for computing education

Line Have Musaeus, Ole Sejer Iversen

Over the last few years the availability and usability of generative AI systems have increased tremendously, impacting everybody's lives, also the everyday lives of students. Hence, there is a growing call for teaching about AI in computing education (Tedre et al., 2021). Research on how to teach about generative AI systems and not only about the use of generative AI is increasing in computing education research, and there are now an interesting array of approaches to teaching about AI. This body of research allows us, as researchers, to focus our concentration on questions such as: What kind of tools can support students in being designers and creators of AI

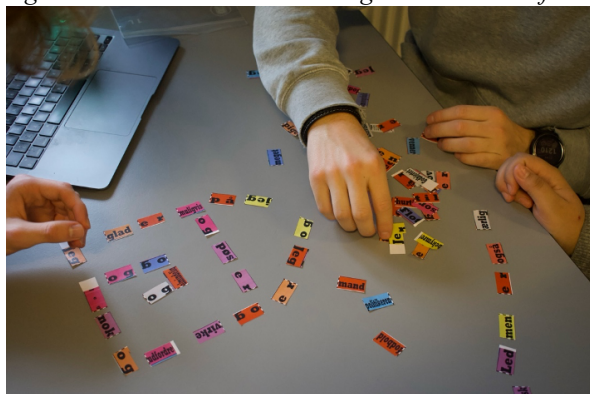
systems? What and how can students learn about generative AI systems when interacting with such tools in various subjects? And most importantly, can students transfer their creative approaches and understanding of how generative AI systems work from a computing education setting to other subjects in school, or even to their everyday lives outside school?

As the questions posed above indicate, there is a research gap on how to teach generative AI with students as creators and designers, and how to foster students' ability to transfer these competences to the world they encounter outside school. Hence, future research should address whether students are able to retain their knowledge and competences about generative AI systems and if they are able to apply them in new contexts. Transfer of knowledge is crucial to education since knowledge about and interactions with AI systems generally aspires to have impact on contexts, such as students' lives outside school, which is quite different from the specific context of learning in computing education. When investigating the nature of students' transfer of knowledge, both the concept of near transfer (learning transfer to closely related contexts and performances) and the concept of far transfer (learning transfer to rather different contexts and performances) are relevant (Barnett & Ceci, 2002; Musaeus & Musaeus, 2024).

At the Center for Computational Thinking & Design, we are concerned with developing critical AI literacy in K-12 education using a design based research approach and participatory design to work closely with teachers during the entire research process. We present research investigating how to design tools for teaching about the underlying models of natural language processing and about the training of large language models (LLMs) in high schools, while exploring what creative expressions students engage in when interacting with these tools, see Figure 3 (Musaeus et al., 2023). Also, we are studying how students' and teachers' creative interactions with AI systems change after participating in teaching interventions in which these tools are applied, and if knowledge is retained. Finally, we are investigating if and how knowledge and interactions transfer to other contexts outside formal education, leading to computational competent, critical, and creative students.

**Figure 3**

*High School Students Constructing new Sentences from a 'Bag of Words'*



Research such as described above will hopefully give an indication of the opportunities and challenges associated with AI and ML applications in education, e.g. opportunities for students' to become aware of biases through firsthand experiences with LLMs trained on data they have categorized themselves, for teachers to build competences while working with researchers, and challenges in the form of designing appropriate tools for students and teachers to recognize the potential of learning about, and create with, AI. Hence, research such as this will provide guidance of how best to prepare and educate a new generation of students and teachers to understand, interact with, and create generative AI systems that are suited to their specific needs in life.

## Re-situating the salience of context in designing for authentic engagement with AI/ML-based design for athletics and play

Herminio Bodon, Meg Butler, Khushbu Kshirsagar, Vishesh Kumar, Michael Smith, Ashley Quiterio, Marcelo Worsley

As learning scientists, we often remind people that learning takes place across a wide variety of contexts. In this presentation we will focus on what it looks like to design for learning AI/ML across a number of different sports-related contexts. Sports represent a unique social phenomena. Athletic events are one of the few instances where

hundreds of thousands of people may gather together on a weekly basis to cheer for their favorite team or player. In addition to the sheer number of spectators, there are millions of youth around the world that participate in some form of organized or recreational sports activities. Hence, our group has been working to leverage sports to support learning and creating with AI, and similarly, to help youth see how they can use AI/ML to improve their athletic performance. In particular, we have spent the past few years engaging in sports-related AI/ML learning in physical education classes, computer science/coding classes, after-school clubs, multi-week summer camps, STEM festivals, professional sports events, youth sports practices, local community centers, and more (see Figure 4). At a high level, these experiences introduce youth to different sports technologies and challenge them to create sports technologies of their own. Many of the technologies that youth create and engage with are built around wearable sensing (through the micro:bit), computer vision (through Scratch), and other low-cost technologies that are modeled after professional/commercial sports technologies. More than 3000 youth and hundreds of educators/facilitators have contributed to and participated in the activities.

**Figure 4**  
*Group of Youth in Sports Club*



Our research team is inspired by design-based research, and uses a mixed methods approach to design, implement, and study our various implementations of learning experiences that engage youth in talking about and creating novel sports technologies using AI/ML. Broadly speaking, our work across contexts has encouraged us to think about the unique affordances and expectations of each of the different contexts. We find that the spaces require different approaches in terms of tools, ethics, learning, teaching, and assessment. In this presentation we highlight some of these differences. Moreover, we find that working across these different contexts also surfaces the importance of collaborators. Within these spaces we find collaborators in the form of different organizations, and, more importantly, people. For instance, some of our programs include coaches, professional athletes, and sports technology founders, who serve as facilitators/educators for youth. These individuals model what it means to design with and utilize AI/ML in the creation of sports wearables. In so doing, they strengthen youth curiosity and appreciation for the salience of building innovative tools with AI/ML. In sum, by working across a collection of contexts, we are reminded how these different spaces can engage youth in distinct learning with and through AI/ML, in part, as facilitated through the unique set of mentors and collaborators that occupy each space.

## **Building your own generative language model: High school students' engagement with data practices and ethical considerations when designing babyGPTs**

Luis Morales-Navarro, Daniel J. Noh, Yasmin B. Kafai

As generative language models (GLMs) have gained popularity, youth are increasingly using them in their everyday lives. However, most research has centered on supporting youth as users of GLM-powered systems (e.g., Solyst et al., 2024). At the same time, research on how youth engage with the design of ML models has mostly centered on classification tasks with little attention given to generative tasks. Thus, we know little about how to engage youth in the design of these models. We investigated how youth engage in designing small GLMs by building on the rich tradition in learning sciences and child-computer interaction of positioning young people as designers of applications. We conducted a workshop spanning five class sessions (each 90 minutes long) with 35 high school students (ages 14–15) in which they designed very small GLMs (between 30K–600K tokens), which we call babyGPTs, using the nanoGPT framework. In this class activity, we took a data-driven approach that glassboxes, or makes transparent, how data shapes model performance and blackboxes the role of learning

algorithms in the ML pipeline (Morales-Navarro & Kafai, 2024). Building on research on ML data practices (Olari & Romeike, 2024) and ethical sensemaking (Landesman et al., 2024), we analyzed the students' design process, discussions, artifacts, and interviews, to address the following question: What data practices and ethical considerations did participants engage with in the construction process of their own GLMs?

**Figure 5**  
*Fragments from Outputs of the Marvel babyGPT Model when using Different Prompts*

Prompt:	Prompt:	Prompt:
Make Captain America evil	Ironman does not die	Let Thanos win
Fragment from output:	Fragment from output:	Fragment from output:
<p>I'll be a little real person Thanks (DINKING) You think you can get a picture How know you're not what? Go with it Nothing?I'm sorry I don't want to know what I'd be out You're not great How you're all the quantum realm, and then a planet They're not all known faces Do you see the world A little 20 years,'s me looks like you're a I did it We just a bit of weapons, and I need to say "Ndreaming This is what I do, I'm gonna stop you I'll get just radioise me? - You're a little low, are you?- He was a radiation like you leave let's work - What do you get me on - Well, you guys could, we let me know anything - Yeah, I need you Thank you, sir - No</p>	<p>If this is what you are never let it report on the big, it's not the Iron Man They're not the world we're gonna show you The only thing about to the world's working for you, by the plan I want to have a plan And then, or a story that I can't even go to you You're your plane, not I'm working I'll see you guys all throw all Director Stop out of, Happy?(GROANS)Tony, Tony Just make me like, just do you get a perimeter one purpose of this? What?I need you to be a second something at the other thing for the signal But you're a time If you don't speak to you if you we don't even had a lot of them, that will we have to reach in Well, and he'll see you, and now we should have a lot like a problem</p>	<p>That doesn't even know how he went up with me?Not a few years, didn't you?I used to have to bring them a flight? I had to show me my God I've been particularly something I'll need a drink if that you're in as superstoyome, you're the face its stuff up!I've got a txt back to take it You know I need to meet you to be my play a much more enough way to, I know what I have to me?I think I got a distraction, then our cargo?I wish, I think anything be ready men are I thought we won't know You can't stop that?This is what you didn't authorised to do I feel bad guys know I know what? I mean I'll need it Well, you're not here, I got you It's not the day It's not what you were such a man There's like a half form of legendary weapons contractor Can I don't Fury, but then you take it to w'll levels now?</p>

We present a case study of team of three students who designed a babyGPT model to generate Marvel-like screenplays (see Figure 5 for examples of outputs from the model). The team identified that the latest Marvel films were of lower quality and decided to build a screenplay generator that, trained on the scripts of their favored films, would generate new scripts. In doing so, they engaged with data practices (Olari & Romeike, 2024) such as *understanding a task* and *defining success criteria*. While building their model, the team *collected data*, *controlled the quality of the data*, *prepared the data* by tokenizing it and *evaluated the performance* of their model. Engaging in these practices iteratively provided opportunities for students to consider how data quality impacts model outputs and to participate in complex discussions about copyright, authorship, and attribution. After creating these models, participants reflected on ethical implications related to the trustworthiness of generative models, copyright issues, and environmental impact. They also reflected on the importance of data quality and quantity in the training dataset and voiced a more refined understanding of the functionality of generative language models. Our study demonstrates the feasibility of engaging young people in the design of GLMs. Compared to other studies in which youth learned about the functionality of generative models and explored their outputs as users (Solyst et al., 2024) engaging youth in construction activities made more transparent the process of building models. Building babyGPTs supported youth to question the “aesthetic legitimacy” of outputs (Solyst et al., 2024) and develop nuanced understandings of the functionality and ethics of GLMs.

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