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Materializing social media youth practices for algorithmic awareness[☆]

Anna Keune, Santiago Hurtado^{*}

Department of Educational Sciences, School of Social Sciences and Technology, TUM Institute for Advanced Studies, Technical University of Munich, Munich, Germany

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ABSTRACT

Computational thinking is increasingly relevant in technological societies, particularly within social media. Although social media use is prevalent among youth and offers a context for exploring complex digital and non-digital practices, it remains underinvestigated for computer science learning. Drawing on constructionist and post-digital approaches, this study investigated how creating tangible flowcharts of social media practices enables young people to perform computational concepts in digital and non-digital contexts. Thirty-two youths (12–13 years old), participated in a workshop in southern Germany using craft materials (i.e., instant cameras, thread, sticky notes) to create tangible flowcharts of social media content sharing practices. Data included video observations, photos, and interviews, analyzed qualitatively using the K-12 Computer Science framework concepts (i.e., algorithms, variables, control, modularity, troubleshooting). Findings show tangible flowchart creation supported performing and recognizing social media content creation as computational. Participants represented algorithms, identified variables, depicted control structures, demonstrated modularity, and reflected on troubleshooting with physical construction and discussion of their flowcharts. Additionally, by materializing these connections, the activity made abstract concepts visible, feelable, and personally relevant, highlighting computation's embeddedness in more-than-digital contexts. The research advances an approach for young people to recognize computation as more-than-digital, promising to foster responsible participation in technical societies.

1. Introduction

Computational thinking (CT) is increasingly vital in our technology-saturated world (Bocconi et al., 2022). CT involves problem-solving processes expressed in computational steps executable by computers (*K-12 Computer Science Framework*, 2016). Central to CT is understanding computational concepts like algorithms, sequences of steps in specific structures guiding processes toward an outcome (*K-12 Computer Science Framework*, 2016). Approaches to learning these concepts span a spectrum from non-digital to digital, and a mixture of both. The non-digital end of the spectrum includes tools such as board games, paper flowcharts, and textbooks to help learners visualize abstract computational logic in the physical world (Chen et al., 2023; Ensmenger, 2016; Looi et al., 2018).

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^{*} Corresponding author at: Arcisstraße 21, 80333, Munich, Germany.

E-mail address: s.hurtado@tum.de (S. Hurtado).

Conversely, digital approaches, such as the [Code.org](#) platform, engage learners through screen-based interactive lessons ([Choi & Choi, 2024](#)). Finally, hybrid approaches mix digital and non-digital contexts by linking digital processes to physical devices and for example, using the digital Scratch platform to program a tangible Makey Makey controller ([Lee et al., 2014](#)) or utilizing artificial intelligence curricula that blend tangible and digital activities ([Kim & Kwon, 2024](#)). Such hybrid approaches make the tangible aspects of computing visible, emphasizing the importance of examining how youths' everyday computational practices are situated in the physical world.

Social media is such a context for understanding how computational thinking is digitally and materially related. Social media platforms rely heavily on complex algorithms for content delivery ([Kardan & Hooman, 2013](#); [Narayan, 2023](#)). People interact with and shape algorithms through their interactions, as algorithms draw on routine digital (e.g., liking, posting) and non-digital practices (e.g., staging photos). Although young people perform such socio-material algorithmically structured routines often, these prevalent practices remain underexplored aspects of computational thinking. Little is known about how we can make social media practices, spanning digital and non-digital contexts, visible as performances of computational thinking to young people, and how to ensure young people recognize computation as contingent on both digital and non-digital contexts. Thus, this paper asks: How does creating tangible flowcharts of social media content creation support young people in representing computational concepts in both digital and tangible forms?

We approach social media activities from a socio-material perspective ([Turkle, 2007](#)), which emphasizes that human social practices and tangible objects are deeply intertwined. To investigate how young people demonstrate computational conceptual performance within socio-material social media activities, this study builds on a constructionist approach to learning, which emphasizes learning as a process of designing personally meaningful projects ([Papert, 1993](#)). In constructionism, the manipulation of digital and tangible materials toward personal projects requires engagement with domain ideas. Building on these constructionist ideas, we designed a three-session workshop for young people to create tangible maps of their digital-non-digital social media practices. We facilitated a workshop for 32 youths (ages 12–13) at a school. This study focuses on the first session (55 min), during which youths worked in seven small groups (3–5 per group) to create tangible flowcharts of their social media content-creation practices using instant cameras, sticky notes, yarn, and other craft materials. Data sources included video observations of the groups' design processes (4.5 h total), 43 photographs documenting the flowchart-making, and semi-structured interviews conducted during the activity (average 2 min; 49 min total). To assess the performance of computational concepts in action, we analyzed the data based on *algorithms*, *program development*, *variables*, *control*, *modularity*, and *troubleshooting*. We also analyzed the design process for each group's tangible flowchart and created Python pseudocode to transform their algorithmic logic into a computational language. Finally, we iteratively and thematically analyzed the semi-structured interviews to identify whether and how the youth related their tangible flowcharts with computational concepts. Findings show that the tangible flowchart-making activity facilitated the youth's performance of computational concepts in their social media practices, allowing them to represent algorithms, variables, control structures, modularity, and aspects of troubleshooting in their everyday use. Advancing a broader perspective of computation as more-than-digital promises to foster thoughtful and responsible participation in a technological society.

2. Theoretical background

As the number of social media users has been increasing every year, young people's participation on social media also increased in prevalence (We Are [Social & Meltwater, 2024, 2025](#)). As of early 2025, 5.24 billion social media profiles have been recorded, 67.9% of the world's population, and 70.5% of people use a mobile phone, of which 87% are smartphones ([We Are Social & Meltwater, 2025](#)). This is an increase of 136 million accounts from the previous year ([We Are Social & Meltwater, 2025](#)). Young people use social media to connect with peers, find information, create content, and share it online ([Aichner et al., 2021](#); [Kligler-Vilenchik & Literat, 2025](#)). In the process, young people integrate digital and non-digital practices in reciprocal ways, shaping both online and offline practices.

As young people spend substantial time on social media, social media as a learning environment can offer opportunities to examine how youth engage with algorithms, how algorithms intersect with and are shaped by offline practices, and whether and how young people learn about such online-offline computation. For instance, as the number of social media users grows, so does the content shared online. To organize large quantities of content, social media platforms include recommendation algorithms that can provide personalized experiences ([Aichner et al., 2021](#)). This also includes that social media platforms track interactions to provide personalized content that keeps people engaged while presenting advertisements that are likely to be of interest ([Kardan & Hooman, 2013](#)). To make this possible, social media platforms offer a degree of control over these algorithms through features that allow users to express preferences about content, which are tracked to inform what else to show ([Chen & Huang, 2024](#)). Young people customize social media, intentionally or not, by using platform features. This often involves repetitive steps, similar to algorithms, to create and share content on social media ([Keune & Hurtado, 2023](#)). These steps occur digitally (e.g., clicking buttons, scrolling, and pausing on images) and non-digitally or tangibly (e.g., while young people hold their phones and pose for a picture). It remains understudied how young people learn about such computation in the world.

More broadly, as digital technologies have been heavily integrated into everyday life, the prevalence of algorithms influencing non-digital life has greatly increased. Social media is more than a collection of websites and apps. It is a dynamic, evolving system that shapes political realities, social interactions, and cultural landscapes. Social media's reach beyond the screen makes it a crucial more-than-digital context for understanding young people's experiences ([Ito et al., 2020](#)). For example, social media has impacted various offline contexts, blurring the lines between the digital and the tangible, providing an avenue for marketing, business, and employment, and enabling the advertising and purchase of tangible goods ([Kardan & Hooman, 2013](#)). Moreover, social media enabled people to stay in touch, share updates about their lives, and organize events ([Aichner et al., 2021](#)).

Additionally, and most relevant to the present study, people interact with social media through tangible artifacts, such as smartphones, that are handheld and that require fingers to move on a screen. For example, the steps for creating social media content involve digital actions (e.g., commenting on a picture) and non-digital actions (e.g., posing for a picture). Young people interact with social media as a digital platform sharing content using digital features, while at the same time necessitating the tangible, for example, taking a picture of a sunset. Social media offers opportunities to participate in both digital and non-digital contexts, as it provides access to recent trends and allows people to share and comment on personally relevant content about their own lives (Aichner et al., 2021). This also promises an opportunity to better understand how to consider computational thinking in both digital and non-digital contexts, and whether and how young people learn about it.

2.1. Computer science learning as more-than-digital

Computational thinking (CT) is becoming increasingly important as technologies embedded in everyday life continue to develop (Bocconi et al., 2022). Although CT lacks a consolidated definition, it can be described as a thought process in problem solving expressed in computational steps carried out by a computer (*K-12 Computer Science Framework*, 2016). Developing CT is not limited to learning how to program on a computer but also includes learning and engaging with related computational conceptual ideas in non-digital environments (Horn & Bers, 2019). CT often involves learning computational concepts, such as algorithms, variables, and control structures (Huang & Parker, 2023; Jacob et al., 2018; *K-12 Computer Science Framework*, 2016; Wing, 2006). For example, learning about algorithms (i.e., a sequence of steps executed in a specific order toward an outcome) is foundational to developing the CT practice of conceptualizing and building computational challenges and artifacts (*K-12 Computer Science Framework*, 2016).

Engaging with computational concepts is not limited to engaging with digital and programming-based environments. Learning about computational concepts outside of programming environments can reinforce understanding of such concepts before starting to program (Horn & Bers, 2019). Further, tangible contexts for computational conceptual learning are also important because digital interactions are always bound to tangible interactions and environments (Macgilchrist, 2021). Digital engagement cannot occur without physical engagement (Burnett & Merchant, 2020; Colvert et al., 2024; Ehret et al., 2022). For example, the routine of using a hand to take a phone, open a camera app, capture a digital image of the tangible world, using fingers to edit the picture, and share it digitally is a more-than-digital social media practice. The digital always resides in relation to non-digital contexts, such as a cellphone that is used to open digital applications. Interactions with digital technologies are sometimes referred to as *more-than-digital* practices (Bhatt & Gourlay, 2024) to acknowledge that digital interactions require non-digital actions. Such approaches point to the importance of integrating the continuum of digital and tangible into the learning of computational concepts, and by extension, computational thinking. Investigating contexts in which more-than-digital is explicit, such as social media, can help connect computational conceptual learning to young people's cultural practices, making the continuum between the digital and the tangible relatable and feelable for learners. This prior work calls for an analysis of how young people experience and talk about the ways tangible practices relate to the production of computational practices.

To identify opportunities for investigating how young people become aware of the tangible and digital interplay of computation, we turned to flowcharts. In computer science (CS), flowcharts became a popular tool in the late 1940s as a programming blueprint, serving as a visual representation of a computer program's structure (Krajewski, 2020). Flowcharts became useful for planning and executing programming tasks. In education, the creation of digital flowcharts aids learners in visualizing algorithms and other computational concepts, thereby supporting understanding of complex processes (Ensmenger, 2016). Flowcharts can help young people represent algorithm structures and organize elements in computer software (e.g., Hooshyar et al., 2015; Rahman et al., 2020). Flowcharts are also used non-digitally, for example, by drawing a program flowchart on paper (Looi et al., 2018). Flowcharts primarily focus on representing algorithms and programmatic logic within digital systems, but also seem promising for representing computational conceptual practices that span beyond digital practices and into non-digital realities because they can map actions that occur in both contexts. However, it remains understudied how flowcharts could support understanding of the intersections between digital and tangible aspects of computational conceptual performance on social media.

2.2. Constructionist approaches to learning computational concepts

In this study, we took a constructionist approach to learning (Papert, 1993). This perspective on learning has a long history of theorizing and designing digital and tangible learning environments, also for learning computational concepts (Horn & Bers, 2019; Kafai et al., 2014; Kafai & Resnick, 1996; Resnick et al., 2009). Constructionist learning theory considers that learning of concepts can be substantiated by supporting people in the design of personally meaningful projects (Papert, 1993). Constructionism frames computational conceptual learning as a sociocultural phenomenon that extends beyond treating learning as a set of problem-solving steps, situating it as a process of creating and sharing artifacts (Holbert et al., 2020; Papert, 1993).

Constructionism has a long history with CS and tangible approaches to learning complex concepts. In 1969, Seymour Papert, at the MIT Artificial Intelligence Lab, created the turtle robot. This robot replicated the programming language Logo, which involved simple commands to move a turtle on a screen that drew a line wherever it moved (Solomon et al., 2020). With Logo, the robot, and the programming language, young people engaged in creating personally meaningful projects to learn computational concepts (Solomon et al., 2020). Constructionist learning environments, such as Logo, continue to develop. With technological advances, additional tangible and digital approaches are needed to foster learning about technical complexities through the creation of personally meaningful projects.

Constructionism also emphasizes the importance of tangible learning materials (Papert, 1993). The Logo turtle also supported

tangible representations of programming concepts that young people could see and move in contexts outside the computer screen (Solomon et al., 2020). While young people programmed the robot's movements on a screen, they were controlling a tangible artifact. In constructionist learning theory, tangibles play a crucial role in providing hands-on, interactive learning experiences. Tangibles enable learners to manipulate and create non-digital objects, fostering a deeper understanding of abstract concepts through concrete experiences. For example, Fields et al. (2021) investigated how young people using e-textiles learn CS concepts by having them deliberately create failure artifacts for their peers to debug (i.e., projects specifically designed to contain bugs or errors). The authors used e-textiles as a tangible learning context that supported young people in learning about and designing for coding bugs. Furthermore, the combination of digital and tangible contexts can enhance conceptual understanding by providing unique affordances that improve learning outcomes (Olympiou & Zacharia, 2011). This suggests that integrating digital and tangible opportunities can lead to a more effective learning experience. However, it remains unclear whether and how young people learn about the tangible, relational nature of computing.

3. Methods

This qualitative study investigated a workshop intervention (Brown, 1992) in which young people, in small groups, created tangible flowcharts of social media content creation processes. The study was approved by the [blinded for review] Ethics Commission. The workshop took place during the Digital Life curriculum of a school in Bavaria, Germany. This curriculum focused on creating content with virtual reality tools, exploring algorithms, and developing a social media profile to create positive change. According to the overall school curriculum, the middle school computer science curriculum focuses on the use of technology tools (e.g., software, computers, tablets) and media production, but not yet on specific computational concepts. We facilitated a three-session workshop (55 min each; 2.75 h) throughout a period of one month, with seven small groups (3–5 participants per group) simultaneously. The young people voluntarily participated in the study and provided informed consent signed by themselves and their parents or legal representatives. A total of 32 participants (ages 12–13) contributed to the study. The workshop sessions focused on: (1) creating tangible flowcharts of social media content creation, (2) identifying social media risks, and (3) designing social media features to address risks. For this study, we focus on the first session to investigate how creating tangible flowcharts of social media content creation practices and processes facilitated the performance of computational concepts (i.e., algorithms, program development, variables, modularity, control, and troubleshooting; *K-12 Computer Science Framework*, 2016).

During the session, we asked the participants to recreate a hypothetical post on one or more social media platforms. The posts should include sharing a picture(s) of a vacation or celebrating a friend's birthday. We created the tasks based on prior work that investigated youth social media practices through social media walkthrough interviews, which identified common content-creation practices, such as vacation posts and birthday stories (Keune & Hurtado, 2023). Instead of posting on social media, each small group was asked to detail their process in steps, using a decision tree. Tangible flowcharts are step-by-step process diagrams that use tangible design materials. During the session, the groups used instant cameras, pins, sticky notes, emoji stickers, printed photographs (e.g., a sunset or a birthday cake), markers, tape, and other crafting materials to help identify the digital and tangible nature of social media practices. The participants pinned these materials on a pinboard and connected them with thread to show their social media content creation processes. Creating tangible flowcharts made it possible for the participants to include digital practices (e.g., shrinking text of a name) and non-digital practices (e.g., posing for a photo), illustrating the complexity of their interactions.

Each group created a tangible flowchart that represented their shared practices. In their groups, youth discussed and enacted the steps to creating social media content, including taking pictures (as they do for authentic social media posts), cutting printed images and pasting them on the flowchart (as a representation of posting), and connecting elements on the flowchart (to illustrate relationships and progressions). The tangible flowcharts did not always show unidirectional flows, as the threads connecting the elements sometimes showed multiple directions. The thread provided a tangible material to show complex relationships. Throughout the session, a facilitator conducted semi-structured interviews with each group about their flowchart designs and whether and how they related their tangible flowcharts to social media algorithms.

3.1. Data sources

We collected three data sources to answer the research question about how young people perform computational concepts through tangible flowcharts of social media content creation practices. The data sources were: (1) Video observations of the groups' flowchart design processes, (2) photographs of tangible flowcharts in progress and final designs, and (3) semi-structured small group interviews about designs in progress.

We recorded *video observations of design processes*, capturing each group separately (average 55 min; 4.5 h total). The videos captured youths' interactions with materials and their verbal utterances throughout the session, showing how the tangible flowcharts were produced. This data source showed youth staged pictures, interacted with materials, and how the tangible flowchart progressed. The *photographs of tangible flowcharts* (43 photographs) showed youths' projects (in progress) and close-ups of the tangible flowcharts that the video observations could not capture in high-quality detail, each part of the flowcharts. We conducted *semi-structured interviews* with each group (average 2 min; 49 min total) to capture how participants related their tangible flowcharts and social media content-creation practices to social media algorithms. The interviews asked youths to explain what they were doing, which platforms they used for content creation, what details they could add to their flowcharts, and whether they related their tangible flowcharts to algorithms and how. The semi-structured interviews provided verbal utterances about how youth connected social media practices to CS concepts.

3.2. Analytical techniques

We analyzed how youth's social media content creation practices relate to CS concepts. First, we analyzed the *video observation of design processes* and *images documenting tangible flowcharts* to answer how youth illustrated CS concepts in their tangible flowcharts. We developed a codebook using a deductive coding approach based on the concepts from the *K-12 CS framework* (2016), including *algorithms*, *program development*, *variables*, *control*, *modularity*, and *troubleshooting*. We focused on social media content creation (Table 1) based on the definitions from the *K-12 CS framework* (2016) and defined how the concepts would be represented as social media practices. For example, the CS concept of an algorithm, defined as the steps executed toward an outcome, is the steps executed to create and post content.

To achieve inter-coder agreement, two raters coded all of the groups' tangible flowcharts (Cofie et al., 2022). Initially, two coders independently coded all the tangible flowcharts to compare codes, refine codebook definitions, and discuss discrepancies in the codebook (Cofie et al., 2022). Then, all data were recoded using an updated codebook, including video observations, semi-structured interviews, and tangible flowcharts. The two coders reviewed the analysis, and discrepancies were resolved again. The codebook made it possible to identify the performance of computational concepts.

We analyzed each group's design process to identify how they developed their tangible flowcharts and presented computational concepts (Jordan & Henderson, 1995). The analysis then provided a detailed look into each group's process for mapping their own performed more-than-digital processes, such as taking pictures in authentic environments and then selecting which ones to post on the screen, showing the digital and tangible relations of computation in social media. Additionally, we digitized the tangible flowcharts and coded them for computational concepts. Finally, we translated the flowchart sections that included program structures into Python pseudocode, describing the algorithm's logic using a mix of plain language and keywords representing programming structures, and highlighting the computational concepts involved in social media content creation.

Moreover, we analyzed how youth articulated their tangible flowcharts during *semi-structured interviews* using iterative and thematic coding (Morgan & Nica, 2020). During the interviews, youths explained the flow of their tangible flowcharts. We transcribed all interviews and analyzed whether the youth related their tangible flowcharts, and therefore their social media content creation practices, to computational concepts and considerations of digital and tangible relations of computation.

4. Findings

The tangible flowchart design enabled youth to present complex, more-than-digital social media content creation as a performance of computational concepts. All seven groups showcased all computational concepts: *algorithms*, *program development*, *variables*, *control*, *modularity*, and *troubleshooting*. Across all of these, young people's flowchart presentations showed how these conceptual performances were produced through more-than-digital practices. All names used are pseudonyms.

4.1. Posting on social media as an algorithmic performance

Algorithms are step-by-step processes executed toward an outcome, and *program development* is the process of designing a program that may include several algorithms. Within social media content creation, *algorithms* involved multiple steps executed toward the outcome of posting on social media. During the session, this also involved *program development*, as the algorithms shared the same outcome of content creation. For example, one group of five youths (two girls, three boys; self-identified) created a tangible flowchart that showed a four-step social media content creation process (Fig. 1).

The tangible flowchart design called for the group to map social media content creation as a step-by-step algorithmic process. First, the tangible flowchart included two sticky notes that read (1) "Taking the photo! Remember the moment" and (2) "Because of: birthdays, events, trips, special occasions, accomplishments, etc." The flowchart also included cutouts of a phone taking a picture, a birthday cake, a boat view, and an instant picture of a group member. Then, as a second step, the flowchart showed two sticky notes

Table 1
Codebook of K-12 CS framework concepts and how they appeared in the data.

Codes	Definition from K12CS	Representation in the data
Algorithms	Steps executed toward an outcome.	Steps executed in linear, conditional, and loop statements, with the outcome of posting on social media or not.
Program development	The design of a program toward a particular outcome.	The process of designing an everyday algorithm for social media content creation with tangible materials (e.g., defining variables, specifying sequence order, and constructing decision trees).
Variables	Containers for tracking and modifying data.	Trackable containers in the social media algorithm, such as events, pictures, and/or audiences.
Modularity	Breaking down the program into smaller, reusable parts.	Reusable parts representing sections of the algorithm, such as editing images (i.e., choose edits [caption, hashtags, emojis])
Control	The flow of sequences in the program.	Decision trees and rules in sequences for posting content on social media, such as choosing a platform or requesting consent if a picture includes other people (e.g., for each group picture, ask for consent; if consent is given, continue; else, do not post).
Troubleshooting	Finding and solving sources of computational malfunction.	1. Long-term experience with posting on social media has refined practices over time. 2. Revisiting the social media content creation process to add steps or expand variables (e.g., adding another platform).

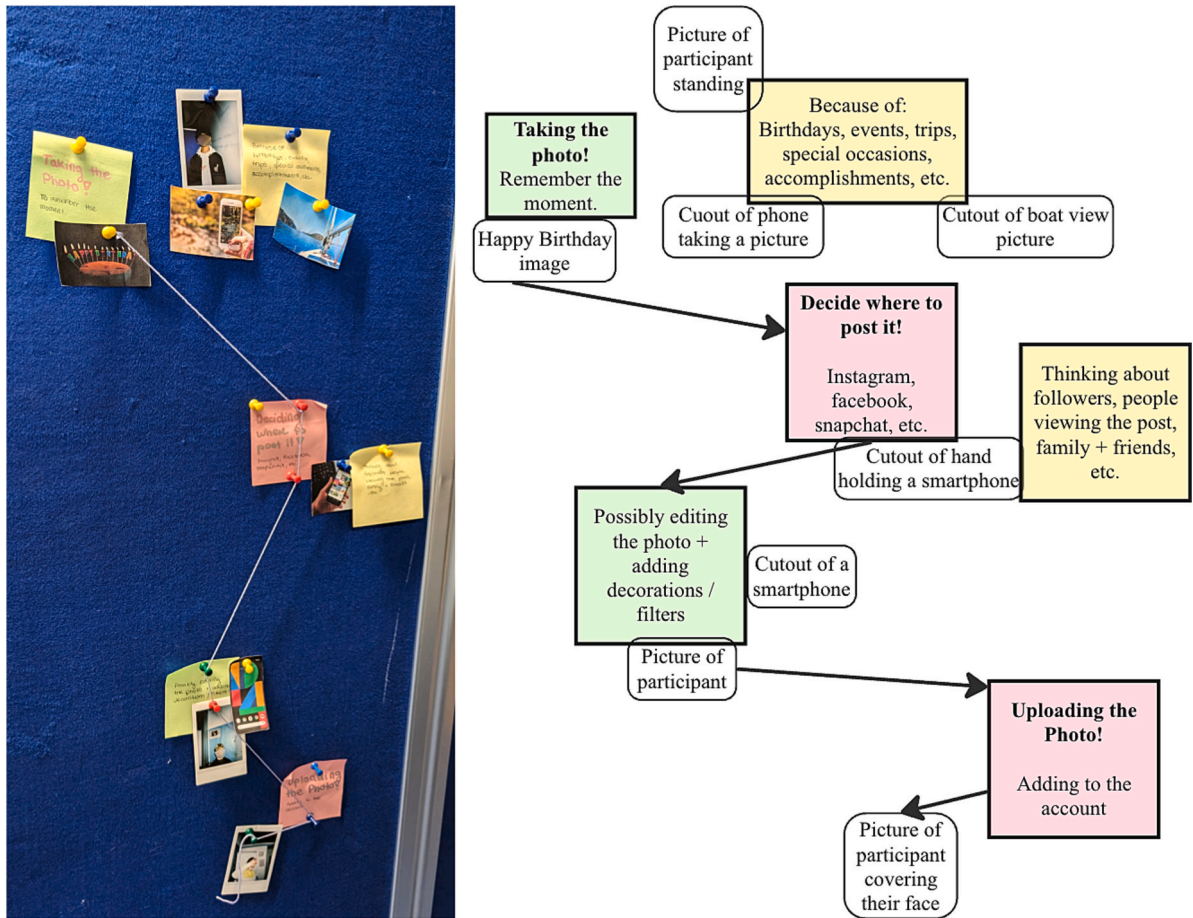


Fig. 1. Tangible flowchart showing the algorithmic process of posting on social media.

with the text (3) “Decide where to post it! Instagram, Facebook, Snapchat, etc.” and (4) additional considerations “Thinking about followers, people, viewing the post, family + friends, etc.” The third step was editing, described with a sticky note that read (5) “Possibly editing the photo + adding decorations/filters,” a cutout of a smartphone, and an instant picture of a participant. Finally, the fourth step showed a sticky note with the words “Uploading the Photo! Adding to the account” along with an instant picture of a participant covering their face with a hand. This represented the group’s collectively decided steps, illustrating the repetitive steps performed to post on social media.

Youth identified their own social media content-creation practices as repetitive and algorithmic. For instance, one group said that creating social media content is similar across platforms and that they engage in this process every time they create content. One group member, Nancy, said: “With algorithms, it’s basically kind of like a repeating pattern that continues, and here it’s the same. It’s really similar, every time you want to post a photo (...).” She connected her practice of creating social media content to an algorithm by equating content creation with a repeating process executed the same way each time. Nancy added:

“Because I think whenever you post something, you kind of go through the same algorithm. Like first you take the picture, then you think about where you want to list it, and then you look at it again, maybe you edit it a little, and then you go through the same process every time you post something.”

Nancy said that creating social media content involved a series of steps she followed each time she posted. Nancy’s quotes exemplify how youth relate their social media content-creation practices to algorithms, echoed across all groups. The tangible flowchart design made it possible for youth to break down the steps of social media content creation, perform them, and tangibly connect them. This process helped them recognize their practices as algorithmic. What is more, Nancy showed that the social media algorithm was not only directed by the digital social media platform but was more-than-digital. It was also shaped by an interplay between the platform (e.g., follower function, filter options) and young people’s tangible and non-virtual practices (e.g., taking pictures, posing).

4.2. Social media content creation as program development

We also identified the K-12CS concept of *program development* with all seven groups. *Program development* means the process of

designing a program toward an outcome. In this study, we examined *program development* as the recreation of the processes youth engage in during their everyday social media use. Thus, youth did not create a program in itself but rather represented the process of the content creation. Youth engaged in *program development* through tangible flowchart-making, reflecting on their everyday social media practices as a shared performance with recurring steps. The concept of *program development* was evident in the session, as youths successfully demonstrated the programmatic steps they followed to create social media content.

For example, one group of four girls (self-identified) created a tangible flowchart for a birthday story with three options: A picture of one person, a group picture, or a funny picture (Fig. 2). The group added conditions or consequences about posting each picture using tape stuck to the edges of the sticky notes (e.g., the individual picture could be embarrassing or lonely; the group picture needs to be checked for consent). The group developed their tangible flowcharts by deciding which content to include (e.g., a birthday story), discussing the relevant steps, and performing picture-taking with the instant camera (Fig. 2, right).

The flowchart design involved the performance of digital and tangible practices of social media content creation. The group represented these practices, such as holding a phone to take a picture, by incorporating cutouts and instant pictures into their flowchart. Performing these processes was made possible by the available materials (i.e., instant camera, printed pictures), with which they could both perform the tangible parts of the actual process (e.g., taking pictures) and represent it with the printed photo that showed the group performing the process (e.g., holding a phone for editing a picture). This was related to *program development* because it represented the everyday algorithmic process youth engaged with using tangible materials, showcasing that digital algorithms (e.g., content creation on social media) also occurred in more-than-digital contexts (e.g., taking a picture while holding a phone).

The concept of *program development* was showcased, as youth converged their everyday algorithmic practices into a single artifact (i.e., flowchart). Throughout the activity, they discussed what should be included in their flowchart, added elements, and edited them. Youth reflected on their practices and, in a group setting, agreed on the steps for creating social media content. Further, developing their tangible flowchart provided opportunities to stage their process as it would happen on social media, showing the more-than-digital aspects, including staging pictures. This relates to the concept of *program development*: developing a program that results in an outcome the program developers are satisfied with. It also made visible that the tangible flowchart creation supported them to identify social media as a context in which computation was more-than-digital.

4.3. Variables of social media content creation

Variables are containers for tracking and modifying data. On social media, *variables* can be considered trackable containers for elements like pictures or audiences. During the session, youths added elements to their flowcharts that could be recognized as *variables*. Although the tangible flowcharts of all small groups differed, variables occurred across flowcharts, such as pictures, audience, and platforms.

One variable in all seven flowcharts was *pictures*. Some groups included additional modifiers to the variable, such as selecting the best pictures or the number of pictures to include per post. When posting on social media, this variable meant taking pictures with a phone and selecting the best ones to post. During the session, the youth performed this process with instant cameras. For example, one of the groups specified that the pictures for an Instagram post should consist of multiple group photos, each featuring people who posed differently. To represent this variable on their flowchart, the group staged the pictures by having one participant take a picture while the other three participants posed (Fig. 3). The group performed this by posing in front of an instant camera just as they would pose during authentic picture-taking moments when creating social media content with a smartphone. This example showcased that groups performed *variables* as a more-than-digital computational concept by identifying which parts of their tangible flowcharts could contain different values and representing these values with tangible materials.

Another variable was *audience*, which was repeated across groups, meaning considerations of who would see the created social media content and, depending on this, which content could or could not be posted. On social media, this means choosing a platform with content visibility filtering, or using features such as Instagram's Close Friends, which makes it possible to post a story that only a predefined list of friends can see. During the session, the youth included audience variables in their tangible flowcharts. For example, one group specified that they had to be careful about what they posted online because most of their friends' parents followed them. Thus, the *audience* variable included values such as friends, parents, or family, which could vary depending on the social media platform used to share content.

The flowcharts enabled youths to understand the variables of social media content creation. Variables were represented with tangible materials, such as instant pictures or sticky notes. The thread that connected nodes in the flowchart enabled youth to connect variables and consider how those variables could have modified the data depending on the algorithm's flow (e.g., if parents were part of the audience, consider what to post). Tangible props that represented variables and their values helped identify how social media content creation required the performance of variables.

4.4. Control structures during social media content creation

Control is the flow of sequences in the program or algorithm, such as linear, conditional, or loop. On social media, *control* meant the steps, decision trees, and rules for posting content, such as asking for consent. The tangible flowcharts did not always follow a linear flow, as youths added to them throughout (e.g., by changing a variable's position). We recreated the flowcharts digitally for better visual clarity, coded them with K-12 CS concepts, and created Python pseudocode translations (Keune, 2022) to analyze how the flowcharts represented different control structures (i.e., linear, conditional, and loops).

First, a linear control structure involves a series of steps executed one after another until the end, without conditions. One example

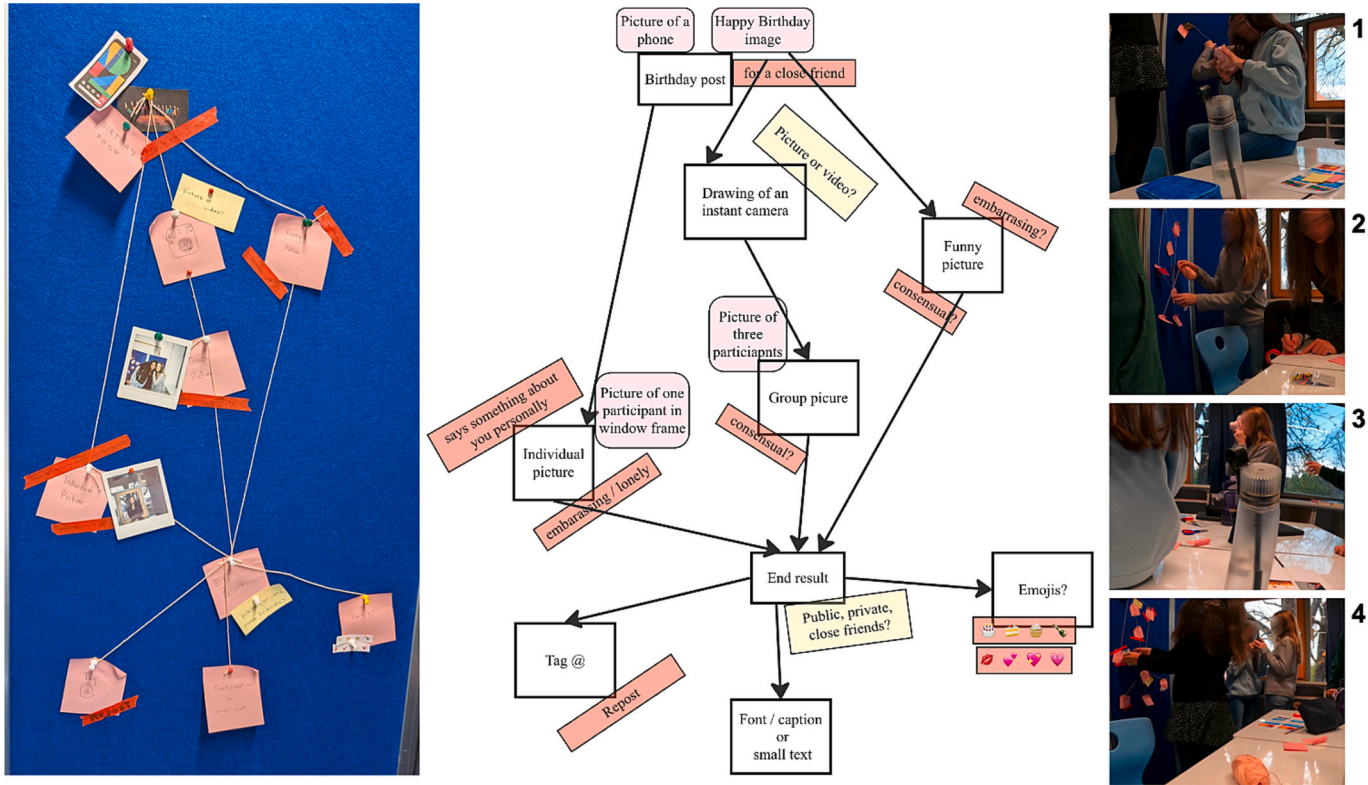


Fig. 2. One group's tangible flowchart (left), digital translation (center), and moments in their tangible flowchart-making process (right): (1) adding the first elements, (2) connecting elements with yarn thread, (3) taking an instant picture, and (4) finalizing details of their flowchart.



Fig. 3. Staging of three group pictures that represent an Instagram Post.

of a linear control structure encompassing the complete content creation process was evidenced by a group of four youths (two girls and two boys; self-identified; Fig. 4). The steps included in the tangible flowchart were: (1) Start with the platform (Instagram), (2) take a picture, (3) choose a picture, (4) edit the picture, and (5) ask a friend for feedback. This representation offered a simplified content creation process that followed a step-by-step approach (Fig. 4). The tangible flowchart also included cutouts representing the physical space where the group would have taken the picture (i.e., at sundown or on a boat). By creating a tangible flowchart, the group developed a linear control structure with five steps and added cutouts representing the spaces they would have engaged in with these practices, illustrating the more-than-digital nature of the control structure.

Second, a conditional control structure allows a program to make a decision based on whether a condition is true or false. An example of a tangible flowchart with a conditional control structure was by a group of six youths (one girl and five boys; self-identified). The group's tangible flowchart described the process of creating social media content for a friend's birthday. This was one of two flowcharts that included consent as part of their social media content creation practices. The flowchart specified that posting content for a friend's birthday meant posting a picture of someone else warranted asking for consent prior to posting. The flowchart showed that two conditions would have to be true when looking for pictures of a friend: (1) Searching for pictures, if pictures are found, asking for consent, else terminating the post, and (2) requesting consent, if consent received, posting, else terminating the post. Fig. 5 shows the flowchart and a Python pseudocode translation that illustrates how the group's social media practice could be considered the performance of computational control structures.

Third, a for loop is a statement that allows for the repeated execution of a block of code a specific number of times or for each item in a list. An example that included a for loop was part of the tangible flowcharts by a group of four girls (self-identified). This group created two tangible flowcharts, one for a vacation post on Instagram and another for a birthday story on Snapchat (Fig. 6). The group differentiated the two flowcharts in the types of pictures included. Instagram posts, they specified, should consist of group pictures. Snapchat stories, on the other hand, should feature individual people. Anne, one of the group members, said:

"We have three options because that's usually what you post, we don't only post one thing on Instagram, like for a story, you only post one story, but for a post, you post multiple of your best ones or favorite ones."

Anne explained that the flowchart should show multiple pictures, because that would reflect the youth's actual social media content creation practice. The creation of the flowchart allowed youths to represent tangible practices they engage in on social media, such as staging and taking pictures, and to organize them in structured ways that relate to complex computational concepts, such as a for loop. We translated the for loop practice into Python pseudocode (Fig. 6), to illustrate how posing, taking, and choosing pictures could be considered a for-loop.

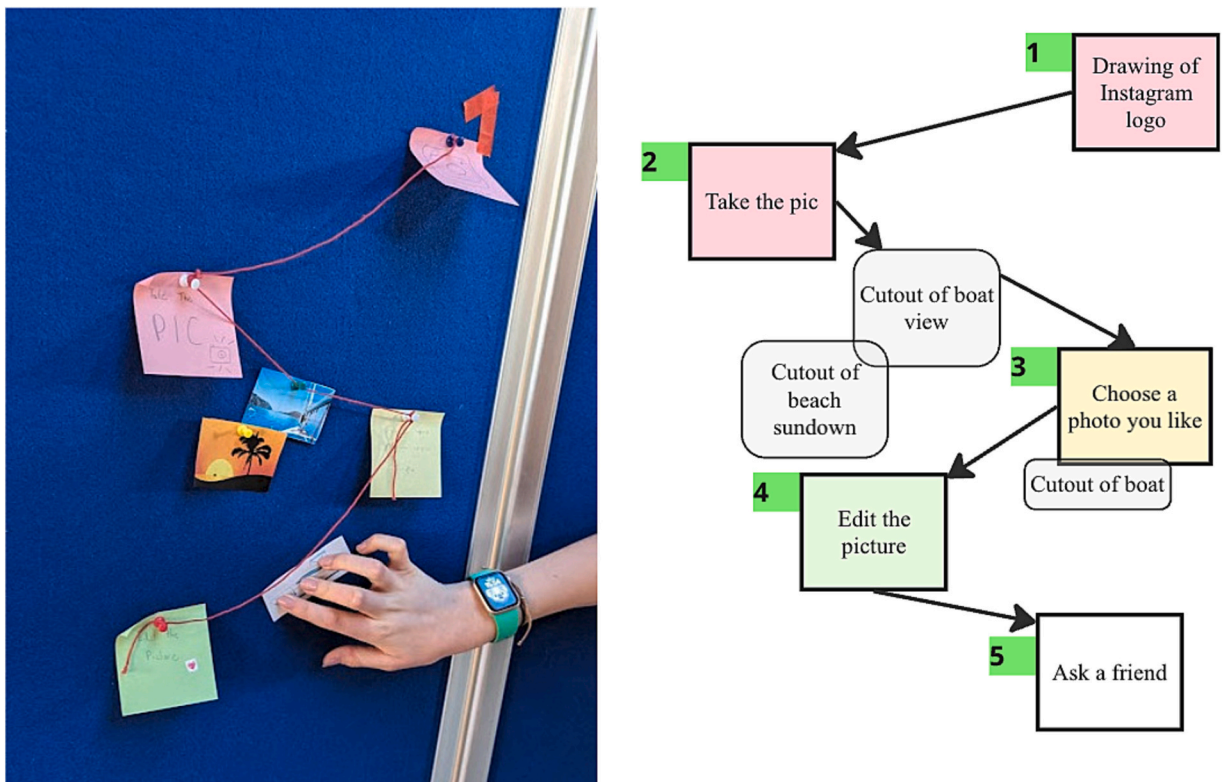
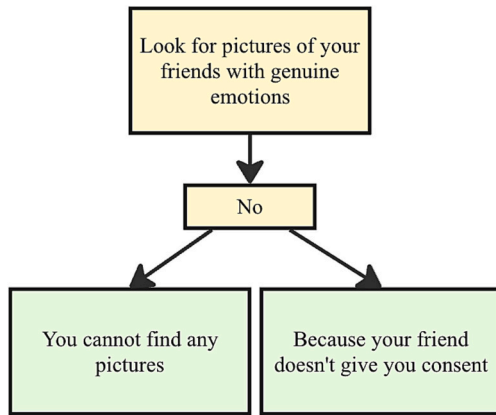


Fig. 4. Linear control structure that follows five steps to create content on social media.



```

1 print("Look for pictures of your friends")
2
3 response = input("Did you find pictures? (yes/no): ")
4
5 if response == "no":
6     print("You cannot find any pictures")
7     print("You cannot create a post")
8 else:
9     print("You found pictures")
10    consentResponse = input("Did your friend give you
11                             consent to post? (yes/no): ")
12
13 if consentResponse == "no":
14     print("Your friend doesn't give you consent")
15     print("You cannot create a post")
16 else:
17     print("You have consent to create a post")
  
```

Fig. 5. Consent condition in creating content that includes others in pictures.

Overall, all groups evidenced control structures (i.e., linear, conditional, and for loops). Some of the tangible flowcharts included more detail and branches than others. The tangible flowcharts made the control structures visible as steps in their everyday practices. They showed how different parts of it involve digital (e.g., editing) and non-digital (e.g., asking for consent) practices.

4.5. Modules across posting practices

Modularity is the breaking down of a program into smaller parts that can be reused. On social media, *modularity* was the reusable part of content creation processes. Modules in the tangible flowcharts included repetitive chunks of code that could be executed separately. These modules included taking a picture, selecting a picture, assessing the audience, editing, requesting consent, or creating a post. Some of these modules were simpler, such as asking for consent (Fig. 5), which involved a yes-or-no condition, while others were more complex, such as editing, which involved various conditions or sometimes for loops (Fig. 6).

Four out of the seven groups included the selection of a platform and audience in their tangible flowcharts (Fig. 7), which we coded as a module in the content creation process. One platform could have various audience subtypes, because it allowed audience customization depending on the type of post. For instance, Instagram Close Friends enabled filtering to a curated list of friends, or choosing from separate private or public accounts. Although the groups included choosing a platform and audience in their tangible flowcharts, they did not make their rules for choosing explicit, and sometimes the perspectives of different groups conflicted. In one group, close friends included family, while in another, it was a separate friend subgroup. Such discrepancies depended on each individual's social media context, implying that they defined their own audiences, platforms, and what content they felt was appropriate to share with each. We visualized all the group's audiences and platforms in Fig. 7, illustrating how posts could be directed to different platforms based on audience.

This module represented an explicit, more-than-digital aspect of the content creation process because it called for considering the young people's online and offline networks. It also called for considering the relationship they had with each network and what they felt comfortable sharing with each. Overall, all the groups engaged with modules with social media content creation, and the tangible flowcharts made them visible as chunks of the content creation process (e.g., taking pictures, editing, asking for consent, choosing audience, and platforms).

4.6. Troubleshooting social media content creation

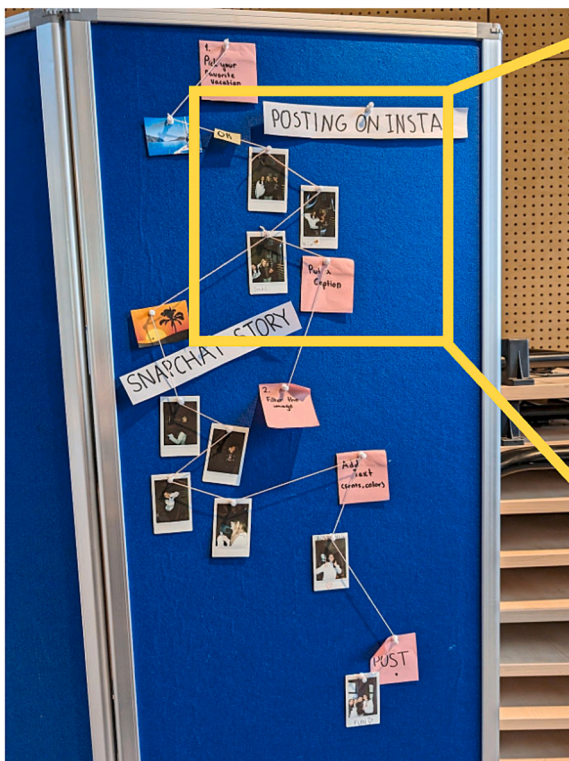
Troubleshooting is the process of identifying and resolving computational malfunctions. *Troubleshooting* could be seen as the optimization of social media content-sharing practices over years of use, including expanding or changing practices in line with observed social media practices spreading across youth groups, and changes in the digital interfaces of social media platforms. The concept of *troubleshooting* was evidenced in two ways.

First, the youth mentioned that they learned to engage with social media content creation through years of participation on social media platforms. Youths expressed that they learned on the go. For example, Nancy shared her experience:

"I feel like you learn it [creating content] while using social media because when you get an app the first time, you don't really know how to post a photo or how to use it, probably, so I think you learn while using them."

Nancy's quote exemplifies what all the groups shared about developing a sense of the shared discourses and norms for creating content on social media. *Troubleshooting* was something the youth engaged with throughout the years as they learned how to create content on social media.

Second, the tangible flowcharts provided opportunities for youth to troubleshoot social media algorithms by moving elements or adding missing ones. As youth created tangible flowcharts, they talked about how their decision trees could be expanded, such as adding options on a variable (e.g., adding more platforms to the variable of platform) or reconsidering which modules were missing (e.



```

1 def post_instagram_post_vacation():
2     num_pictures = random.randint(2, 4)
3     pictures = []
4     poses = ["standing", "silly", "funny", "jump"]
5
6     for _ in range(num_pictures):
7         pose = random.choice(poses)
8         picture = capture_picture(pose, num_people=
9             random.randint(2, 6))
10        pictures.append(picture)
11        print(f"Captured: {pose}")
12
13    create_and_publish_post(pictures, "#Cool")
14    print("Post published!")
15
16 def capture_picture(pose):
17     return f"pic_{pose}.jpg"
18
19 def create_and_publish_post(pictures, caption):
20     print(f"Creating post with {pictures} and caption:
21         {caption}")

```

Fig. 6. A for loop for creating a vacation Instagram post.

```

1 # 1. Define the Audience Containers (Who is this for?)
2 audience_types = {
3     "Public":      ["Everyone", "Followers"],
4     "Friends":     ["Classmates", "Peers"],
5     "Close_Friends": ["Best friends", "Trusted"],
6     "Family":      ["Parents", "Siblings", "Relatives"]
7 }
8 # 2. Define the Posting Options (Where does it go?)
9 posting_channels = [
10     "Instagram_Public",
11     "Instagram_Private",
12     "Instagram_Close_Friends",
13     "Facebook",
14     "Snapchat_Story"
15 ]
16 # 3. Select platform and type based on audience container
17 def post_content(target_audience):
18     if target_audience == "Public":
19         return "Instagram_Public", "Family"
20     elif target_audience == "Friends":
21         return "Instagram_Private", or "Instagram_Close_Friends"
22     elif target_audience == "Close_Friends":
23         return "Instagram_Close_Friends", "Snapchat_Story"

```

Fig. 7. Pseudocode translation of the module for choosing the audience and platform.

g., adding a consent module). The tangible flowcharts made it possible for youth to revisit their social media practices, troubleshooting them together. We observed the youth remove pins and reconnect them using threads. This showed a change in the shared production of their collective social media content-creation processes.

The algorithms the young people showed were not new; rather, they were the result of years of experience creating social media content. The group setting provided an opportunity to share how each individual created content and how one practice converged with or diverged from others. They materialized their approaches with the flowcharts.

5. Discussion and implications

The research shows that social media is an everyday practice for performing computational concepts when young people critically examined social media practices and mapped them in detail. The work adds an everyday context to computational learning, promising to broaden participation by showing young people that the practices they use in their daily lives are already computational. By using tangible materials like instant photos, yarn, and sticky notes, youth mapped social media content creation in ways that made computational concepts tangible. The tangible flowchart design made it possible for young people to perform what we can recognize as computational concepts in tangible ways. Youth performed *algorithms* as a series of executed steps toward the outcome of posting on social media. Youth also performed *program development* by collaboratively designing tangible flowcharts. *Variables*, such as pictures and audience, became tangible and were represented by photographs and sticky notes on the flowcharts. The yarn pathways performed *control structures* in linear statements, conditional statements (e.g., consent checks), or loops (e.g., selecting multiple photos). Grouping steps within the tangible flowcharts showed *modularity*. The ease of rearranging elements facilitated iterative refinement akin to *troubleshooting*, reflecting on long-term learned practices, and making immediate adjustments to the tangible flowcharts. The tangible creation process made it possible for young people to perform what we can recognize as computational concepts, demonstrating that their everyday social media use was computational.

Further, the research showed that creating tangible flowcharts of social media content creation enabled youth to represent computational concepts as both digital and tangible. This effectively adds to the pedagogical use of flowcharts to foster understanding of computation as more-than-digital. Tangible flowchart design made it possible to recognize social media as a context in which computational concepts are performed digitally (e.g., pressing buttons on a screen, posting a picture) and non-digitally (e.g., posing for photos, maneuvering a physical device with a screen). *Algorithms* were performed as sequences that seamlessly integrated physical actions, such as posing for a picture, with digital steps, such as applying filters or tagging locations. *Program development* involved the collaborative design of hybrid routines, in which youth structured their everyday social media use by negotiating both physical staging and digital uploading. *Variables*, such as audiences, served as containers for both digital values, like the Close Friends feature on Instagram, and non-digital social relationships, such as those with family members. *Control structures* were evidenced in decision-making processes that bridged digital (e.g., posting) and non-digital (e.g., asking for consent) conditions. *Modularity* was achieved by breaking the content creation process into distinct, reusable parts, such as digital and non-digital picture editing. Finally, *troubleshooting* emerged as an iterative optimization of these practices, in which youth refined their approaches over years of participation in response to digital interfaces, non-digital relationships, including social norms.

The research also extends constructionist work that focused on the interplay of digital and tangible contexts for conceptual learning (e.g., Fields et al., 2021; Horn & Bers, 2019; Kafai et al., 2014; Kafai & Resnick, 1996; Resnick et al., 2009) by introducing post-digital perspectives that illustrate how design contexts, such as the collaborative creation of flowcharts, can support learning about computation as more-than-digital. The study showed that a tangible approach, when applied to the more-than-digital context of social media, makes computational concepts visible and feelable. The findings were possible through the integrated perspective of constructionist approaches to learning and more-than-digital approaches to computer science learning. Integrating physical materials

enabled learners to externalize their ideas, making perceptible the otherwise invisible algorithmic aspects that underlie ordinary social media experiences. This hands-on engagement surfaces the subtle interplay between the embodied work of content creation and the digital processes that guide participation and content sharing online. This promises to support learners in developing critical awareness of how algorithms and digital practice arise from and reshape real, material practices.

Learning designs can build on this approach by crafting process-oriented, tangible activities that make the digital-material entanglement of computational contexts explicit. Such designs not only support CT development but also cultivate the capacity to question, interpret, and respond to the growing, yet increasingly obscured, presence of algorithmic systems in the world. Together, the findings underscore the need to design tangible learning environments for computational thinking (CT) that foreground how digital computation and material practice reciprocally shape one another. Tangible flowchart design provides learners with a way to trace how computational processes permeate and structure everyday activities. By drawing on familiar more-than-digital contexts, such as social media, these environments help learners recognize CT as not only abstract and screen-based, but as related to digital platforms (and their design) and the tangible actions through which people create, share, and interact.

5.1. Limitations and future directions

The research highlighted flowchart creation as a tool to illustrate computational conceptual performance on social media and the digital and tangible relations of this process. The findings point to the need for further research on flowcharts as a means to assess young people's learning over time, for example, by comparing computational concepts and more-than-digital practices produced over time, and by comparing flowcharts and their changes within and across workshops. As an assessment tool, tangible flowcharts can capture learning beyond individuals and enable comparative analysis of learning differences across groups, thereby creating a profile of how young people present more-than-digital practices differently. Further investigation across different contexts and populations could provide further insights. Future research could compare tangible versus digital flowchart design to map the creation of digital and tangible social media content, or explore other more-than-digital youth cultural practices as contexts for critical engagement with the digital and tangible nature of computation, such as the use of artificial intelligence. This work suggests that grounding computational learning in more-than-digital contexts highly familiar to young people offers a promising path toward critically engaging with computational thinking as a relational process that involves digital and tangible realities.

The study served as an exploration that laid the groundwork for visualizing computational thinking through social media using a tangible approach. Future work should focus on broader CS education by comparing more-than-digital social media activities with other unplugged and hybrid activities to better understand their unique affordances. Additionally, as an initial qualitative intervention, the study focused primarily on the performance of concepts, rather than measuring individual proficiency or retention. Future research could expand this work by more explicitly investigating recognition of these concepts as prompted through more targeted instructional design and young people's talk, for instance, how youth might reflect on computational concepts as both digital and tangible in contexts beyond social media.

The research offers future directions for learning processes that are particularly conducive to learning about computational contexts such more-than-digital. The flowchart creation provided young people the opportunity to recognize how computation on social media, as an everyday context, requires both digital and tangible practices. Recognizing computation as more-than-digital means understanding that computation is not limited to computers, coding, or screens, but rather a broader way of processing information, solving problems, and organizing systems that comes into being and is shaped by everyday practices. In this way, the research contributes to computer science education as more-than-digital, presenting an additional context for broadening participation through seeing computation as related to everyday practice. Additionally, the opportunity to become aware of more-than-digital promises to contribute to research on critical computation that focuses on understanding computation beyond specific tools and toward recognizing patterns, modeling complex interactions and systems that can transfer beyond contexts. This broader view of computation as more-than-digital promises to foster thoughtful and responsible participation in a technology-driven society.

CRediT authorship contribution statement

Anna Keune: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Santiago Hurtado:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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