Computational Action in Action: Process and Tools that Empower Students to Make a Real-world Impact Using Technology

by

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B.S., Massachusetts Institute of Technology (2016)

Submitted to the Department of Electrical Engineering and Computer Science
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Abstract

How can we help K-12 students who are learning computer science and artificial intelligence (A.I.) feel motivated, competent, and empowered? The computational action framework, proposed by Tissenbaum, Sheldon, and Abelson, suggests that the preferable way is to ensure that young people are creating technology projects that address issues in their community. I add to this framework by creating the computational action process, which is composed of curriculum, toolkit, and website that teach five key concepts: defining a real-world problem; understanding users and communities; designing responsibly with and for users and communities; teamwork, project management, and implementation; and planning and making a long-lasting impact. From a research study conducted with 101 international young people in middle school and high school, results show that after learning the computational action process, students showed significant increase in computation skill, digital empowerment, and self-efficacy. Students also demonstrated an improved understanding of the impact of technology on people and society and improved ability to work towards solutions to ambiguous problems. This thesis describes the computational action process, presents the research, and analyzes the results, concluding with key findings, recommendations, and how this work contributes to the field of K-12 computer science education and A.I. literacy.

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Contents

Chapter 1

Introduction

1.1 Motivation

Reducing barriers for young people to start coding is an effort championed today by organizations big, small, and all around the world. Programs for computer science and artificial intelligence (A.I.) literacy for young people are numerous and more popular than ever, including free online resources like Elements of AI, ai4k12.org, MIT RAISE, and more [1, 2, 3]. At the same time, important education research has shown that self-transcendent goals (e.g. to improve the lives of others) can be more motivating for students even above intrinsic (e.g. to increase their own knowledge) and extrinsic motivations (e.g. to make money or receive rewards) [4, 5]. In addition, educators believe that students building applications that address real-world issues is meaningful both for the student as well as beneficial for society [6, 7]. This paradigm dovetails nicely with the development of the engineering design process which has been widely adopted both in industry and in design practices [8, 9]. There is an abundance of data that indicate that young people today proactively want to make a change, help others, and make a contribution to their communities. This is where computational action can make a difference.

The goal of computational action is to motivate learning of technology by focusing on making applications addressing problems in the world, rather than "just coding". This thesis introduces the computational action process, which is a comprehensive process made to address this goal. The framework for computational action was created by Tissenbaum, Sheldon, and Abelson with a goal of increasing students' computational identity and digital empowerment [10]. I have added to their work by developing the full process, which consists of a curriculum, toolkit, and website for students to practice "computational action in action". By running a research study teaching the process to young people, I sought to answer two research questions:

- What interventions enable students to make a socially responsible impact in their community?
- Is the computational action process effective in empowering students to make a good impact using technology?

To create the process, I was informed by related work in education, computer science and A.I. literacy, engineering design, self-efficacy, and motivations for learning. I also drew from authentic practices in the technology and engineering industry, including my own experiences in product management. The three parts of the computational process are: (1) an engaging curriculum for K-12 students that covers five key topics of computational action, (2) a computational action toolkit for students to practice each topic, and (3) a website for students and teachers to access materials and learn autonomously. The process was tested in two pilot studies, from which participant feedback was valuable for improving the materials. A final research study was conducted to evaluate three workshops that taught the computational action process to 101 young people from the U.S. and international countries who were mostly between ages 11 and 18.

Pre-post questionnaires deployed during the final research study measured computational identity, self-efficacy, digital empowerment, and knowledge and skills on the Likert scale. Pre-post coding activities measured student ability in the key areas of computational action. Analysis of survey responses indicate that after the computational action workshop, students showed an increase in computation skill, an increase in knowledge of and confidence in their ability to make an impact, and an increase in their confidence in defining and solving ambiguous problems on their own. Analysis of student work, which includes toolkit work and coding projects, supports these findings. Students' coding projects after the workshop show more defined impact, better understanding of people and communities affected, and more complete code. Quantitative results as well as qualitative results and student work all support the hypothesis that the computational action process helps students better understand the steps to make a good impact using technology. The results also support the hypothesis that teaching the computational action process through three parts (curriculum, toolkit, and website) is effective for achieving this. This thesis will explain in detail the computational action process, the pilots and studies conducted, and the results from the research.

1.2 Key Contributions

This thesis contributes to the field of computer science literacy and artificial intelligence (A.I.) education for young people, by presenting:

- A computational action process of consisting of five topics: defining a real-world problem; understanding users and communities; designing responsibly with and for users and communities; teamwork, project management, and implementation; planning and making a long-term impact.

- Curriculum for young people in K-12 grades that teaches the computational action topics.

- Tools that allow students to practice computational action alongside coding projects.

- Results from a research study measuring the efficacy of the computational action process on students' ability to use technology to make an impact in their communities.

1.3 Background and Related Work

Computational action is one of the goals of the Responsible A.I. for Social Empowerment and Education (RAISE) initiative at MIT. In developing the research and work of this thesis, I have built upon work within the RAISE initiative, most notably work from App Inventor, led by Professor Hal Abelson at the Computer Science and Artificial Intelligence Laboratory (CSAIL) at MIT, and work from the Personal Robots Group (PRG), led by Professor Cynthia Breazeal at the MIT Media Lab. In addition, other coding programs that have influenced the work of this thesis include curricula offered by Technovation Girls (technovation.org) and MIT Solve (solve.mit.edu) [11, 12]. Existing materials and programs have been valuable resources for me to set the scope of the curriculum and shape the tools for the best efficacy for student learning. The computational action materials developed in this thesis were informed by three underlying theoretical perspectives: constructionism, purpose and motivation, and engineering design thinking.

1.3.1 Constructionism

Proposed by Seymour Papert in 1991, constructionism is a learning paradigm that is centered around students self-directing their learning by creating real projects around a topic that is personally interesting and motivating to them [13]. Constructionism has influenced a lot of the work in A.I. literacy and technology education at MIT, including the development of Scratch, a prominent block-based programming technology for young kids, created by the Lifelong Kindergarten group at the MIT Media Lab [14]. Much of the research among the groups in the MIT RAISE initiative also share an underlying value of constructionism, including computational action. Constructionism is a core part of computational action. Both champion for students to learn by creating real-world applications for an issue that is evident in their communities or in the world as well as motivating for them personally.

1.3.2 Self-efficacy and Identity

Research has shown that doing something for other people can help students develop a more "purposeful motivation for learning" [5]. This is valuable to computational action because the framework guides students to make meaningful projects for others using technology. Other research has shone light on the importance of identity for young people to feel motivated. Perception of identity related to skills and to personal values have been shown to be important for a person's expectation of success in accomplishing tasks [15]. This is also valuable for informing computational action because fostering a sense of identity as an engineer who can create technology is a core part of the framework.

Perceived ability or self-efficacy is also an important part of an individual's sense of agency and mastery [16]. Proposed by Albert Bandura first in the 1970s, self-efficacy is an prominent theory in education research that has been tied to student success in achieving goals and learning. Self-efficacy scales have been shown to be an effective measurement of a person's confidence in their ability to perform tasks [17]. The research in this thesis measures changes in students' self-efficacy through questions about their confidence in their ability to solve undefined problems. An increase in student's perceived ability to find, understand, and create solutions for ambiguous real-world problems is a big part of the goal of computational action.

1.3.3 Engineering Design Process

The engineering design process is used extensively in the technology industry and taught in various forms in K-12 and college education. This can be seen in curriculum like TeachEngineering (teachengineering.org), and standards like the Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS) which set guidelines for K-12 science, mathematics, and literacy [18, 19, 20]. Typically, the engineering design process covers these concepts: finding and defining a problem, gathering data, designing a solution, implementing and testing, launching a solution and reiterating. Usually the process is presented in a circle to illustrate the cyclical nature of reiterating the process to come to a better solution [21]. This well-established process influenced the development of the computational action process. I created the process by modifying the engineering design process to be more applicable to K-12 grade bands by presenting a curriculum and toolkit composed of five clear topics. Computational action also places an emphasis on goals like helping others and solving issues in the world, rather than on making products in industry. More on the design and details of the process is detailed in the next chapter of this thesis.

1.3.4 Technovation Challenge

Programs that teach coding with engineering and design in mind have also been valuable for providing a foundation for the development of the computational action process. One such program is Technovation, which provides great material on problem-finding and the design process for students. Technovation is a global non-profit organization that provides yearly challenges for middle school and high school students to solve big problems in their communities [11]. Technovation's mission is for girls to become tech entrepreneurs and leaders through working together on teams to create mobile apps that address a real problem in their community. Girls of ages 10-18 are coached by volunteers who are trained in the Technovation curriculum. The Technovation curriculum covers project ideation, designing solutions, ways to implement, writing a business plan, and bringing a product into market. Volunteer coaches are encouraged to guide teams using the curriculum, and in 2021, Technovation offered a new series of video workshops for students covering most of the problem-solving and design curriculum [22]. Students in Technovation were also recruited for the computational action research study, which is described in Chapter 3.

1.3.5 MIT SOLVE

The mission of MIT Solve is solving real-world problems with human-centered solutions. Solve was started by the Office of the President of MIT in 2015, and puts out yearly challenges and encourages anyone in the world to submit solutions, with the prize of significant funding to implement the ideas. The Solv(Ed) Youth Challenge is a new global challenge started in 2021 to inspire young people to think about solving real-world problems and learn skills of problem solving and implementation. The Solv(Ed) toolkit is a list of various resources, articles, and publicly available courses related to design, engineering, and making an impact [23]. I was asked by MIT Solv(Ed) to teach a design workshop for participants in their challenge. This became the second pilot of the computational action materials. Students in Solv(Ed) were also recruited for the computational action research study. Both the pilot and the research study are described in more detail in Chapter 3.

1.3.6 MIT App Inventor

MIT App Inventor is an open-source web platform that allows anyone to build Android and iOS mobile applications using blocks-based programming and a frontend design tool. Since its creation in 2009, more than a million unique monthly users from 195 countries have created over 68 million apps using App Inventor [24]. Young people have created apps using App Inventor that have effected real change in their communities. A group of middle school girls in Texas built Hello Navi, an app created in App Inventor that navigates people who are visually impaired with verbal instructions. In Dharavi in Mumbai, a team of young women created an app called Women Fight Back using App Inventor, which includes features like emergency calls, alarms, and location data to address women's safety issues. Time magazine's first-ever Kid of the Year of 2020, Gitanjali Rao, created an invention called Tethys in 2017 to measure lead levels in water, which involved making an app in App Inventor to present lead information collected using carbon nanotubes [25]. These are but a few examples of millions of projects kids of all ages have created using App Inventor. Students from around the world continue to utilize App Inventor as a tool to create technology to address issues they see in the world around them. App Inventor has been a valuable resource for guiding the development of the computational action process, as well as a key tool in the research study. More on this is discussed in later chapters of this thesis.

1.4 Thesis Outline

In the next chapters, I first present the computational action process, which consists of a curriculum, toolkit, and website. I describe in detail the materials that were created for each part of the process. Then I present the research, which includes two pilot studies and the final study. Afterwards, I analyze and discuss the results, which includes quantitative data, qualitative data, and student work. Finally, I conclude with overall insights and discussion and anticipated future work on this topic.

Chapter 2

Computational Action Process

2.1 Overview

The computational action process was created to address from these key criteria from the computational action framework created by Tissenbaum, Sheldon, and Abelson:

"Supporting computational identity: (1) students must feel they are responsible for articulating and designing their solutions, rather than working toward predetermined "right" answers, (2) students need to feel their work is authentic to the practices and products of broader computing and engineering communities. Supporting digital empowerment:(1) a significant number of activities and development should be situated in contexts that are authentic and personally relevant, (2) students need to feel their work has the potential to make an impact in their own lives or their community, (3) students should feel they are capable of pursuing new computational opportunities as a result of their current work." [10]

I was also informed by the Next Generation Science Standards (NGSS) standards for “Engineering Design” for elementary, middle school, and high school students. The NGSS are K-12 science and engineering education standards. I examined the NGSS rubric for engineering design for middle school and high school students, which includes these relevant standards:

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2.Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [19]

Also helpful to development of the computational action process are Common Core State Standards (CCSS) for mathematics and literacy for science and technical subjects, including the following relevant standards:

- MP.2. Reason abstractly and quantitatively.
- MP.5. Use appropriate tools strategically.
- RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning...
- SL.9-10.4: Present information, findings, and supporting evidence clearly, concisely, and logically...
- SL.11-12.4: Present information, findings, and supporting evidence, conveying a clear and distinct perspective... alternative or opposing perspectives are addressed...
- RST.9-10.8: Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
- RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. [20]

Influenced by the computational action framework, Next Generation Science Standards, Common Core State Standards, and related work covered in the previous chapter, I created the computational action process, which has three parts that together introduce five key topics:

1. Curriculum for K-12 students that comprehensively teaches these five topics:
    (a) Topic one: defining a real-world problem
    (b) Topic two: understanding users and communities
    (c) Topic three: designing responsibly with and for users and communities

    (d) Topic four: teamwork, project management, and implementation
    (e) Topic five: planning and making a long-lasting impact

2. Toolkit which students use to practice concepts in each topic, which consists of:
    (a) For topic one: mind map for brainstorming meaningful problems
    (b) For topic two: user research template, user persona template, and collaborative analysis framework
    (c) For topic three: impact matrix, feature importance vs cost tool, and tools for wireframing design
    (d) For topic four: teamwork task management table, project management board
    (e) For topic five: project reflection matrix, future timeline plan

3. Website (`https://www.computationalaction.org`) for teachers and students to learn about computational action, which provides:
    (a) The computational action curriculum
    (b) The computational action toolkit
    (c) Student projects that exemplify "computational action in action"

My hypothesis was that in order for the computational action process to be an effective intervention to enable students to make a real-world impact, the intervention should show changes in:

- Computational identity: students identify as engineers or programmers
- Self-efficacy: students are confident they can solve an ambiguous problem without a pre-determined right answer
- Digital empowerment: students are confident they can use technology to design a solution to a problem

- Computation skill: students are skilled in technology tools like app programming
- Intrinsic and self-transcendent motivation: students know how to identify real-world problems that are also meaningful to themselves

An overview of the computation action process can be seen in Figure 2-1. The next sections of this chapter will describe in detail each part of the computational action process: (1) curriculum, (2) toolkit, and (3) website, starting with the learning objectives. Links to the slides, guides, and tools are provided in each subsection for review.

2.2 Curriculum

2.2.1 Curriculum Overview

Curriculum Design

As previously mentioned, computational action curriculum was influenced by the engineering design process and frameworks in education research relevant for K-12 grade bands. Most variations of the engineering design process center around some key concepts, most basically: understanding the problem, gathering data, design, prototype, test, and repeat. One model presents a 7-step framework for students: "Ask: Identify the Need Constraints", "Research the Problem", "Imagine: Develop Possible Solutions", "Plan: Select a Promising Solution", "Create: Build a Prototype", " Test and Evaluate Prototype", and " Improve: Redesign as Needed" [18]. The 10-step engineering design process taught in a popular MIT engineering design course (ESD.051: Engineering, Innovation, and Design) is similar but includes into some more granular steps of "Stakeholder analysis", "Operational research", and "Hazard analysis." [26]. The explicit discussion of hazards, or possible negative consequences of a technology, is not always seen in every variation of engineering design frameworks, so it is notable that the 10-step design process in ESD.051 specifically calls out analysis

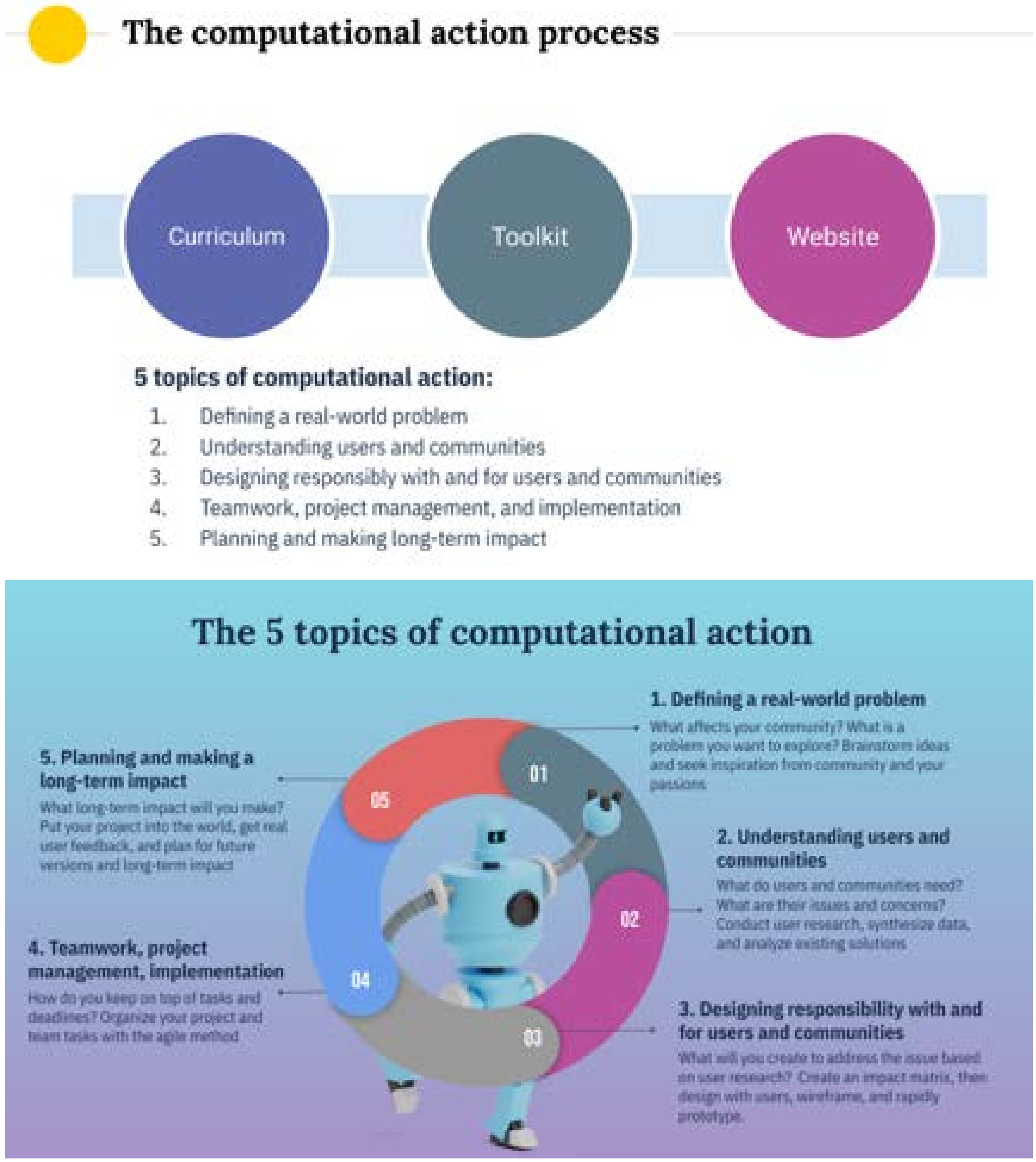


Figure 2-1: The computational action process: a three-part process covering five key topics.

of hazards and harms [8]. This influenced the creation of the impact matrix, a tool in the computational action process, which will be explained in detail in a later section of this chapter. Finally, I also relied on my own background as a product manager in the tech industry to create the curriculum. After discussions with advisors and educators, I simplified the curriculum to five topics, in order for it to be clear and memorable for younger students. We also discussed the most suitable target ages for the computational action curriculum, and again drawing from previous work in the App Inventor and Personal Robots groups, I decided that the material should be accessible to all K-12, but likely most suitable for middle school and high school students. I conducted two pilots of the curriculum with students in middle school, high school, and college to verify the appropriate age range for the material; their feedback contributed to the finalization of the curriculum. I analyze the findings from the pilots in the following chapter.

The ability to learn at their own pace and pursue their interests has been shown to be helpful for student learning. Students engaging with other students as a community has also been shown to be effective for motivating learning [27]. These concepts in education research informed how each lesson of the curriculum was structured. Each lesson generally has a “I do, we do, you do” structure, which takes the form of: (1) introduction of the topic, (2) review of a student project example further illustrating the topic, (3) guided discussion or group activity so students can engage with the instructor and with each other, and (4) autonomous student practice of the new topic. The content and structure of each lesson helped to achieve the learning objectives of the computational action curriculum, which are presented in Figure 2-2.

Creating Apps with App Inventor

To put computational action into action, as proposed by Tissenbaum, Sheldon, and Abelson, students should feel digitally empowered. Coding tools are one of the most powerful levers that can enable this. In particular, the mission of tools like App Inventor is to provide a platform that makes it as easy as possible for students with little or no experience to create functional mobile apps, by abstracting away elements of the frontend design and providing a blocks-based coding experience [24].

To ground the curriculum in technology, it was important to add an element of coding that is friendly to beginners who have very little or no coding experience. A clear choice for the coding tool to add to the curriculum is App Inventor, as discussed previously. A strength of the App Inventor platform is live testing: once connected to a device or emulator, a student can see immediately any changes they make in design or code. Another strength of App Inventor is the ease of designing frontend features exactly the way students want from the design interface that the platform provides. Finally, the platform has a trove of extensions that students can make use of using block programming, many of which offer quite advanced functionalities like FaceMesh (using an A.I. App Inventor extension), sensor data like gyroscopes and accelerometers, language translation libraries, and much more [24]. Students can create a wide variety of advanced apps using App Inventor. For all these reasons, I added App Inventor to the curriculum as a coding tool. An App Inventor coding activity was also used in the research study conducted to understand the efficacy of the computational action process. The research study and results of coding using App Inventor are discussed in Chapters 3 and 5 of this thesis.

2.2.2 License

The following sections explain the five topics of the computational action curriculum. The curriculum is licensed CC-BY-NC under Creative Commons. These materials are licensed as CC-BY-NC under Creative Commons. This license allows anyone to build upon these materials non-commercially as long as they include acknowledgement to the creators.

2.2.3 Learning Objectives

The computational action learning objectives, seen in Figure 2-2, are meant to meet the goals of computational action. The next sections of this chapter go into the details of each part of computational action that meet the learning objectives.

Computational Action Topic	Tools	Learning Objectives
Defining a real-world problem	Individual brainstorming (mind map) Group brainstorming (sticky-note)	• Students learn about the importance of finding a real problem in their community • Students learn about UN sustainable development goals and large global topics that are real problems in the world • Students learn to do individual brainstorming for finding a personally motivating problem • Students learn to do group brainstorming for working together to find a motivating problem • Students practice individual brainstorming through mind maps • Students practice group brainstorming with a team
Understanding users and communities	Writing user research questions Creating user personas Evaluating existing community solutions	• Students learn why understanding user and community needs is important for making an impact • Students learn a template for asking open-ended and user questions • Students learn how to write their own questions to ask affected users in their community based on the problem they identified • Students learn user personas to synthesize understanding from conducting user research • Students learn how to find and analyze existing solutions • Students learn how to engage civically by collaborating with local organizations to develop a solution for the problem they have identified • Students practice writing user research questions • Students practice creating user personas based on user research
Designing responsibly with and for users and communities	Impact matrix Evaluating positive effects and negative side effects Sketching Wireframing (using tools like Marvel App, Balsamiq, and App Inventor)	• Students are introduced to the ethical matrix, impact matrix, and the concept of design prototyping • Students learn why understanding stakeholders and values, through the ethical matrix, is important • Students learn how to fill out an ethical matrix for their project • Students learn why evaluating positive impact and negative side effects is important to design their projects • Students learn how to fill out an impact matrix of positive and negative effects • Students learn about the process of sketching, wireframing, and implementing a project • Students practice sketching and wireframing their projects
Teamwork, project management, and implementation	Agile method Scrum Gantt chart for team task organization Trello Github	• Students are introduced to the agile method and scrum, learning how teams of engineers work together • Students learn about different roles that exist for real-life projects: engineer, designer, researcher, business, team lead • Students learn tools to organize implementation tasks on a team, including Trello, Github, and Gantt charts • Students learn about the agile product development process and kanban boards for task-tracking • Students practice working on a team by organizing tasks and team member roles
Planning and making a long-lasting impact	Communicating about the process and solution Receiving and understanding user feedback on project Planning future work Iteration of computational action process	• Students learn how to communicate impact and details about a finished project • Students learn about the importance of continually receiving user feedback and impact • Students learn why it is important to cyclically go through computational action process • Students learn how to make long-term impact plan and why it's important to communicate about future plans • Students understand the full computational action process

Figure 2-2: The computational action learning objectives.

2.2.4 Topic One: Defining a Real-world Problem

The first topic of the computational action curriculum is identifying a real issue affecting the world or a student's community. The goal of this lesson is for students to be able to find problems in their community or in the world, then define an issue that they feel motivated to work on. This lesson introduces the importance of starting from a real problem, rather than "just coding", which is a core theme of many engineering design processes [21]. Following examples set by other programs like Technovation, students are introduced to the United Nations 17 Sustainable Development Goals [28]. The accompanying mind map brainstorming activity encourages students to solidify an interesting problem that both affects their community and, importantly, is of interest to the student themselves. Rather than jumping to coding a solution, this lesson teaches students the importance of spending time figuring out the right problem to tackle. Discussing the UN Sustainable Development Goals gives students a jumping-off place for finding issues that affect people in their community. The rest of the lesson gives students practice using the tools to solidify the issue they want to work on. Figure 2-3 provides a peek into some of the slides of this first lesson. The brainstorming tools accompanying this computational action topic are discussed in more detail in Section 2.3.

Curriculum: `https://docs.google.com/presentation/d/1AiD-r81_abJkJG_mLidS2yribn5ZRH8InP4jOS5-tMc`

Student guide: `https://docs.google.com/document/d/1WnMzkHl2xmlHMO9T1_FGeo7ItZAcYVoTXuHFrDjX1Lo`

2.2.5 Topic Two: Understanding Users and Communities

Each topic of the computational action curriculum should transition naturally into the next topic and inform the goal of the next topic. The goal of the second computational action topic is for students to investigate further the problem they identified by understanding the needs and issues facing users and the communities affected. Students are introduced to the importance of understanding user problems, and then

Figure 2-3: A few slides from topic one of computational action.

Figure 2-4: A few slides from topic two of computational action.

provided tools to create research questions so they can gather real user data and tools to synthesize data collected into summaries of user personas. This lesson teaches students big-picture themes of being curious and empathetic to learn user needs, and backs it up with concrete examples of user research questions and building user personas. Students' main takeaways from this topic include gaining knowledge of why understanding communities is important, how to conduct user research to gather data, and how to synthesize the data gathered into summaries that will then help students develop solutions. The toolkit for topic two is described in more detail in the next section (Section 2.3). A look at a few of the slides slides for topic two is provided in Figure 2-4.

Curriculum: https://docs.google.com/presentation/d/1WU8ACLdrlKZ_NAmcGPlAyXjcWv_UoUAgMqI3Y-Lt18I

Student guide: https://docs.google.com/document/d/1jr-YVWCmgbUwo-aBiMQDdEiQPrt96t1goT7mwFdNOrQ

2.2.6 Topic Three: Designing Responsibly with and for Users and Communities

The responsible design topic of computational action has three goals:

- Define desired positive impact and potential negative harms on different communities and users
- Convey the importance of designing a solution with positive impact and negative impact in mind
- Introduce helpful concepts of sketching, rapid prototyping, and wireframing to teach students real-world engineering design process

This topic covers the importance of designing solutions based on understanding users and communities, and creating responsible technological solutions. The lesson addresses this by teaching about stakeholders and values, introducing examples of positive and negative effects of certain technological solutions, and teaching students to

Figure 2-5: Some slides from the third lesson.

Figure 2-6: Some slides from the second half of the third lesson.

do the same for their projects. Students are taught the impact matrix framework to summarize positive impact, negative harms, and propose solutions only after laying out the impacts on users and communities. The impact matrix is based partially on the ethical matrix of stakeholders and values [29]. The impact matrix is an important tool for computational action because it guides students to write down findings of their user research and design their projects while grounded in user impact. It also serves as a high-level summary of the problem, user research findings, and project proposal. Students are then guided through sketching, testing paper prototypes of their projects, then wireframing using software tools. This lesson guides students step-by-step through getting started designing using a software tool (i.e. Marvel App, Balsamiq, or App Inventor) that may be new to them [30, 31, 24]. The step-by-step guide is important to help introduce students to a new tool without being overwhelming. In addition, student projects that showcase designing using wireframing are abundant in this lesson to give students helpful inspiration. Figures 2-5 and 2-6 show a few select slides from the two parts of lesson three. More on the impact matrix and other tools accompanying this topic is explained in the next section of this thesis.

Curriculum (two parts): `https://docs.google.com/presentation/d/1M83unILtzNpwo7bI2XG9GqZ5HIOkIE1AVfJ6KTWShbI`,
`https://docs.google.com/presentation/d/1xDcN4Ag4CLUCxLZLbVlQ01OOD6Bq69JFj6cDVJhtWTk`

Student guide: `https://docs.google.com/document/d/1JS9yUF8ushwYLR5UnS8uXN3Kj72XAFizzIcAL4gfxVU`

2.2.7 Topic Four: Teamwork, Project Management, and Implementation

A core theme of computational action is that students feel that their work and practices are authentic to the work of engineers, programmers, designers, and innovators [32]. The fourth topic of computational action is about practices authentic to the

Figure 2-7: Some slides from topic four of computational action.

work of engineers and programmers. Students learn how to manage tasks on a team, how to manage a technical project using project management techniques, and tips for documentation and communication that should be valuable for students' current and future projects. The agile method and Scrum process, Gantt charts, and management tools used in industry are introduced to students because they can be helpful for current projects and future work. These practices are authentic to the work and processes of real-world engineers, programmers, and researchers. The fourth lesson of the curriculum walks students step-by-step through organizing tasks on a project management board on Trello [33]. Trello was chosen based on initial research and feedback from students in the Technovation program who had heard of tools like Trello, Asana, and Jira, but found it too intimidating to use the tools without more step-by-step guidance. I found Trello's default Kanban boards and project management tools engaging and helpful for students of middle school and high school age ranges. Importantly, other project management tools are also introduced to encourage students to explore the best tools for them. Figure 2-7 shows some of the slides from the fourth topic.

Curriculum: `https://docs.google.com/presentation/d/1xqbG04IoYpy-BAi5mJRIH7OZ0D0dhQM70Fa2XOWCilE`

Student guide: `https://docs.google.com/document/d/1dKcC24q0a_bhhJecr1BhBIK38BfJt8xzwMf8lWBcWnM`

2.2.8 Topic Five: Planning and Making a Long-lasting Impact

Oftentimes, emphasis is placed on finishing a project and it may be considered done as soon as the coding is complete. But after completion of a project, there should be a continual cyclical process reevaluating user feedback, redesigning, and reiterating. The last topic of the computational action process teaches students that this process is iterative and making a long-lasting impact is not just about finishing coding. This topic also covers communication skills, gathering user feedback with user permission using logging tools, and planning future versions that can further improve their solution. Included in this topic are past student project presentations explaining their

Figure 2-8: Some slides from topic five of computational action.

future goals and planning for long-lasting impact. some slides from this lesson can be seen in Figure 2-8. Reflecting on what they have or have not made, compared to the plans in their impact matrix, is also a part of this lesson. Students are given reflection and planning tools that help them map out what they achieved, what they changed, and how they want to continue making an impact. These tools are explained in more detail in the next section of this chapter.
Curriculum: `https://docs.google.com/presentation/d/1rEWWwbxWsU5q1Yaz1WglDkS_4UGelEP1bft-TdIFnfM`

2.3 The Computational Action Toolkit

As mentioned in the first section of this chapter which outlines the computational action process, the toolkit was created to allow students to put into practice the material in the curriculum. The toolkit is a collection of templates and frameworks associated with each computational action topic that makes the teaching concrete and actionable for students. After students are introduced to a new concept, group practice helps them learn as a community, and then the toolkit enables them to continue practicing individually.
Entire toolkit: `https://drive.google.com/drive/folders/1aXN1QMVaN72QwUCJOosbzYHnuXRCOGbf`

2.3.1 Tools for Topic One: Individual and Team Brainstorming Frameworks

As discussed in the section above, the curriculum for topic one teaches students the importance of basing their ideas on a real-world problem. To align with the lesson, individual and team brainstorm tools walk students step-by-step through going from large topics, like one of the 17 United Nations Sustainable Development Goals (SDGs), to something impacting their own community. I adapted a mindmap individual brainstorming tool, shown in Fig. 2-9, for students to practice brainstorming issues in their community that they care about. The framework directs students to take inspiration from the UN SDGs and work from there to arrive, through freeform brainstorming, at topics that are personally motivating for them. The framework also explains to students that they can do this activity as many times as is helpful with one or multiple issues. There is also a teamwork brainstorming tool, which is adapted from post-it/sticky note brainstorming techniques, and guides students to brainstorm as a team to come jointly to issues they all care about.

2.3.2 Tools for Topic Two: User Research Template, User Persona Template, and Collaborative Analysis Template

The tools for the second topic are templates for students to gather and synthesize data from their community. I created the template of user research questions based on user research questions commonly used in the engineering and design industries, and modified them to be more suitable for a K-12 student project. I created a user persona template tool based on existing industry solutions, and modified it with diagrams and illustrations to be most engaging and usable by K-12 students. Finally, discussions with advisors and educators indicated that a type of market analysis called collaborative analysis would be useful to guide students to research existing solutions and organizations in their community that they can collaborate with. I created a worksheet for them to get started with researching existing solutions. A look at these tools is provided in Fig. 2-10.

2.3.3 Tools for Topic Three: Impact Matrix and Wireframing Tools

One of the key contributions of the computational action process is the impact matrix, which is a tool tied to topic three (designing responsibly with and for users and communities). Building off of user research data, students are guided to consider positive impact and negative side effects, and then use these to inform what they will build and how they will go about building the solution. This tool should help students

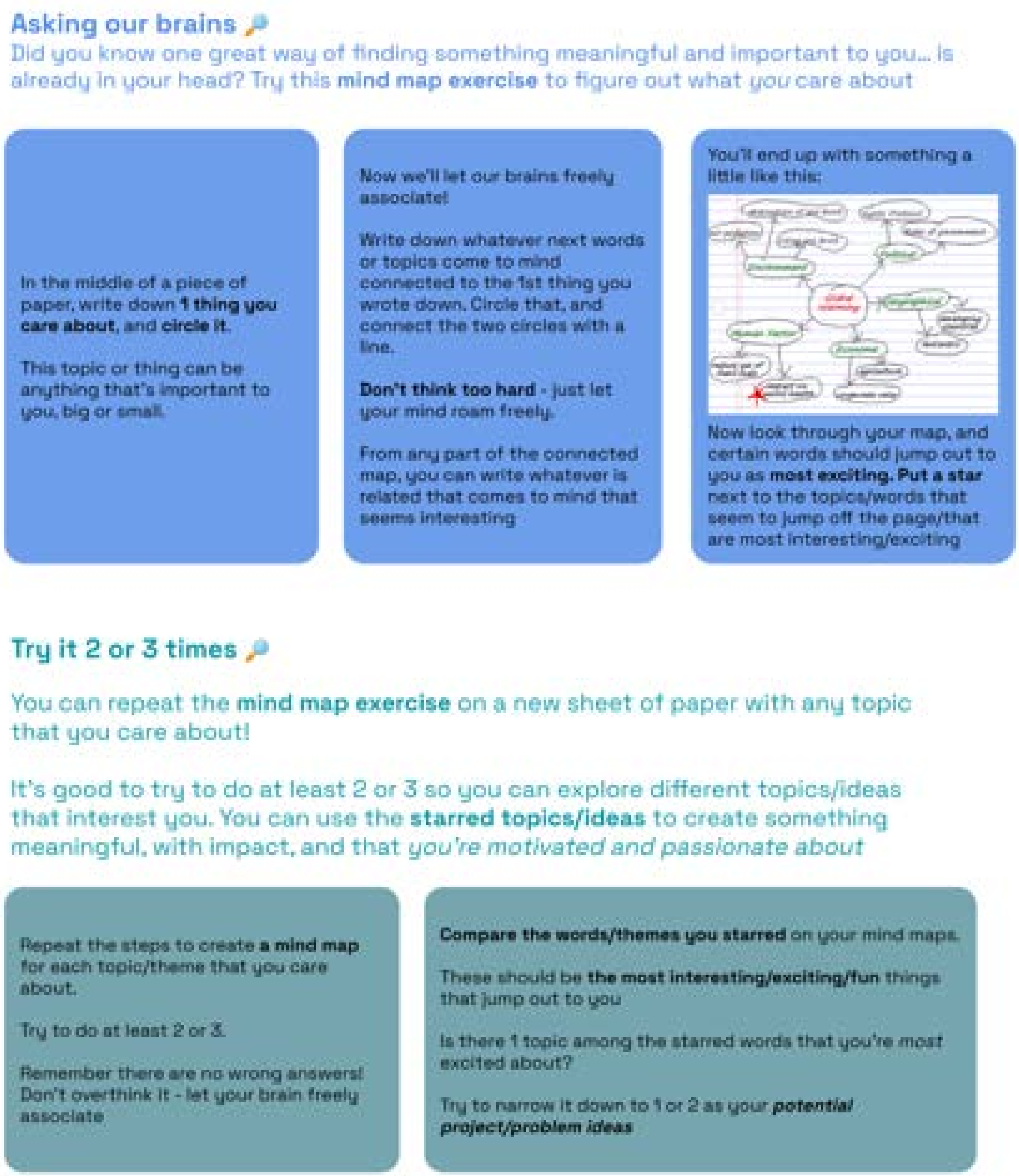


Figure 2-9: The individual brainstorming tool.

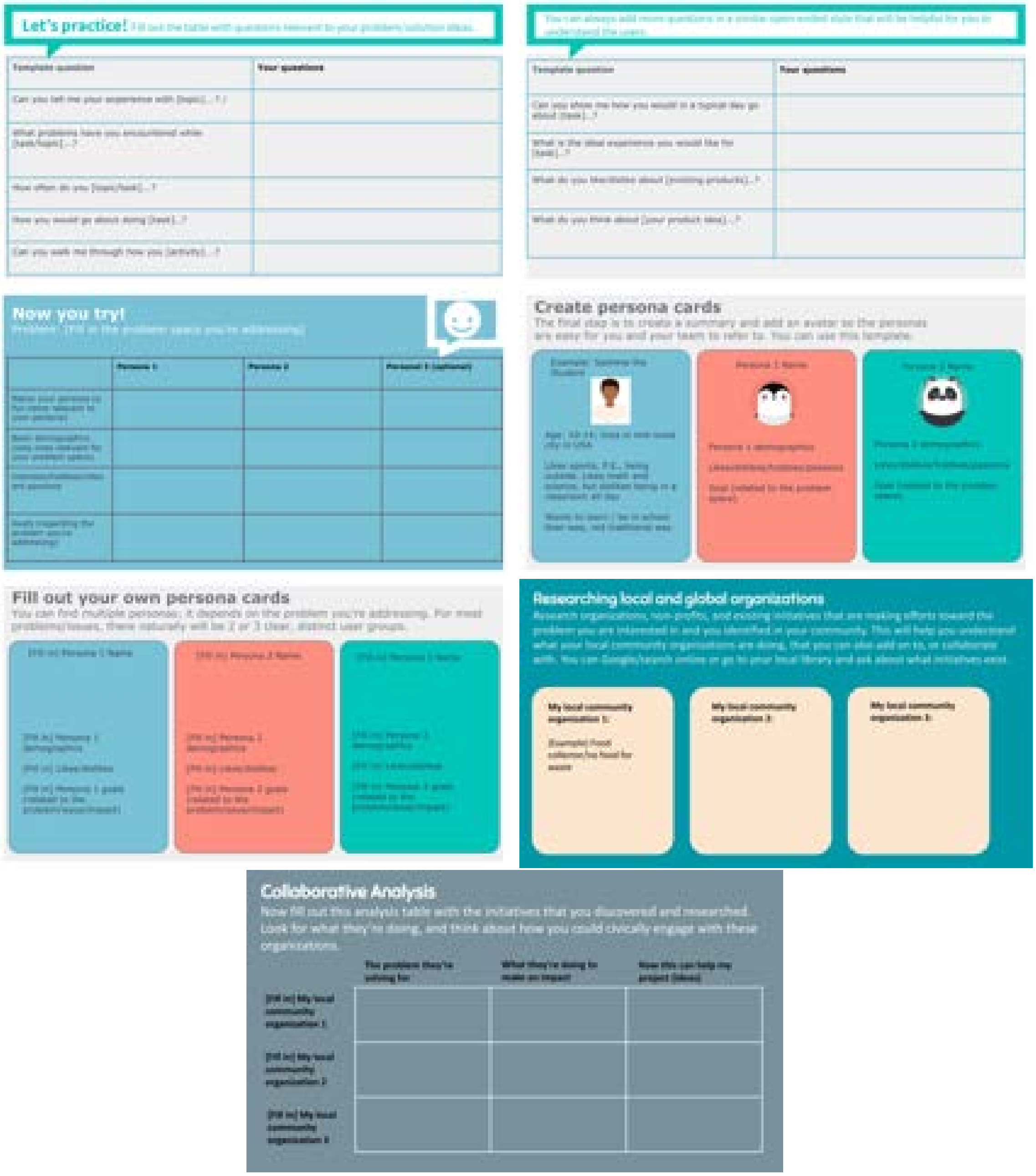


Figure 2-10: The tools for understanding users and communities.

feel that their design process is authentic to the practice of engineers and programmers because it is modeled off of the design process in industry, while designed for young people to use easily. I created the impact matrix, shown in Fig. 2-11, based on discussions with advisors Professor Hal Abelson and Professor Cynthia Breazeal, and it is inspired by the simplicity of the ethical matrix [29]. I wanted to give students the most useful tool for designing a solution grounded in impact, so the impact matrix is posed for students to consider both positive impact as well as potential negative side effects or harms. Only after doing this, do they design features of the project that take into consideration impact and harms. In this way, the impact matrix is a structure that naturally guides students to design technological solutions based on real problems and making an impact. For students in more advanced coding programs, I also created an industry-relevant project feature design tool that goes into more detail cost of implementation vs. importance. This optional tool, shown in Fig. 2-12, is intended to provide scaffolding for students who want to deeper dive into the implementation design of their solution ideas. Since the impact matrix is intended to be a summarized and shortened view of the project that can be fully understood in one table, it may not be enough for students designing more complex projects. The optional detailed feature design template gives students more guidance for weighing the value of feature proposals against the effort to implement these features.

In this lesson of the curriculum, the importance of first sketching, then wireframing, and testing wherever possible each prototype is introduced. To empower students to practice designing, steps for sketching are taught and tools for wireframing are also introduced, shown in Fig. 2-13. The wireframing tools selected are some of the most popular and easy-to-use wireframing tools in industry, and are well-known among those in product design and engineering fields. A demo of App Inventor is included as an easy way for students to design the frontend of their projects.

Figure 2-11: The impact matrix framework.

What problem is this addressing for your users?	Short description of what feature you'd like to include	Short description of technical components of what you're building	How important is it to have? 1 = absolutely needed, 2 = would be good to have, 3 = not necessary/nice to have	How hard is this to create and finish? How many people will have to work on it for how many days/weeks?	Other notes
[illegible]	[illegible]	[illegible]	Example: 1	[illegible]	Example: This is a must-have!
[illegible]	[illegible]	[illegible]	Example: 3	[illegible]	[illegible]

Figure 2-12: The project feature design tool.

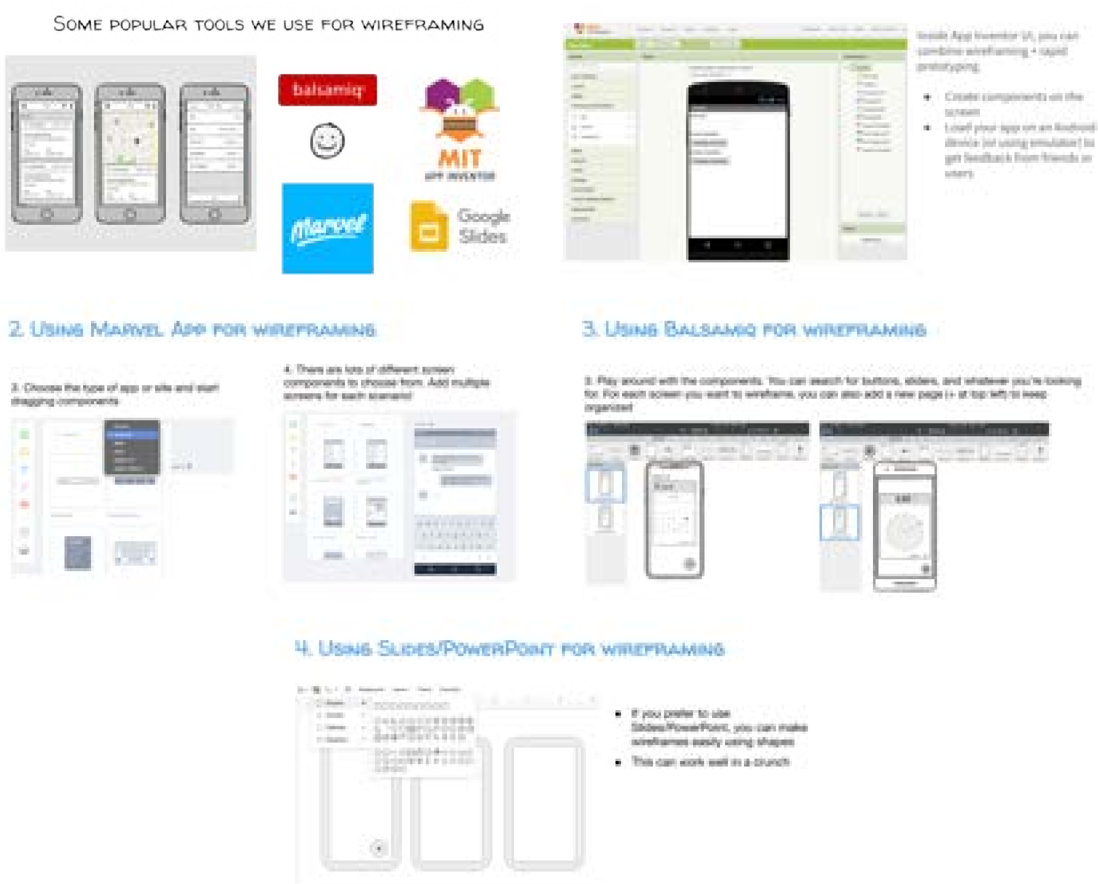
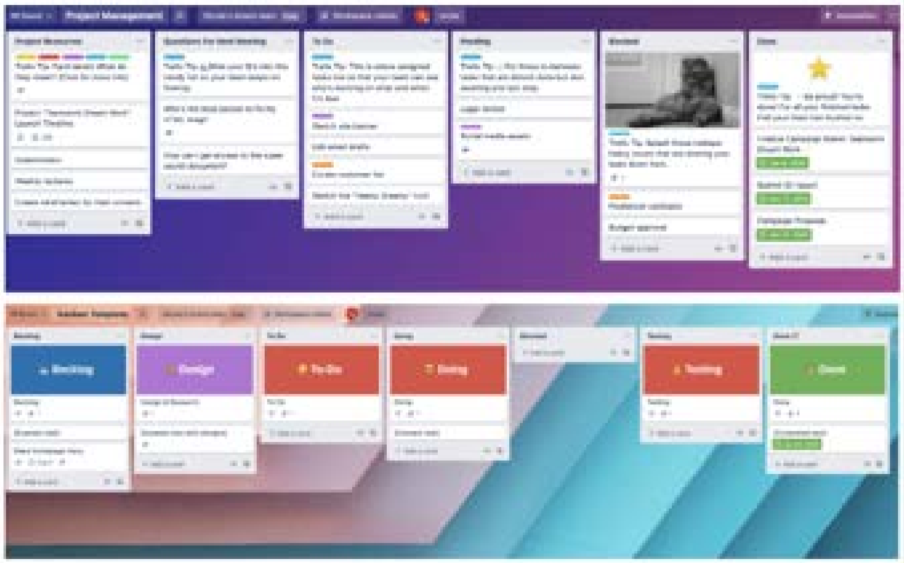


Figure 2-13: The wireframing tools.

Figure 2-14: Teamwork and project management tools.



Example: Creating a task and tracking it on Trello

1. You can make a free account to work with your team on tasks at www.trello.com. Create a free account by signing up, and then invite your teammates so you're all on the same workspace.
2. Choose "Add a board to your workspace" to start managing your project.
3. Get started by taking a look at the **Project management** and **Kanban board** templates. You can use both or one to form the framework of your project board.
4. Some important categories that would be useful to have in your board:
    a. Backlog
    b. Doing
    c. Blocked
    d. Testing
    e. Done
5. How to write a task card:
    a. Select "Add a card" and write your task title. It's most helpful if the task is small enough to encapsulate a specific thing to do, but comprehensive enough for it to be meaningful. E.g.: "Create login backend", "Create login frontend", "Create user

Figure 2-15: In addition to toolkit, students are also given student guides, which go through the tools step-by-step.

2.3.4 Tool for Topic Four: Project and Code Management Frameworks

In the last two lessons, the tools become lighter touch because the majority of the heavy lifting of discovering an issue, understanding users and communities, and designing for impact are covered in the first three topics of computational action. Implementation, i.e. coding and managing the coding, is a large part of topic four. Building off of tools of the previous topic, the tools here guide students through project management and teamwork, which can be seen in Fig. 2-14. Students can use a project management board on a tool like Trello to more easily manage the coding tasks of their project. As noted before, from initial student interviews, one pain point students mentioned was staying on top of coding as a team during long programs like the Technovation Challenge which gives students 12 weeks to create their projects. The student guide for this lesson, shown in Fig. 2-15, instructs students step-by-step through making project boards.

2.3.5 Tool for Topic Five: Future Planning Guide

Finally, as students wrap up the implementation of their project, the last tool of computational action helps them plan for long-lasting impact by emphasizing reflection, iteration, getting feedback from the community on the project, and making plans for future goals. As the process concludes and students are taught about the cyclical nature of the computational action process, students are encouraged to reflect on what they accomplished against their impact matrix, using the tools seen in Fig. 2-16, and plan for what they want to keep doing in the future. This final tools should inspire students to continue using the computational action process for their future projects.

2.4 The Computational Action Website

The computational acvtion website brings together curriculum materials, toolkit, and exemplary student projects as a comprehensive online resource for students and teach-

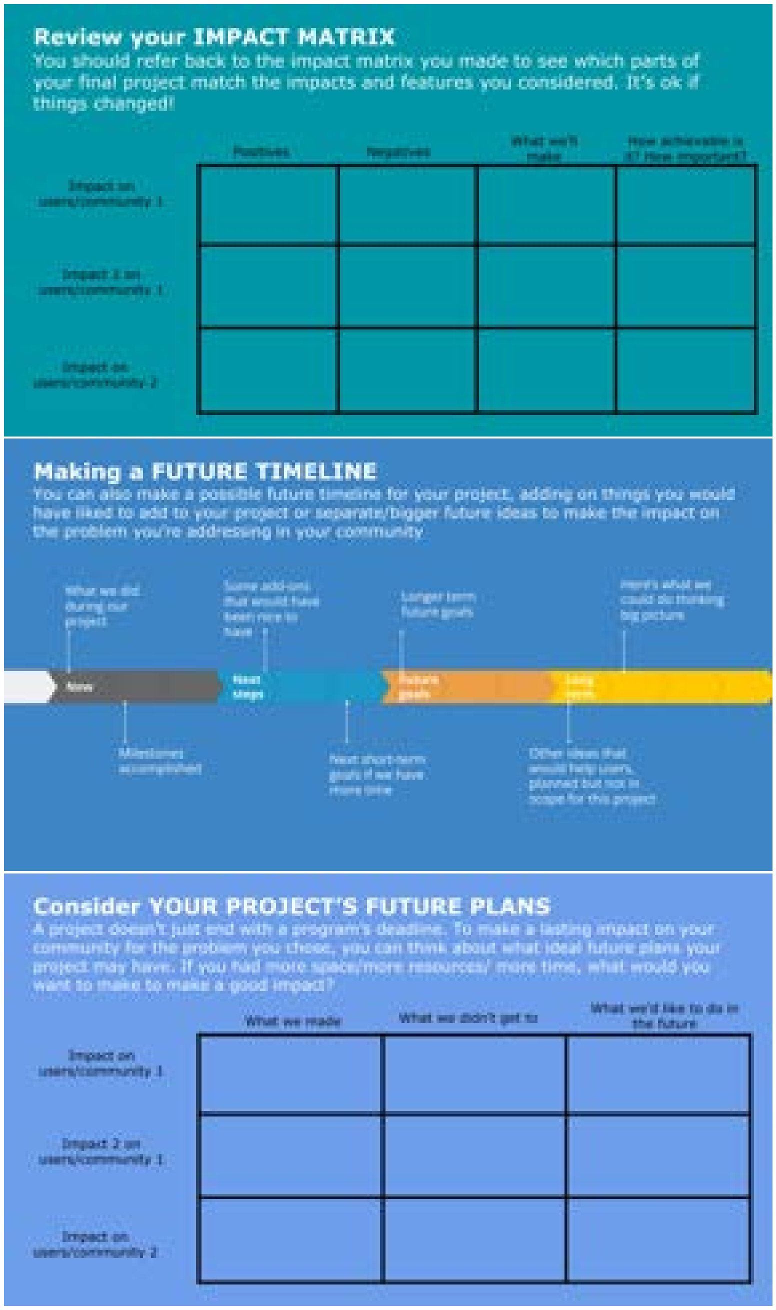


Figure 2-16: Tools for review of project and planning for long-lasting impact.

ers (`https://www.computationalaction.org`). Research has shown that students respond well to having control over their own learning and choosing their preferred methods for learning [34]. Therefore, the full set of computational action materials are made available for a student to learn and use autonomously.

Exemplary student projects, shown on the website, can be inspiring for other students. Initially, I had included many more examples from industry in the first round of the curriculum, including discussing machine learning recommendation systems and mental health app products like Oura Ring [35]. After more discussions with my advisors Professor Abelson and Professor Breazeal and an insightful conversation with educator and writer Alan November, I decided to exchange the industry examples for more student examples. This was influenced by the desire to emphasize making a beneficial impact in the world, rather than focusing too heavily on industry products. The student teams in the first pilot of computational action created impressive final presentations for the MIT Futuremakers program, where many teams showcased the steps they took using the computational action process, including user research questions and wireframing prototypes. With the teams' permissions, I chose projects from both the machine learning and app programming tracks of the program to include as exemplary student projects on the website.

One of the projects I particularly liked as an example of great computational action work is Vividly, an app created using App Inventor by a team of middle school students (Youth of Tech team: Netra Ramesh, Christopher Blake, Ian Son, and Katherine Xu). The team also entered their app in the 2021 global Appathon for Good challenge and won second place in the mixed youth and adult category. This team started with the issue of mental health for young people and created user research questions based on the computational action template to understand what teens really need for their mental wellbeing. Based on their research, this team prototyped then programmed an app that serves as an intermediary for kids and their parents to talk about feelings, thoughts, and difficult subjects. The team put out a real functional app for phone and tablet that addresses an issue that the students themselves discovered, researched, and coded. The Vividly app is one of the many great examples of impressive student work embodying computational action in action that are showcased on the site.

Computational action curriculum: `https://www.computationalaction.org/courses`

Computational action toolkit: `https://www.computationalaction.org/tools`

Exemplary student projects: `https://www.computationalaction.org/student-projects`

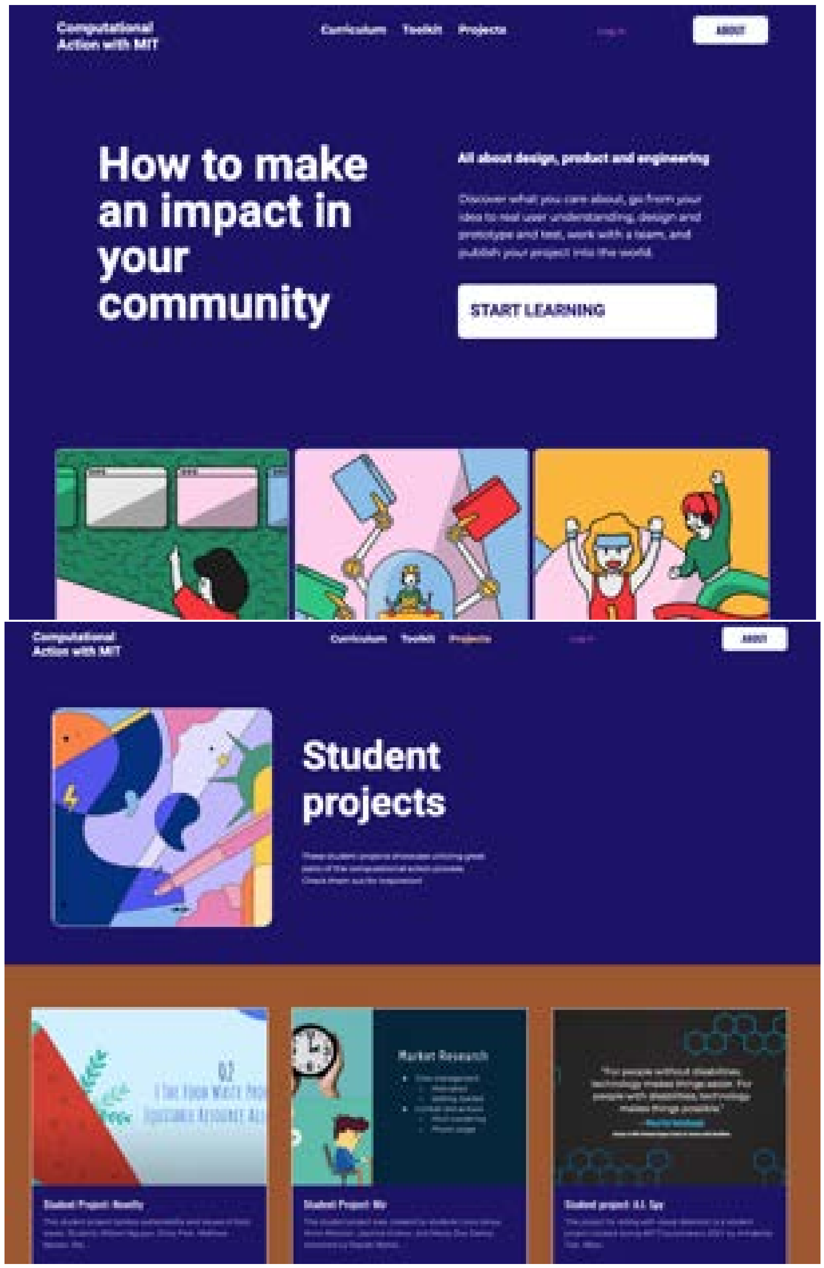


Figure 2-17: The computational action website for students and teachers.

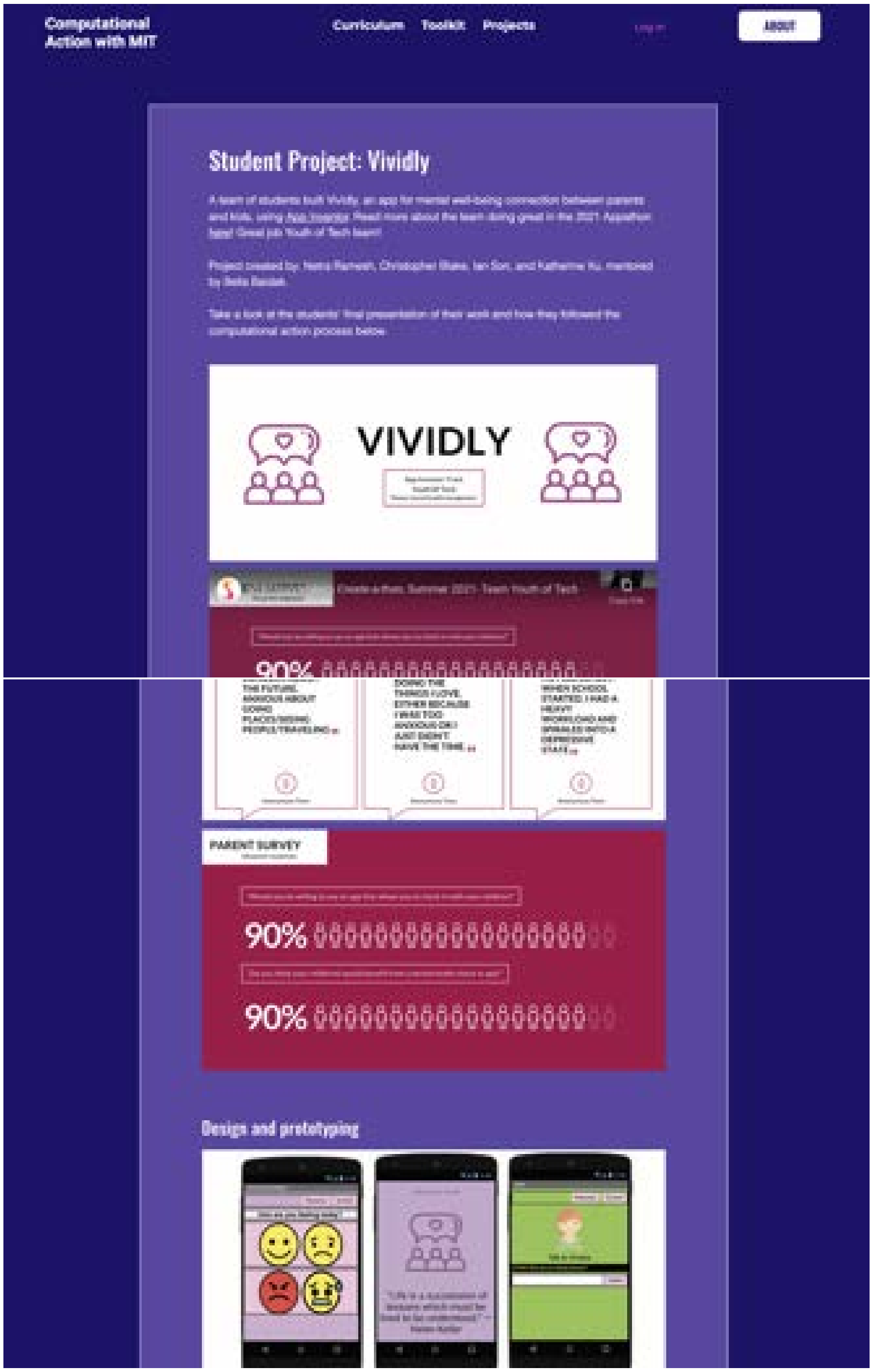


Figure 2-18: The Vividly app is one of the student projects on the website that demonstrates computational action in action. Credit: Netra Ramesh, Christopher Blake, Ian Son, Katherine Xu.

Chapter 3

Studies

3.1 Research Questions and Overview

The research questions I investigated were: (1) What interventions enable students to make a socially responsible impact in their community? and (2) Is the computational action process effective in empowering students to make a good impact using technology?

In this chapter, I first discuss two pilot studies with domestic and international students, from which I got feedback on the first versions of curriculum and tools. Then I discuss the final research study, also with domestic and international students, that was set up to answer the research questions and investigated the efficacy of the computational action process. The results from the research study are analyzed in the next chapter.

3.2 First Pilot

3.2.1 Procedure

The first version of the computational action process was piloted to a group of 79 participants in the 2021 MIT Futuremakers program, which was created by MIT RAISE in partnership with an A.I. education program called SureStart [36]. Students ranged from middle school to college age, with most middle school students electing to learn App Inventor over the 6-week program, and older high school and college age students generally electing to learn machine learning over the program. The last two weeks of the program culminated in a Create-a-thon, where students create and implement a project that has real-world impact. I made the first version of the five-topic computational action curriculum for this pilot, and I taught the materials over five one-hour workshops, one per day over the first week of the Create-a-thon. This pilot study was not for research, but was valuable for me to pilot the process, get feedback on the structure as well as the curriculum and tools, and refine the process based on the feedback. I also held office hours for any student teams that wanted more help on any of the sections and tools. This also proved valuable for finessing and improving the finalized curriculum, toolkit, and examples, which underwent many rounds of workshopping after this first pilot. I also created a one-hour long video breaking down "Computational Action 101" for this first pilot. Links to this video and the other videos teaching computational action are in Appendix B.

3.2.2 Findings

Student feedback and anecdotal data from the first pilot were helpful for me to change and add on to the curriculum and tools. Students had the most questions regarding creating user research questions. I was available for office hours with student teams, and learned through these sessions that a templatized toolkit would greatly benefit students and answer many of the questions they had about the specifics of creating helpful user research questions. Another helpful learning from the first pilot was that students wanted to use the tools after the workshops, and wanted to continue reviewing the curriculum material as well as the examples of projects and A.I. technology. From this feedback, I worked next on putting the computational action materials and toolkit on a website so that students in future workshops can have the evergreen materials for autonomous learning. In addition, as mentioned in the previous chapter, with permission from students from the pilot, their projects that went through the entire computational action process were highlighted as exemplary work on the computational action site. Based on the learnings from the first pilot, I wanted to continue to study the efficacy of a revised computational action material that is less industry-influenced. I also wanted to continue to study the efficacy of a more concrete series of computational action tools that can be used autonomously by students.

3.3 Second Pilot

3.3.1 Procedure

A small second pilot with domestic and international students was conducted specifically on a deep-dive of the third topic of computational action. I wanted to incorporate more concrete tools into this design topic, which is arguably one of the most important parts of computational action because this is where research data is incorporated into designing a socially responsible solution for a real-world problem. The MIT Solv(Ed) program asked me to teach a one-hour design workshop for students participating in their challenge, which was a great opportunity to pilot an updated version of topic three of computational action. With help from the staff on the App Inventor team, I amended the lesson by adding a demo of coding using App Inventor. The rest of the workshop emphasized elements of sketching, rapid prototyping, and wireframing as aligned with the learning objectives.

3.3.2 Findings

Students responded very well to the App Inventor coding demo and wanted to see more implementation examples. Students also had questions about coding using other technology like Javascript, HTML/CSS for websites and Android Studio for apps. From these learnings, the final study was adjusted to measure the effect of adding more coding and implementation elements to the process. The pre-post coding activity was added to the final research study based on this feedback. This coding activity included a demo of how to use App Inventor and gave free reign to students to create a app project for a problem of their choosing. More about this activity is discussed in the next section that describes the final study.

3.4 Final Study

3.4.1 Procedure

Participants were recruited from mailing lists associated with Technovation Challenge, MIT Solv(Ed), and MIT Education Studies Program (ESP). These programs are primarily for students in K-12 grades and under 25 years of age, with a focus on grades 6 to 12, corresponding to ages 11 to 18, which is highly suitable for the computational action study. Based on the learnings from the pilots, I shortened the workshop for the final study to be a one-day workshop covering the computational action process in a crash-course manner and focusing on student ideas and coding projects. In addition, I was interested in how students from different coding backgrounds and design backgrounds would respond to the computational action process. In particular, I wanted to add an evaluation of the added value of this new process to existing programs, like Technovation or MIT Solv(Ed), that have resources available to students covering concepts similar to computational action.

For this reason, the study was designed with two cohorts: cohort 1 consisted of students who have been previously introduced to coding and elements of product-design-engineering thinking and cohort 2 consisted of students who have not been in these types of programs. As much as possible, the other variables between the two cohorts were kept constant, but not everything could be controlled. A few differences between cohorts 1 and 2, both in participant demographics as well as workshop procedures, are outlined below. The research study protocol was approved by MIT Committee on the Use of Humans as Experimental Subjects (COUHES) which serves as MIT's Institute Review Board (IRB). The consent forms for parents and guardians and assent forms for children under 18 years of age are provided in Appendix F.

3.4.2 Workshop Outline

Each workshop of the final study measured whether the intervention of learning the computational action process changed a student's sense of computational identity, digital empowerment, and self-efficacy. Measurements also included knowledge and skills of the concepts of computational action that I believed would enable students to achieve the above (i.e. improved mastery of the five computational action topics).

To measure these changes, I set up workshops to teach and help students practice computational action. I was the lead instructor for all the workshops in this study, and received valuable help from facilitators from the App Inventor and Personal Robots groups to engage students in small breakout room activities. Students joined an online workshop conducted over Zoom, a video conferencing platform, and had the option to share thoughts or discussion answers over chat or video and audio. In consideration of student comfort, anyone could have videos on or off, and could always take more breaks than the scheduled regular breaks in the workshop. Due to time constraints, there were a few changes between the workshops for the two cohorts of the final study. Students in cohort 1 attended a 4-hour workshop, and all five topics of computational action were covered. After the workshop ended, students were asked to complete a post-workshop coding in App Inventor on their own time. Feedback from one student noted that even though regular 10-minute breaks every half hour to 45 minutes of the workshop were good, the workshop was still quite long. Based on this feedback, the workshops for cohort two were slightly changed, so students in cohort 2 attended a 3-hour workshop, where the teaching focused on the first three topics of computational action. The hands-on portion of the workshop was lengthened to give students more time to code their post-workshop app. More facilitators were recruited so that students could be moved into small groups (via Zoom video conferencing) and get help on coding questions. Overall, the two cohorts received the same pre-post activities, the same curriculum, and the same computational action toolkit. A detailed breakdown of the workshop structure is included Appendix E.

3.4.3 Participants

A total of 101 total participants from the two cohorts filled out the pre-survey, and 65 filled out the post-survey. The ages of the majority of participants between both cohorts were within 11 to 18, corresponding to U.S. grade bands 6 to 12, which was suitable for measuring the efficacy of the computational action process for middle school and high school students.

40 participants from cohort 1 filled out the pre-survey, and 26 filled out the post-survey. Cohort 1 participants' ages ranged from 9 to 30, while 85% of the participants were between ages 11 to 18. Of the cohort 1 students, 33 identified as female and 7 identified as male. The locations of cohort 1 varied greatly, with 9 from Lebanon, 5 from India, 5 from the U.S., 3 from Indonesia, 3 from Romania, 2 from the Philippines, 2 from Georgia, and the remaining distributed (1 student each from: Bangladesh, Japan, Italy, Spain, Tanzania, Thailand, and Malaysia). 61 participants from cohort 2 filled out the pre-survey, and 39 filled out the post-survey. Cohort 2 participants' ages ranged from 12 to 15, while 92% of participants were of ages 12 and 13. 25 students identified as female, 35 identified as male, and 1 identified as non-binary. 54 participants from cohort 2 considered the U.S. their home, 2 were from Taiwan, 2 were from Hong Kong, and 1 each from Colombia, the Philippines, and India.

Participants in cohort 1 signed up for a 4-hour workshop from interest forms sent to students in MIT Solv(Ed) and Technovation programs. It is worth noting that the computational action process introduces new concepts and specific tools that may not be present in these programs (e.g. mind maps for brainstorming, user research question template, and the impact matrix). Participants in cohort 2 signed up for a 3-hour workshop from interest forms sent to 7th and 8th graders in Massachusetts and other U.S. states via the MIT ESP program. The participants of cohort 2 were randomly divided into two sessions of approximately equal size. The differences between cohorts 1 and 2 are summarized in Table 3-1.

	Cohort 1	Cohort 2
Participant ages	9 to 18+ (most 11 to 18)	12 to 15
Student backgrounds	16 out of 40 participants were in a Technovation Challenge project; 24 participants were in MIT SolvEd	Participants were not in Technovation or SolvEd programs. There were 61 participants in this cohort.
Pre-post activities	Pre- and post- activities: write project ideas and code the project in App Inventor. Students were asked to finish post-workshop App Inventor app on their own time.	Pre- and post- activities: write project ideas and code the project in App Inventor. Students had time during the workshop to finish their post-workshop App Inventor project.
Study	4-hour study allowed for full 5-part computational action curriculum to be taught	3-hour study focused on parts 1-3 of computational action process, emphasizing problem, users, and design

Figure 3-1: Participant summary.

3.4.4 Survey Instruments

Participants in both cohorts received the same pre-post questions, all scored on the Likert scale from 1 (strongly disagree) to 5 (strongly agree), excepting question 7. For question 7, the Likert scale was slightly modified, from 1 (very beginner) to 5 (very advanced). All the survey questions can be seen in Table 3-2.

3.4.5 Analysis Method

The analysis of quantitative survey data was done using tests corresponding to the data distribution (whether normal or not normally distributed). Paired tests compared pre-post data of the same individuals, and unpaired tests compared different segments of either pre- or post-data (e.g. female vs male responses). Pre-surveys were completed by students before the workshops, and post-surveys were completed shortly after the workshops. For paired results, data that followed normal distribution were analyzed using paired t-test; otherwise, non-normally distributed data were analyzed using the Wilcoxon signed-rank test. For unpaired results, data that followed normal distribution were analyzed using a two-group t-test, and data that was

Question Type	Question number	Question
Computational identity	Q1	I see myself as a computer programmer
Self-transcendent motivation	Q2	I want to learn things that will help me make a positive impact on the world
Self-transcendent motivation	Q3	I want to become an educated citizen that can contribute to society
Self-motivated	Q4	I want to expand my computer programming knowledge
Extrinsic motivation	Q5	I want to learn computer programming to earn more money
Computation skill	Q6	I do well on computing tasks such as app programming
Computation skill	Q7	I would rate my computer programming skills (including app programming) as:
Knowledge & skill, self-efficacy	Q8	I know how to find and define a real problem
Knowledge & skill	Q9	I know how to figure out what users and communities need
Knowledge & skill	Q10	I know how to design technology with an ethical framework in mind
Knowledge & skill	Q11	I know how to work on a team
Knowledge & skill, digital empowerment	Q12	I know how to make a lasting impact in my community or in the world
Self-efficacy	Q13	I am confident in my ability to design and create solutions using technology, rather than working toward a "right" answer someone else gives me
Perception of responsible A.I.	Q14	I want to include artificial intelligence (A.I.) in technology projects I create
Perception of responsible A.I.	Q15	I am concerned about the use of artificial intelligence (A.I.) in technology

Figure 3-2: Survey instrument used in the research study.

not normally distributed were analyzed using the Mann-Whitney U-test. P-value of 0.05 determined whether results were significant.

Chapter 4

Results

In this chapter, I present first an overview of notable quantitative results from the surveys deployed during the research study as well as a brief look at the qualitative data that support the results. Then the significant pre-post paired results are discussed, followed by significant findings in unpaired pre-survey and unpaired post-survey data.

4.1 Results Overview

Analysis of quantitative data from pre-post surveys shows that after the computational action workshop, students felt more confident in their coding ability (e.g. they rated their programming skills higher), more confident in their ability to solve ambiguous problems and make an impact (e.g. students more strongly agreed with questions like "I know how to make a lasting impact in my community"), and more knowledgeable about the ways to make an impact responsibly with technology (e.g. students more strongly agreed with questions like "I know how to design technology with an ethical framework in mind"). Students demonstrated this increase in computational ability and self-efficacy regardless of previous level of coding or engineering and design experience. The paired pre-post results are analyzed in detail in Sections 4.2 and 4.3.

Analysis of qualitative data supports the findings from the pre-post survey results. Student responses and student work showed an increase in deeper understanding of responsibly using technology to make a good impact in society. In particular, students pointed out that after the workshop, they now feel confident they know the steps to make an impact with technology, and it feels more manageable than before. Students' project proposals after the computational action workshop showed more discussion about impact and more defined users and communities affected than their project ideas before the workshop. Students' App Inventor apps coded after the workshop generally had more code and more fleshed out designs than apps created before the workshop. More discussion of qualitative data and student work is presented in the next chapter (Chapter 5).

Both before and after the workshop, female participants rated their knowledge of how to work on a team higher than male participants. Both before and after the workshop, participants who were in Technovation rated their computational identity and computation skills higher than those who were not in the Technovation program. This and other notable results from unpaired pre-post surveys are analyzed in more detail in Section 4.4.

4.2 Notable Pre-Post Results

This section presents significant paired results found through quantitative analysis of pre-post surveys. The raw outputs from the analysis, using paired t-tests and Wilcoxon signed-rank tests, is included in Appendix C.

4.2.1 Computational Identity

Cohort 1 students' responses to the computational identity question ("I see myself as a computer programmer") showed a statistically significant change when comparing pre-post (Pre/Post: $\bar{x}$=3,3.52; p=0.0001; t(25)=-3.76). When data from both cohorts are analyzed together, there is also a significant increase (Pre/Post: $\bar{x}$=3.19,3.48; p-value=0.02; W(63)=68). When analyzed separately, there was no significant increase for responses from cohort 2 students.

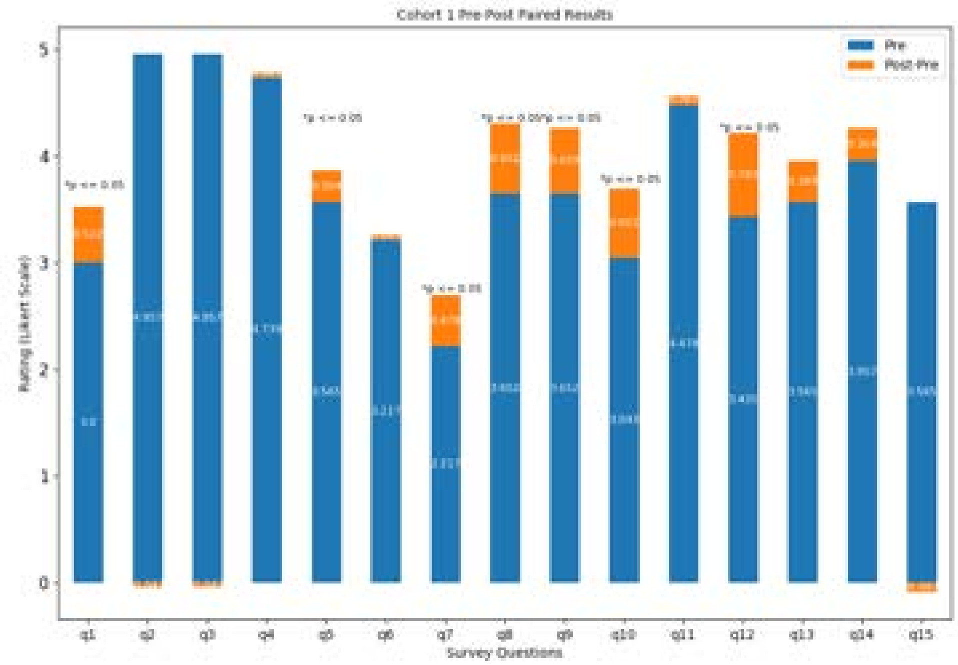


Figure 4-1: Paired pre-post results for cohort 1: significant changes ($p <= 0.05$) in computational identity (Q1), computation skill (Q7), knowledge/skills and self-efficacy (Q8, Q9, Q10), and digital empowerment (Q12). The delta between post-pre means are shown in orange. Some questions (Q2, Q3, Q15) show a slight decrease comparing pre-post means but these changes are not significant ($p > 0.05$).

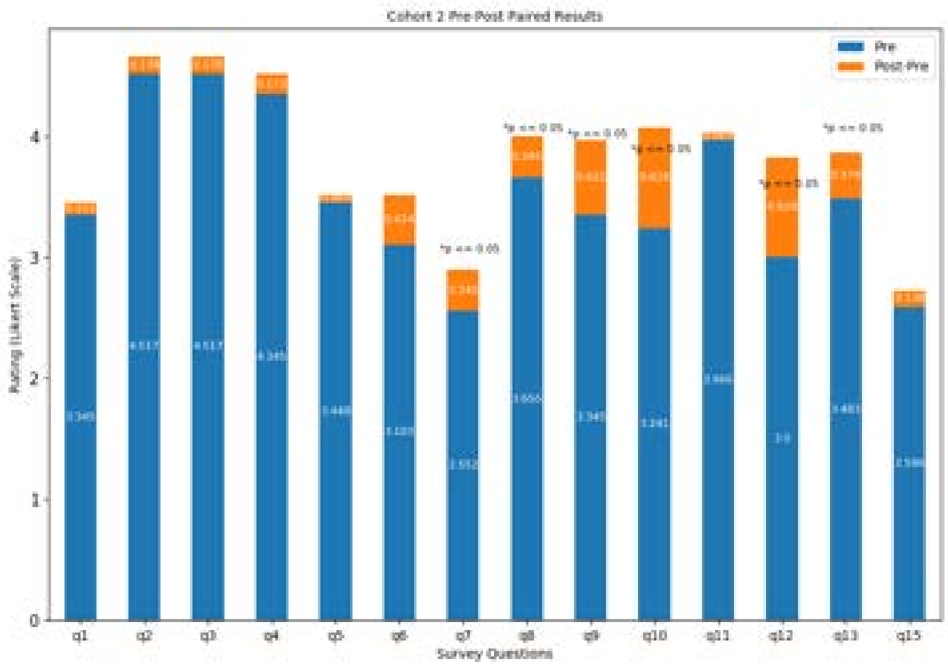


Figure 4-2: Paired pre-post results for cohort 2: significant changes (p <= 0.05) can be seen in computation skill (Q7), knowledge/skills and self-efficacy (Q8, Q9, Q10, Q13), and digital empowerment (Q12). The delta between post-pre means are shown in orange. All changes from pre-post results are increases.

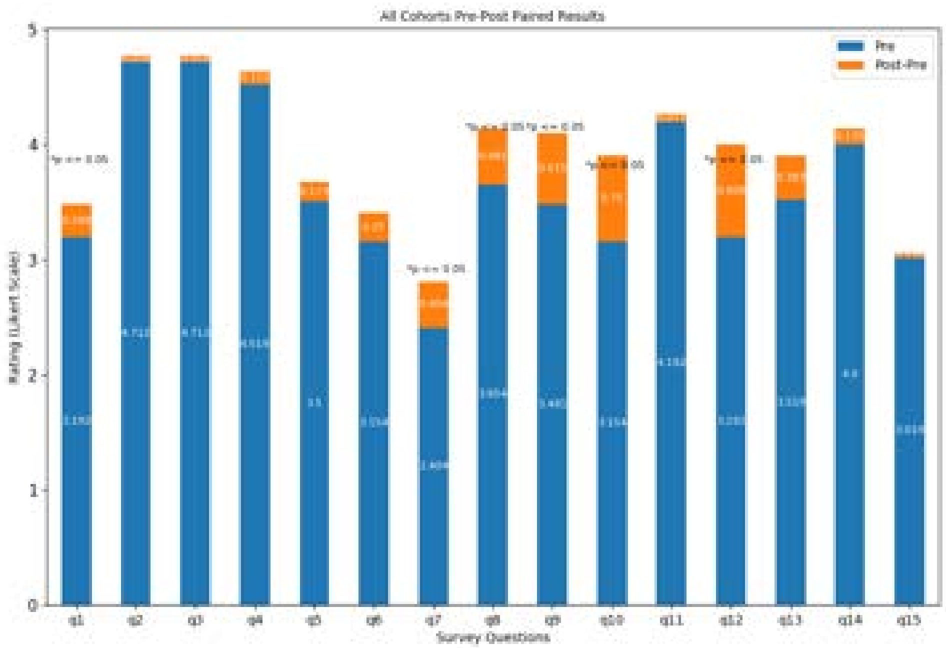


Figure 4-3: Paired pre-post results for all cohort data: significant changes ($p <= 0.05$) in computational identity (Q1), computation skill (Q7), knowledge/skills and self-efficacy (Q8, Q9, Q10) and digital empowerment (Q12). Comparing the pre-to-post changes, all changes in means are increases. The deltas between pre-post means are shown in orange.

4.2.2 Computation Skills

Question 7 from the pre-post survey asks students to self-rate their computation skills to the question "I would rate my computer programming skills (including app programming) as" on a Likert scale of 1 (very beginner) to 5 (very advanced). Students from cohort 1 showed a pre-post increase in their rating of their computation skills (Pre/Post: $\bar{x}$=3.04,3.69; p=0.004; W(25)=17). Students from cohort 2 also also showed a pre-post increase in their self-rating of their skills (Pre/Post: $\bar{x}$=2.552,2.897; p=0.048; t(38)=-2.069). When responses from both cohorts were analyzed together, all participants showed a significant increase in their rating of their computational ability (Pre/Post: $\bar{x}$=2.404,2.808; p= 0.0048; W(68)=2.404). One difference is that students from cohort 1 rated their computation skills pre-workshop higher than students from cohort 2. This is aligned with the hypothesis that students from cohort 1, having come from Technovation and MIT Solv(Ed) programs, have more experience in coding before joining the study workshop.

4.2.3 Self-efficacy and Digital Empowerment

Two questions in the pre-post survey measured self-efficacy and digital empowerment: question 12: "I know how to make a lasting impact in my community or in the world" and question 13: "I am confident in my ability to design and create solutions using technology, rather than working toward a "right" answer someone else gives me." For Q12, both cohort 1 and cohort 2 students show an increase in their feeling of empowerment of making a lasting impact in their community or in the world (Cohort 1 Pre/Post: $\bar{x}$=3.43, 4.21; p=0.00258; W(25)=12; Cohort 2 Pre/Post: $\bar{x}$=3,3.83; p=0.0019; W(38)=12.5). When analyzing data from both cohorts for this survey question, all participants showed an increase in empowerment to make a lasting impact (Pre/Post: $\bar{x}$=3.18,4, p=0.000002; t(63)=-5.366). A statistically significant result was seen in the survey responses of cohort 2 for the self-efficacy survey question (question 13). Students in cohort 2 demonstrated an increased feeling of self-efficacy to solve ambiguous problems using technology (Pre/Post: $\bar{x}$=3.48,3.86; p=0.012; W(38)=13).

The analysis of responses from cohort 1 for question 13 did not show a statistically significant change.

4.2.4 Computational Action Skills and Knowledge

Computational action knowledge and skills were measured through questions on each topic. Both cohorts 1 and 2 demonstrated significant changes in their responses to the following questions:

- Question 8: I know how to find and define a real problem (Defining a real-world problem)
- Question 9: I know how to figure out what users and communities need (Understanding users and communities)
- Question 10: I know how to design technology with an ethical framework in mind (Designing responsibly with and for users)

Question 8 is also a measurement of self-efficacy. Students from cohort 1 showed an increase pre-post for all questions 8, 9, and 10 (Q8 Pre/Post: $\bar{x}$=3.652,4.304; p=0.0003; W(25)=0; Q9 Pre/Post: $\bar{x}$=3.65,4.26; p=0.008; W(25)=12.5; Q10 Pre/Post: $\bar{x}$=3.043,3.696; p= 0.004; t(25)=-3.185). Students from cohort 2 also showed an increase pre-post for all three questions (Q8 Pre/Post: $\bar{x}$=3.65,4; p=0.048; t(38)=-2.069; Q9 Pre/Post: $\bar{x}$=3.34,3.96; p=0.0048; W(38)=34; Q10 Pre/Post: $\bar{x}$=3.24,4.07; p=0.0002; t(38)=-4.296).

4.3 Notable Similarities

The paired pre-post results for the other questions in the questionnaires did not show significant changes. The pre-post means for some questions were equally quite high (indicating students "agree" or "strongly agree" with the statements both pre-workshop and post-workshop). These questions in the survey measured learning motivations (Q2, Q3, Q4), teamwork (Q11), and interest in A.I. (Q14). Although these results were not statistically significant ($p > 0.05$), they can be seen in Figures 4-1, 4-2, and 4-3.

4.3.1 Learning Motivations

It is worth analyzing questions 2 through 5 in the survey which measured learning motivations, namely: intrinsic, extrinsic, and self-transcendent motivation, which were based on survey questions in work established in the education field [5].

- Question 2: I want to learn things that will help me make a positive impact on the world (self-transcendent)

- Question 3: I want to become an educated citizen that can contribute to society (self-transcendent)

- Question 4: I want to expand my computer programming knowledge (intrinsic)

- Question 5: I want to learn computer programming to earn more money (extrinsic)

Students' responses in both pre- and post-surveys show that all participants had high self-transcendent and intrinsic motivations. What about extrinsic motivations? Cohort 1 students demonstrated a significant change pre-post to question 5 (Pre/Post: $\bar{x}$=3.565,3.869; p=0.0497; $t(25)$=-2.0765). There was no significant change in the pre-post results for cohort 2. When all cohort data was analyzed, there was also no significant change. Students from cohort 1 come from a more varied group of countries, while most students from cohort 2 are in the U.S. It should not be surprising that the potential for economic gain is one motivator for many students to learn programming, given the high-earning potential of today's tech industry.

4.4 Notable Differences

4.4.1 Pre-survey Notable Results

Female vs. Male

Out of 101 total participants from both cohorts, 58 identified as female, 42 identified as male, and 1 participant identified as non-binary. In the analysis of the pre-survey data, two questions presented a significant difference between female vs. male data. Females agreed more strongly to question 11: “I know how to work on a team” than males (Female/Male: $\bar{x}$=4.241,3.738; p=0.0248; U(100)=1522). In addition, females also agreed more strongly to question 15: “I am concerned about the use of artificial intelligence (AI) in technology” than males (Female/Male: $\bar{x}$=3.172,2.667; p=0.046; t(100)=2.02).

Participants in Technovation Challenge

Out of 40 participants from cohort 1, 16 also participated in the Technovation Challenge, and 24 did not. From the pre-survey data, those who participated in Technovation answered higher on the questions regarding computer identity and computational skill. For computational identity (Q1: “I see myself as a computer programmer), students who were in Technovation identified more strongly as a computer programmer pre-workshop (No/Yes: $\bar{x}$=2.54,3.25; p=0.0319; U(40)=116). For computation skills (Q6: “I do well on computing tasks such as app programming” and Q7: ”I would rate my computer programming skills (including app programming) as:”), Technovation students agreed more strongly that they do well on programming tasks and ranked their programming skills higher than students not in Technovation (No/Yes: Q6: $\bar{x}$=2.708,3.427; p=0.0486; U(40)=116; Q7: $\bar{x}$=1.75,2.812; p=0.002; U(40)=122). As mentioned before, since students in the Technovation Challenge are expected to finish implementing a project using App Inventor or another programming language (which includes but is not limited to Android Studio, Kotlin, and Swift), these pre-survey responses makes sense with the nature of the coding program.

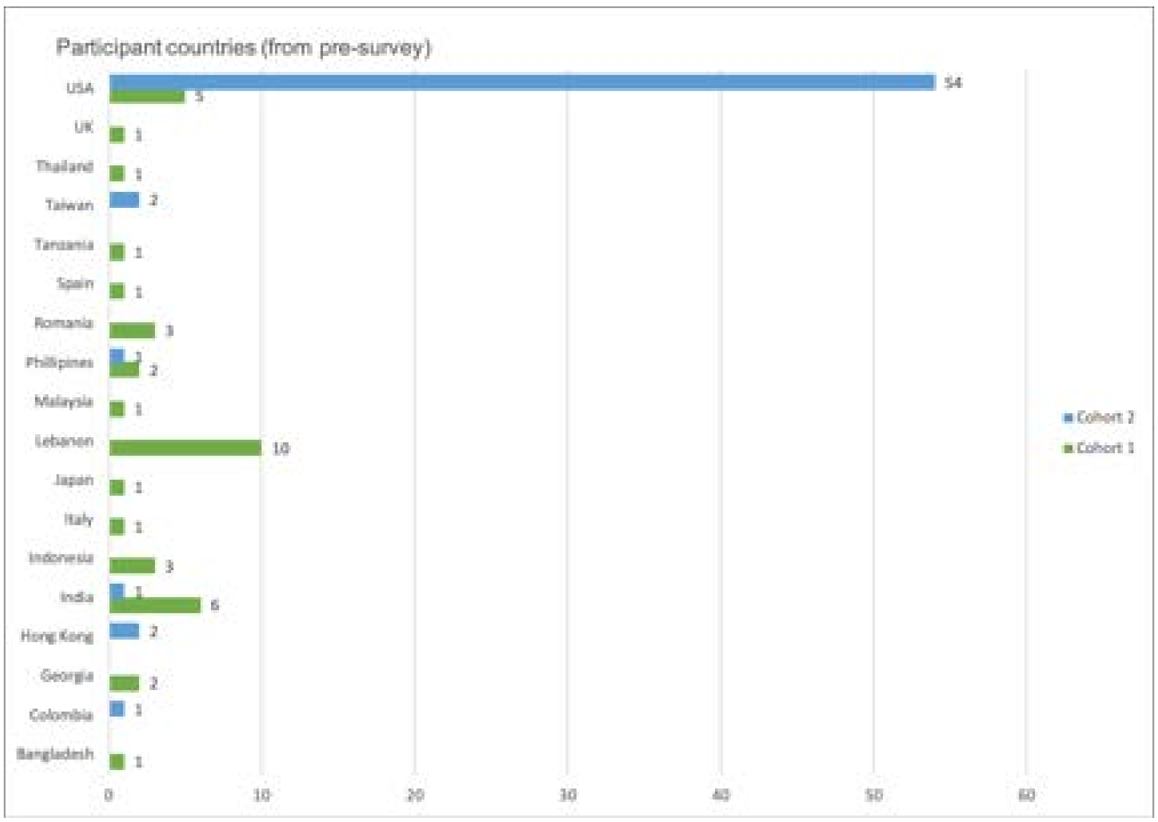


Figure 4-4: Participant country distribution from pre-survey data.

WEIRD vs. Non-WEIRD Countries

Out of 101 total participants from both cohorts, 60 were from WEIRD countries (Western, educated, industrialized, rich, and democratic) and 41 were from non-WEIRD countries. A distribution of countries from both cohorts can be seen in Fig. 4-4.

United States vs. India

From 101 total participants from both cohorts, 59 were located in the U.S. and 7 were located in India. Participants from India scored higher than participants from the U.S. on self-transcendent motivation, self-reported knowledge of understanding user needs, and interest in using artificial intelligence (A.I.) in their projects. On self-transcendent motivation (Q2: "I want to learn things that will help me make a positive impact on the world"), all students from India answered this pre-survey question with the highest possible score ("5 - Strongly agree") (US/India: $\bar{x}$=4.54,5; p=0.046; U(66)=126). Participants from the U.S. and India all rated their self-transcendent motivation highly. On understanding community and user needs (Q9: "I know how to figure out what users and communities need"), students from India ranked their knowledge and skill higher (US/India: $\bar{x}$=3.135,4.285; p=0.004; U(66)=75). On their interest in using A.I. in their own projects (Q14: "I want to include artificial intelligence (AI) in technology projects that I create"), students from India ranked their interest more strongly than students from U.S. in the pre-survey (US/India: $\bar{x}$=3.847,4.714; p=0.0387; U(66)=111.5).

United States vs. Lebanon

Out of 101 total participants, 59 were from the U.S. and 10 were from Lebanon. Pre-survey responses from students from Lebanon show a stronger agreement with learning programming because of economic motivation, as well as higher concern for the use of A.I. in technology in society. On external motivation (Q5: "I want to learn computer programming to earn more money"), students from Lebanon responded with

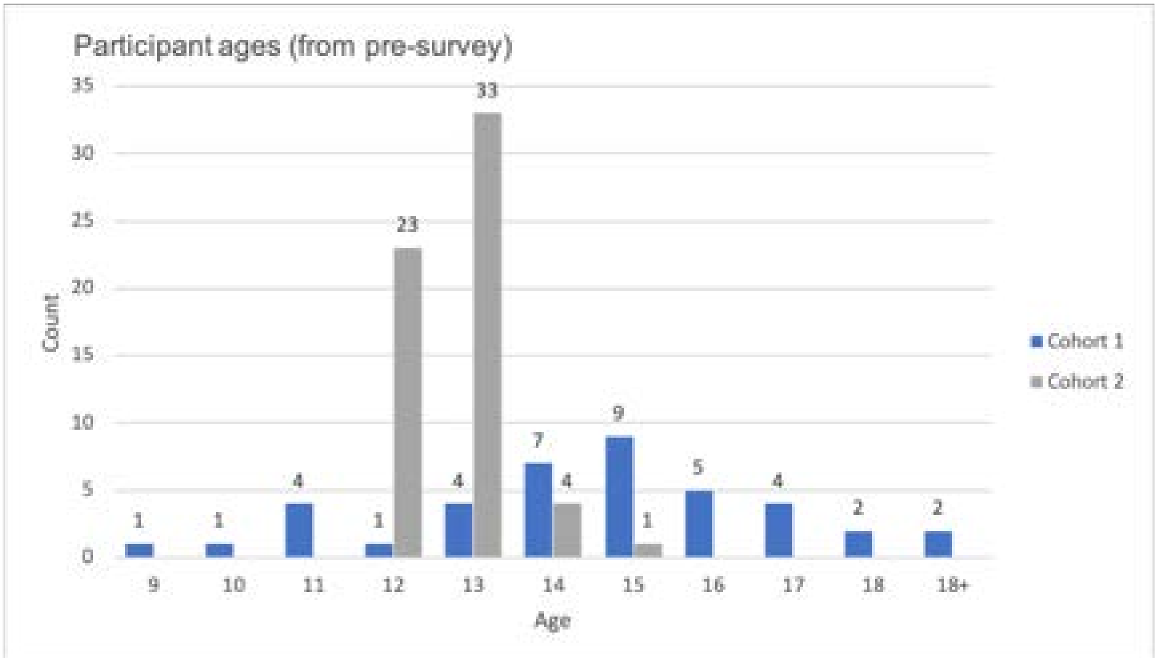


Figure 4-5: Participant age distribution from pre-survey data.

stronger agreement than students from the U.S. (US/Lebanon: $\bar{x}$=3.32,4.2; p=0.0287; U(69)=170). On perception of A.I. (Q15: "I am concerned about the use of artificial intelligence (AI) in technology"), students from Lebanon more strongly agreed with concerns than students from the U.S. (US/Lebanon: $\bar{x}$=2.73,3.6; p=0.039; U(69)=178.5).

Middle School vs. High School

Out of 101 total participants from both cohorts, 24 were of age 12, 37 were of age 13, 11 were of age 14, and 10 were of age 15, with other age ranges comprising a long tail, which can be seen in full in Fig. 4-5. The pre-survey data was compared between all age groups with all other age groups, and significant differences can be seen for certain questions between ages 12 vs. 15 and ages 13 vs. 15 (both comparisons illustrate a difference between a middle school participant vs. a high school participant). Participants in high school felt more self-transcendent motivation to learn computer programming than participants in middle school (Q2: "I want to learn things that will help me make a positive impact on the world"), more digital empowerment (Q12: "I know how to make a lasting impact in my community or in the world"), and a stronger concern of the use of A.I. in technology (Q15: "I am concerned about the use of artificial intelligence (AI) in technology"). The results are as follows: Q2 Age 13/Age 15: $\bar{x}$=4.54,5; p=0.0123; U(47)=105; Q2 Age 12/Age 15:$\bar{x}$=4.458,5; p=0.0296; U(34)=75; Q12 Age 13/Age 15:$\bar{x}$=2.84,3.6; p=0.0298; U(47)=104.5; Q15 Age 12/Age 15:$\bar{x}$=2.375,3.7; p=0.0039; U(34)=45.5.

4.4.2 Post-survey Notable Results

Female vs. Male

Of the 65 participants from both cohorts who filled out the post-study workshop, 42 identified as female, 21 identified as male, and 2 identified as non-binary. Post-workshop, female participants still had a higher response to the question of knowledge of how to work on a team than male participants (Male/Female: $\bar{x}$=3.905,4.405; p=0.0389; t(63)=-2.11). This is a similar result to the unpaired pre-workshop result for this question between female vs. male participants. Of the 26 participants from cohort 1 who filled out the post-study survey, 22 identified as female and 4 identified as male. Post-workshop, female participants from cohort 1 had a higher response than male participants to the knowledge/skill and self-efficacy question of knowing how to find and define a real problem (Male/Female: $\bar{x}$=3.5,4.4545; p=0.0462; U(26)=18). Of the 39 participants who filled out a post-study survey, 20 participants identified as female, 17 identified as male, and 2 identified as non-binary. Post-workshop, male participants from cohort 2 rated their interest in expanding their computer programming knowledge higher than female participants (Male/Female: $\bar{x}$=4.765,4.2; p=0.0386; U(37)= 228). There were no significant differences among the answers to the other questions in the post-survey when examining the independent variable of gender.

Middle School vs. High School

Of the 65 post-study participant responses, 21 participants were of age 13, 17 were of age 12, 6 participants were of age 14, 8 of age 15, and 4 of age 16. Post-workshop, participants of high school grade bands (i.e. age 15 and above) indicated a higher concern about the use of artificial intelligence (A.I.) in technology than participants in middle school grade bands (i.e. age 12). (Age 12/Age 15: $\bar{x}$=2.294,4; p=0.00237; U(25)=17). Another difference showed that students of age 15 indicated more strongly that they want to continue to learn things that will help them make a positive impact on the world than participants of age 13 (Age 13/Age 15: $\bar{x}$=4.428,5; p=0.0334; U(29)=48).

One interesting result about knowledge/skill and self-efficacy in regards to making responsible technology ("I know how to design technology with an ethical framework in mind") also emerged. Students of middle school ages (i.e. ages 12, 13, and 14) rated their skill and self-efficacy on this topic higher than students of age 16 (Age 12/Age 16: $\bar{x}$=4.059,x=2.25; p=0.0144; U(21) = 60.5; Age 13/Age 16: $\bar{x}$=3.762,2.25; p=0.0204; U(25)= 72.5; Age14/Age 16: x=4,2.25; p=0.0055; U(10)=24). The mean post-study response to this question by the 4 participants of age 16 is much lower than those of the other ages. There were only 4 responses of age 16, compared to many more from the other ages, so this result may need more investigation. Measuring these questions with a larger sample of students of all ages would be helpful for drawing a confident conclusion about any significant results.

WEIRD vs. Non-WEIRD Countries

Of the 65 responses to the post-survey from both cohorts, 38 participants identified the United States as home, whereas the remaining were distributed among many other countries (6 from Lebanon, 6 from India, 3 from Romania, 2 from Georgia, 2 from the Philippines, and 1 each from a large gamut of other countries). In total, 40 were from WEIRD (Western, educated, industrialized, rich, and democratic) countries, and 25 from non-WEIRD countries. As noted before, students in cohort 2 were predominantly U.S.-based, whereas students in cohort 1 were largely international. No significant results emerged from the unpaired comparisons of unpaired post-study data comparing geographic locations because the sample sizes of non-U.S. participants were very small.

Participation in Technovation

Of the 26 participants in cohort 1 who filled out the post-survey, 13 participated also in Technovation and 13 did not. The unpaired post-study results showed some interesting significant differences between these two groups. Post-workshop, students in the Technovation program still rated themselves higher for computational identity ("I see myself as a computer programmer") (No/Yes: $\bar{x}$=2.846,4.077; p=0.0165; U(26)=39) and computation skill ("I do well on computing tasks such as app programming") (No/Yes: $\bar{x}$=2.769,3.768; p=0.019; U(26)=44). Students' self-ratings of their computer programming skills was also higher for those in the Technovation program (No/Yes: $\bar{x}$=2.077,3.308, p=0.019; U(26)=40).

This is very similar to the unpaired pre-survey results comparing the two groups. Interestingly, as discussed in the previous sections of this chapter, when we look at the paired pre-post data, students in Technovation from cohort 1 still demonstrated significant pre-post increases in computational identity, self-efficacy, digital empowerment, and general computation knowledge and skills. This gives us more confidence that the computational action process is effective even for students who have had previous experience with coding and engineering design processes.

Chapter 5

Results Discussion

In the following sections, I discuss the results presented in the previous chapter by supporting each finding with qualitative data from surveys and student work. First is a discussion of the qualitative survey results, followed by a detailed look at toolkit student work, and concluding with a discussion of students' pre-post coding activities using App Inventor.

5.1 Discussion of Survey Results

5.1.1 Computational Identity

Students from both cohorts showed an increase in their own rating of their identity as a computer programmer. In the pre-survey, students were asked the open-ended question: "What do you plan to do in the future?" which they could freely respond to. Out of the 48 pre-survey responses to this question, 21 answers fell under "Be an engineer/programmer/study computer science", 9 answered "Unsure or I don't know", 5 specifically called out "Helping others in society", and the remaining ranging from going to school or into a specific field like "pediatric anesthesiologist". Out of the 40 post-survey responses to this question, 19 responses fell under "Be an engineer/programmer/study computer science", 8 answered "I don't know", 2 called out "Helping a community", and the remainder were miscellaneous. After the workshop,

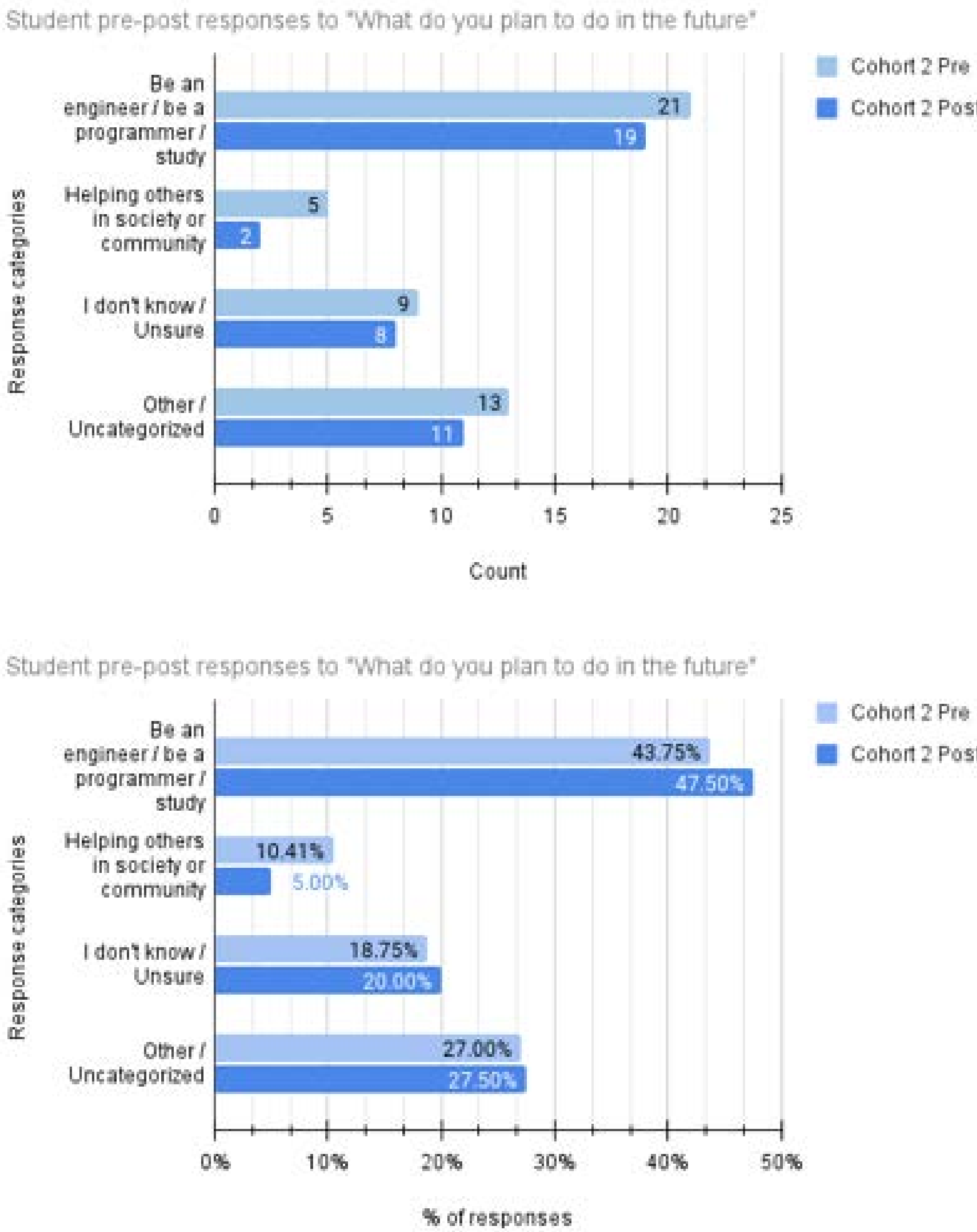


Figure 5-1: Students' open-ended responses to the question of what they want to do in the future showed a slight shift post-workshop to more in the category of "Be an engineer/programmer/study computer science". These results were not analyzed quantitatively for significance, but merely illustrate the change in themes of the written pre-post qualitative responses from students.

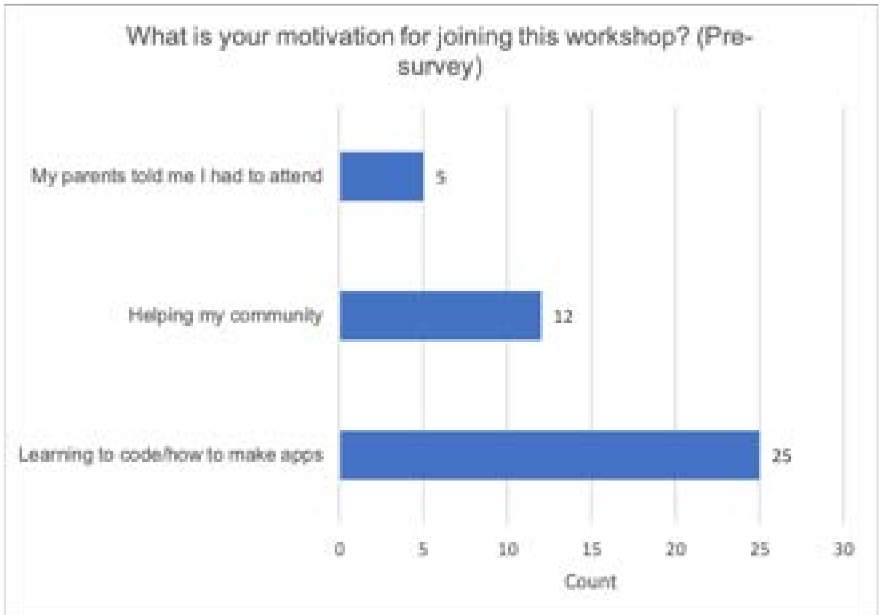


Figure 5-2: Students' open-ended responses to the pre-survey question of their motivation for joining the workshop show that a majority were motivated by learning programming, followed by helping their community.

a higher percentage of students wanted to be a computer programmer or study computer science(43.7% pre vs. 47.5% post), which corresponds with the increase seen in the computer identity question (Q1) paired pre-post result. Of interest is the decrease of students calling out "Helping others in society" from 5 responses pre- to 2 responses post-. While the numbers are too low for a significant conclusion to be reached, it is possible that the intervention inspired some students to realize that becoming a programmer is one way they can help society.

5.1.2 Learning and Motivation

Responses to open-ended pre-survey question "What is your motivation for joining this workshop?" varied, ranging from:

- *"My motivation for joining this class is the chance to learn more of how to create computer programs to benefit others."*

- *"I have always wanted to design an app, but have never known how."*

- *"I would like to know how to apply my future computer programming skills in real life to help my community"*

- *"I want to learn how to program"*

- *"I'm interested in a possible career and computer science and AI."*

- *"I like to code and I want to learn how to code an app."*

- *"My mom says I need to come"*

For this question, 25 out of 48 responses to this question fell under "Learn to code or how to make apps", 12 under "Helping my community", and 5 under "My parents told me I had to attend". Students seem most motivated by an intrinsic motivation to learn programming, followed by self-transcendent motivation to help others in their community through technology. The results for these questions in the paired pre-post results were not significant. However, qualitative results indicate that students are motivated nearly equally by these goals: both gaining coding knowledge (intrinsic) and using technology to help others (self-transcendent). No open-ended survey responses mentioned "earning money" or external motivation.

5.1.3 Self-efficacy and Digital Empowerment

Students demonstrated an increase in their feeling of digital empowerment (creating an impact in their community using technology) and self-efficacy (solving ambiguous problems using technology) in the quantitative results analyzed in the previous section, and the qualitative results support this. After the workshop, students were asked to write freely to answer the question "How do you now think about making an impact in your community?". Responses include:

- *"I think even the smallest things could help."*

- *"I'm thinking about identifying more problems and how users will respond to the app."*

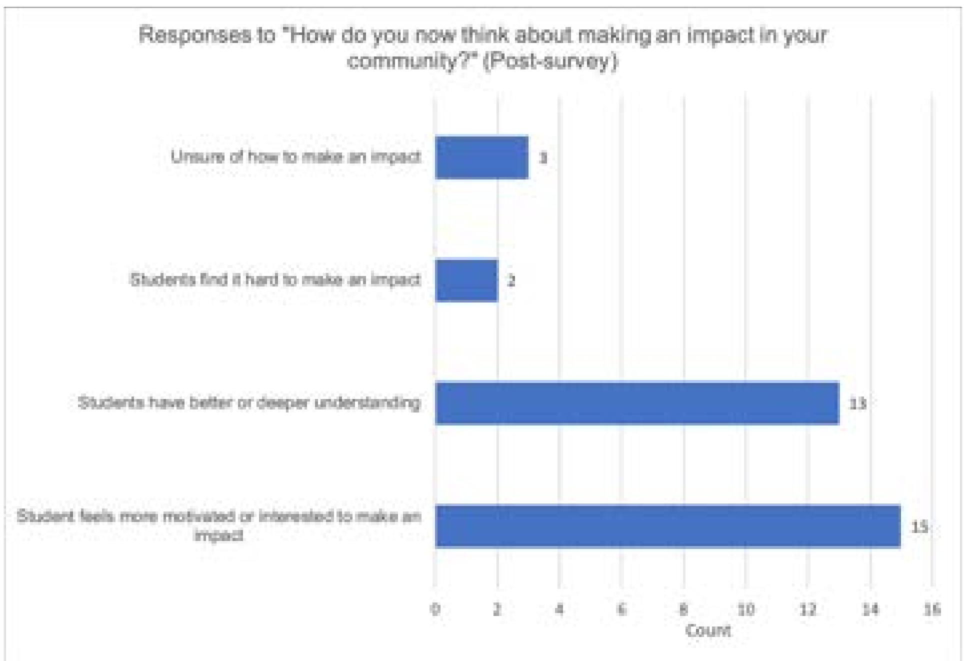


Figure 5-3: Students' open-ended post-workshop responses on the topic of making an impact show that a majority of students feel more empowered, more interested, and find it easier, followed by students feeling that they have a better or deeper understanding. Some students were still unsure or found it hard to make an impact, but not the majority.

- *"I have a lot more motivation, and it feels fun."*
- *"By thinking of an idea that seems needed and then finding a way to implement it"*
- *"Making an app can help making a positive impact on my community"*
- *"I now think it is easier to make a change and know how to make a strong app."*
- *"Its hard. And you have to be careful."*

Out of 39 responses to this question, 15 fell under “Student feels more motivated or interested to make an impact”, 13 under “Students have better or deeper understanding of how to make an impact”, 2 under “Students find it hard to make an impact”, and 3 were “Unsure of how to make an impact”. 72% of students’ responses to this question demonstrated more motivation or better understanding of how to make an impact, which supports the increase seen in pre-post paired result to question 12, which measured digital empowerment. For the question “How, if at all, did the workshop and activities change how you think about making an impact in your community?”, many students responded with detailed, insightful answers. Their responses include:

- *"It made it seem less ginormous and manageable."*
- *"I think it is inspiring because it kind of simplifies how we can help people."*
- *"I think I feel that it’s more doable than I did before."*
- *"It taught me that you need to think a lot to make a solid idea"*
- *"Asking the user questions in my thing and using feedback to help them"*
- *"The class made me think of making an impact as a process with clear steps."*
- *"I can actually do it"*
- *"I now think to pinpoint problems rather than look at a broad spectrum. it showed me more steps and ideas"*

- *"It made me understand the steps in order to create an impact"*
- *"i used to think it would be really tiresome but not actually."*
- *"I now think that making an impact is possible while before the class it was almost out of the question."*

Out of the 39 responses to this question, almost all students reflected on and discussed an increased feeling of being able to make change in their community and now knowing tools and steps to make an app for impact. This supports the increase seen in the pre-post survey results that saw an increase in self-efficacy after the computational action workshop.

5.1.4 Computation Skills

As explained in Chapter 3, in the final research study, a pre-post App Inventor activity was used to shed more light on changes in computation skill. Both cohorts 1 and 2 student responses to the computational skills question ("I would rate my computer programming (including app programming) skills as") showed significant increase pre-post. The increase in computation skill seen in results analyzing both cohorts indicate that the coding demos and activities included in the workshop likely made a difference. Examination of the student apps also supports this conclusion, which is discussed in detail in subsection 5.2.5.

5.2 Discussion of Student Toolkit Work

5.2.1 Brainstorming Using Mindmaps

Students' brainstorming work from the study indicate, for the most part, good grasp of the concept and effective utilization of the tool. Students grasped the concept of individual brainstorming using mind maps quickly and produced a variety of detailed mind maps that covered many areas of interest (some are pictured in Figures 5-4 and 5-5. Since students were introduced to the United Nations Sustainable Development

Goals in the lesson immediately prior to brainstorming, many students chose a UN sustainable development goal as the center of their mind map in order to brainstorm from. Feedback from students on this brainstorming tool indicated students found it new, helpful, and fun. Students who did not know about the brainstorming tool before the workshop caught onto it quickly.

5.2.2 User Research Questions

To review, the toolkit provided for students to better understand users included: user research question templates for them to write their own questions, user persona templates for them to create personas, and a collaborative analysis table for them to analyze existing solutions in their community. Students quite effectively created their own open-ended, empathetic research questions to ask users, as can be seen in some of the work shown in Figure **??**. During the workshop, students were guided in break-out room sessions to write user questions and facilitators and other students gave responses as users if the questions applied to them. Students were instructed that to further develop their project, they should gather data from users around them for the problem they want to address, either in-person or by making an online survey. The research template table is a jumping off place for students.

In the first pilot of the computational action toolkit, students were given the template of suggested questions and encouraged to create an online survey using a tool like Google Forms to source anonymous user feedback. Because the pilot ran during the MIT Futuremakers Create-a-thon program that lasted two weeks, students had time to write their questions as online surveys and deploy to those in their community as well as on broader online communities. The results of the user research was instrumental to all teams in designing their solutions, and teams presented user research summaries in their final project presentations.

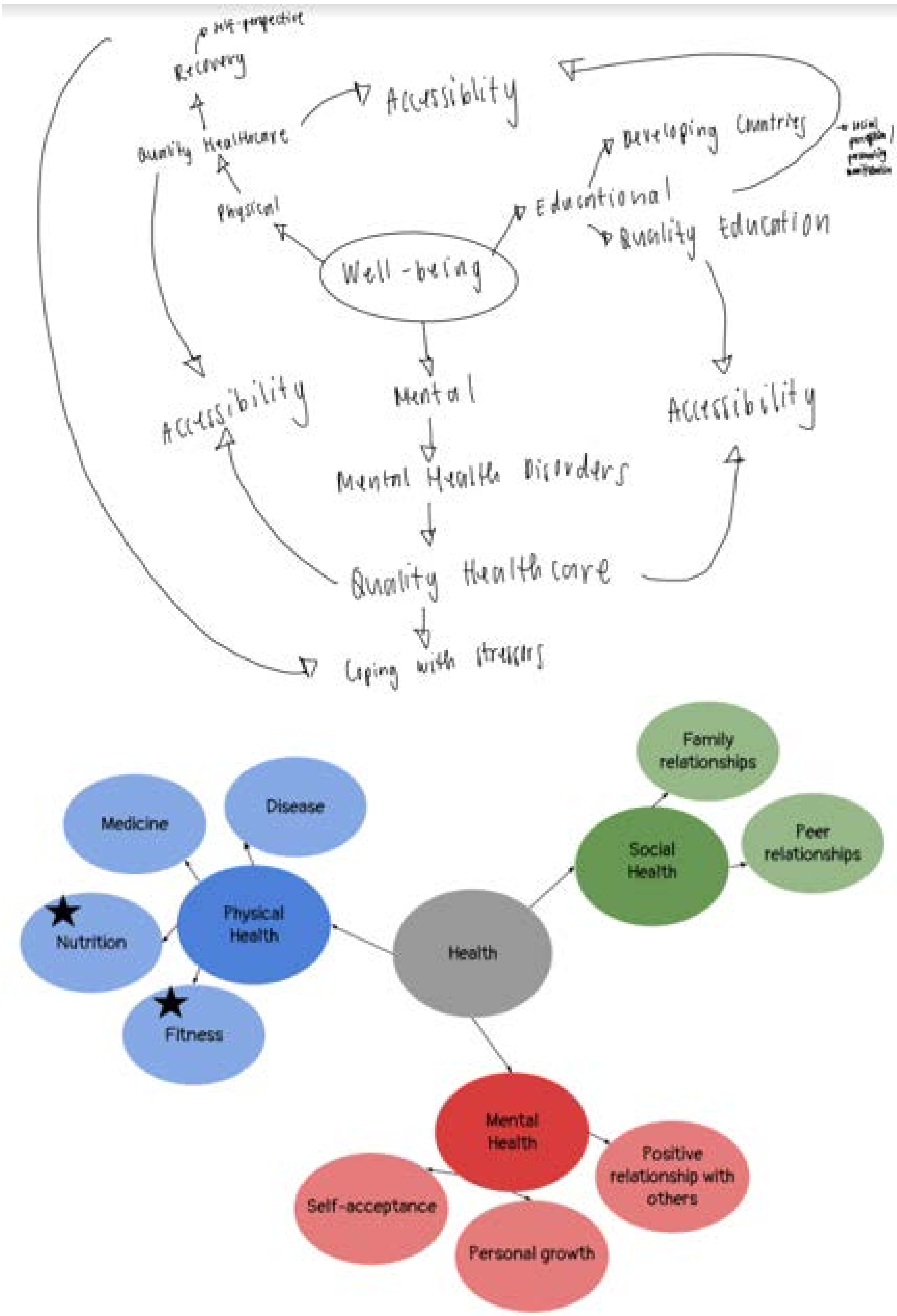
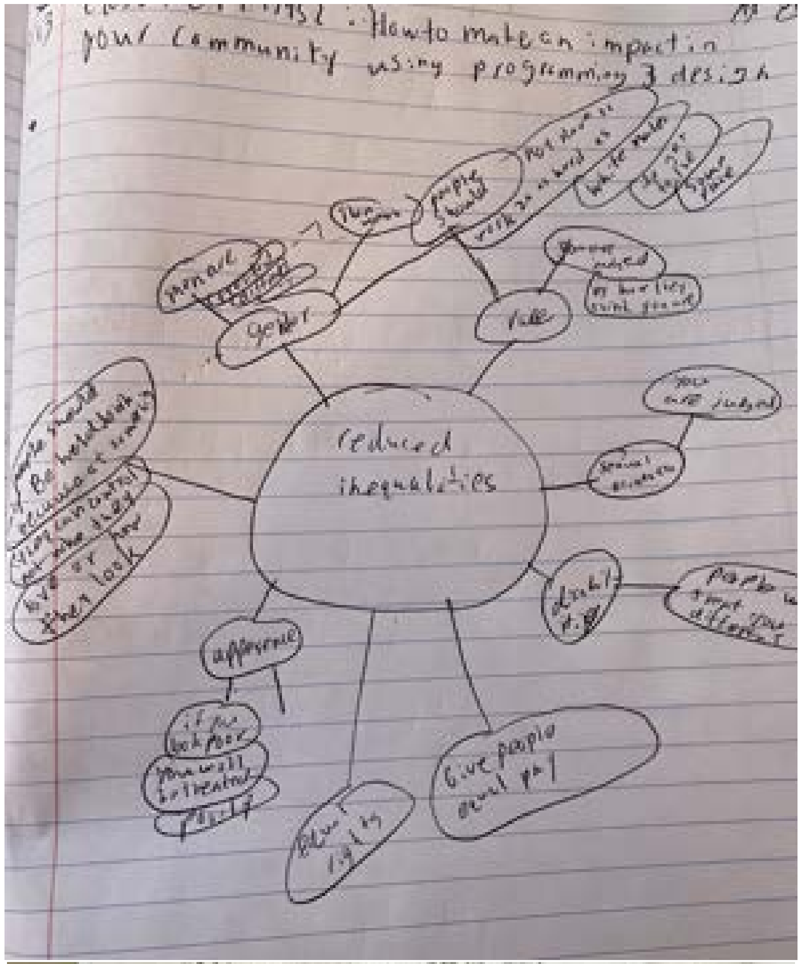
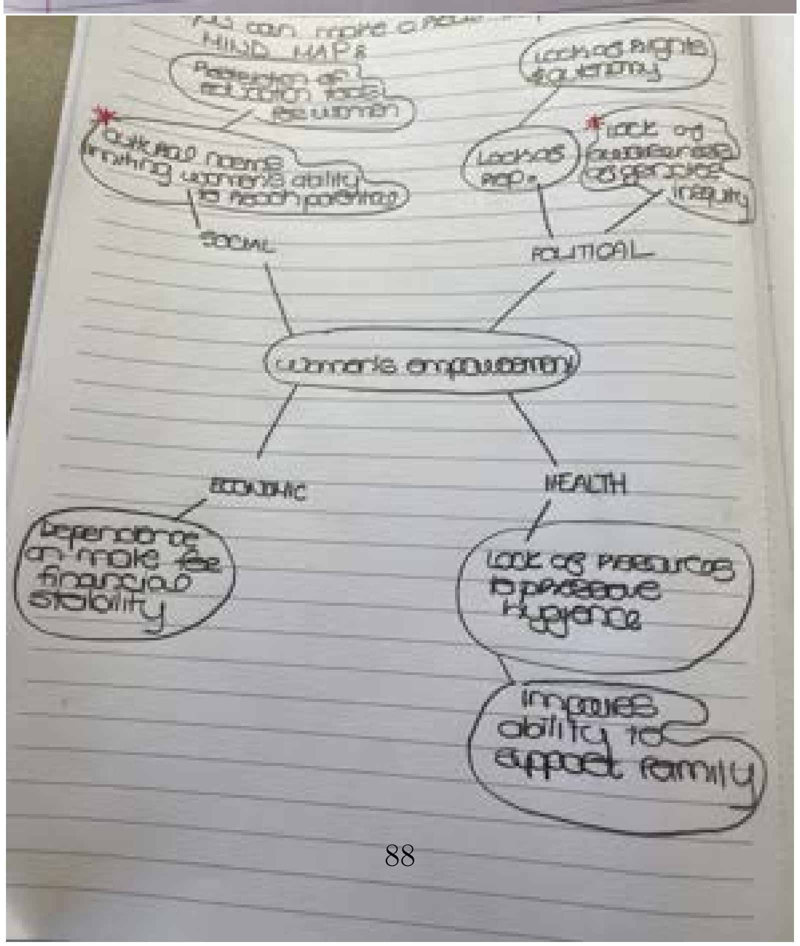
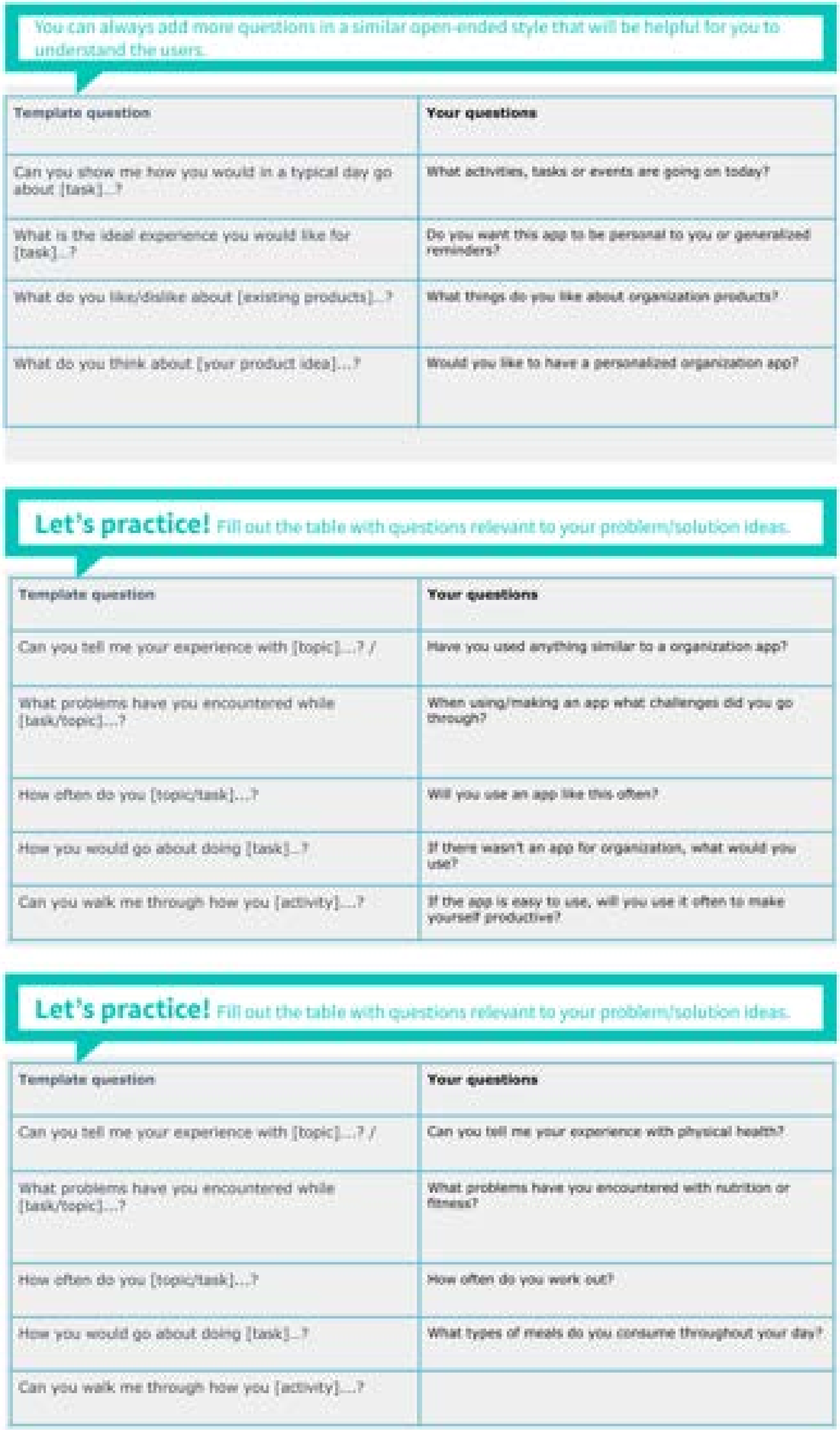


Figure 5-4: Students drew impressively exploratory mind maps during a 5-minute brainstorm activity.


How to make an impact in your community using programming & design
reduced inequalities
gender
Give people equal pay


MIND MAPS
Lack of rights & autonomy
Perception of education for women
Lack of rep.
Lack of awareness of gender inequity
SOCIAL
POLITICAL
Women's empowerment
ECONOMIC
HEALTH
Dependence on male for financial stability
Lack of resources to preserve hygiene
Improves ability to support family



You can always add more questions in a similar open-ended style that will be helpful for you to understand the users.

Template question	Your questions
Can you show me how you would in a typical day go about [task]...?	What activities, tasks or events are going on today?
What is the ideal experience you would like for [task]...?	Do you want this app to be personal to you or generalized reminders?
What do you like/dislike about [existing products]...?	What things do you like about organization products?
What do you think about [your product idea]...?	Would you like to have a personalized organization app?

Let's practice! Fill out the table with questions relevant to your problem/solution ideas.

Template question	Your questions
Can you tell me your experience with [topic]...? /	Have you used anything similar to a organization app?
What problems have you encountered while [task/topic]...?	When using/making an app what challenges did you go through?
How often do you [topic/task]...?	Will you use an app like this often?
How you would go about doing [task]...?	If there wasn't an app for organization, what would you use?
Can you walk me through how you [activity]...?	If the app is easy to use, will you use it often to make yourself productive?

Let's practice! Fill out the table with questions relevant to your problem/solution ideas.

Template question	Your questions
Can you tell me your experience with [topic]...? /	Can you tell me your experience with physical health?
What problems have you encountered while [task/topic]...?	What problems have you encountered with nutrition or fitness?
How often do you [topic/task]...?	How often do you work out?
How you would go about doing [task]...?	What types of meals do you consume throughout your day?
Can you walk me through how you [activity]...?	

Figure 5-6: Students wrote good open-ended and specific user research questions.

5.2.3 Impact Matrices

In the final study workshops, guided group activities introduced the topic of the impact matrix to students.

Cohort One

In the workshop with cohort 1, as the instructor, I introduced students to an exemplary student project that targeted the issue of youth mental health and well-being. Students learned about one solution a student team created with App Inventor in partnership with Youth Radio Media called Mood Ring [37, 38]. Together, we discussed the aspects of the impact matrix in the context of this problem and proposed solution. Only lightly facilitated by the instructor, students in the workshop enumerated multiple ideas for positive impact, potential negative side effects and harms, and proposals for a solution that take into account both the positives and negatives.

Cohort Two

In the two workshops with cohort 2, as the instructor, I introduced students to a different exemplary student project that targeted the problem of faster stroke detection. Students learned about a group of students who delved into the problem for their MIT Futuremakers project. Together as a group, students in the workshop discussed with each other the positive impacts and potential negative side effects. In both workshops with students from cohort 2, students proactively shared many examples of potential negative harms to consider when planning a solution for this problem. Guided only lightly by the instructor, the students in the workshop produced insightful, deep discussion and also many ideas for solutions that are mindful of negative consequences on users. The impact matrices created jointly by the students can be seen in Figure 5-7.

IMPACT MATRIX: LET'S FILL OUT AN IMPACT MATRIX FOR FACIAL ASYMMETRY DETECTION (STUDENT PROJECT)

	Positive impact	Negative impact/side effect	What we'll make	How will we achieve this?
Impact 1 on users/community: Promotes awareness of strokes	Allow people to be more aware of strokes / could be life-saving	People could be very anxious/checking all the time/scared they might have a stroke	Inform people also add AI disclaimer.	
Impact 2 on users/community: AI for stroke detection	AI can look through prev. images of faces and easier for detection. AI can find more specific patterns that humans may not be able to. Model/answer may be wrong! (May misunderstand stroke signs) / False alarm	Model/answer may be wrong! (May misunderstand stroke signs) / False alarm / Different problem but may have similar symptoms	AI model should be as accurate as possible	
Impact 3 on users/community:				

IMPACT MATRIX: LET'S FILL OUT AN IMPACT MATRIX FOR FACIAL ASYMMETRY DETECTION (STUDENT PROJECT)

	Positive impact	Negative impact	What we'll make	How will we achieve this?
Impact 1 on users/community: Using AI for detection	AI to help automatically/more quickly detect potential warning signs of stroke	Mis-detect / false positive -> cause panic	A.I. model should be as accurate as possible	Get lots of data to try to improve A.I. model (expand the training set)
Impact 2 on users/community: Potentially life-saving early diagnosis	Save lives!	Emergency contact is not most helpful (ambulance?) data privacy? Data collection?	Multiple back-ups, give location!	Ensure data privacy is addressed, we can add info disclaimers about data to the user
Impact 3 on users/community: Educating all people, whether at risk or not	Educating people about early signs	People might self-diagnose incorrectly	Accurate, reliable educational material. Caveats about self-diagnosis	CDC/WHO (reliable resources). Make sure disclaimers are clear and center

Figure 5-7: In group work, students co-created impressive impact matrices that listed meaningful impacts, insightful potential negative harms, and innovative solution ideas.

Creating Individual Impact Matrices

After discussion of the value of using an impact matrix, students were given time to create an impact matrix for the problem they identified earlier. Some of the impact matrices that students came up with were very fleshed out, and some a little less so. During the workshops, students had a breakout room session of 20 minutes to work on their own impact matrix. Despite the limited time, many students wrote at least one clear positive impact, one negative side effect or harm, and brainstormed one possible solution. Students were encouraged to revisit or continue working on their impact matrix after the workshop if they didn't have enough time. Some student impact matrices from the study are shown in Figures 5-8, 5-9, and 5-10.

Sketches and Wireframes

In the design activity of the computational action process, sketching and wireframing tools were introduced to students: namely, rapidly prototyping using pencil and paper for sketching, and tools like Marvel App, Balsamiq, and App Inventor for easy designing. Students were encouraged to sketch their new project ideas before coding it in App Inventor. Some sketches from student work during the workshops can be seen in Figures 5-11, 5-12, and 5-13.

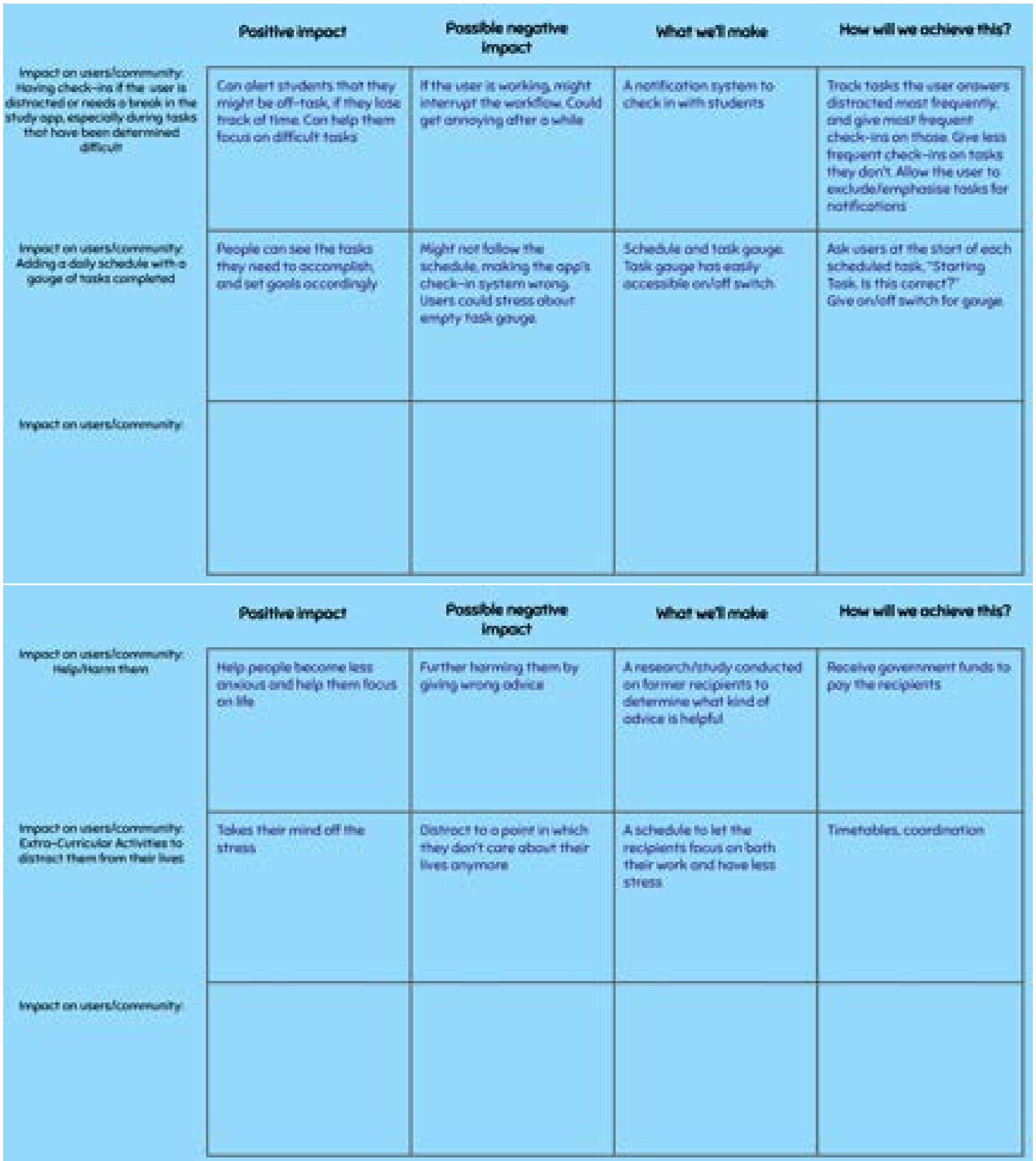
5.2.4 Pre-Post Student Project Ideas

Students from both cohorts were asked to complete a pre-workshop activity that involved writing a project idea and coding the idea in App Inventor. This was repeated at the end as a post-workshop activity. Of the 40 cohort 1 students who participated in the study, 27 students completed the pre-workshop project idea activity, 5 students submitted a pre-workshop app created using App Inventor, 9 students completed the post-workshop project idea activity, and no students submitted a post-workshop app created using App Inventor. Of the 61 cohort 2 students who participated in the study, 46 students completed the pre-workshop project idea activity, 14 students submitted a pre-workshop app created using App Inventor, 40 students completed

	Positive impact	Possible negative impact	What we'll make	How will we achieve this?
Impact on users/community:	Give early warnings for potential storms and advice on how to deal with it.	Misidentify your location and potential storms, giving false warnings or not giving warnings at all.	A larger data set and a way for the user to input their own location.	Allow users to submit storm data and use larger databases from reputable sources.
Impact on users/community:	An open database for people to view ocean sea levels and the sea level rises in their area.	Users could be concerned about how their data is being used - especially their location data.	Include a disclaimer about location data and allow the user to select when they want their location to be used.	Give notifications asking when they want their location to be used especially when a storm is approaching. Ensure that data privacy is protected.
Impact on users/community:	Save lives.	Inaccurate data that leads to no warnings being given.	A larger data set	Using resources from news outlets and weather channels to collect data.

	Positive impact	Possible negative impact	What we'll make	How will we achieve this?
Impact on users/community: Having check-ins if the user is distracted or needs a break in the study app, especially during tasks that have been determined difficult	Can alert students that they might be off-task, if they lose track of time. Can help them focus on difficult tasks	If the user is working, might interrupt the workflow. Could get annoying after a while	A notification system to check in with students	Track tasks the user answers distracted most frequently, and give most frequent check-ins on those. Give less frequent check-ins on tasks they don't. Allow the user to exclude/emphasise tasks for notifications
Impact on users/community: Adding a daily schedule with a gauge of tasks completed	People can see the tasks they need to accomplish, and set goals accordingly	Might not follow the schedule, making the app's check-in system wrong. Users could stress about empty task gauge.	Schedule and task gauge. Task gauge has easily accessible on/off switch.	Ask users at the start of each scheduled task, "Starting Task. Is this correct?" Give on/off switch for gauge.
Impact on users/community:				

Figure 5-8: Individually, students created great impact matrices that listed impacts and solution features.



	Positive impact	Possible negative impact	What we'll make	How will we achieve this?
Impact on users/community: Having check-ins if the user is distracted or needs a break in the study app, especially during tasks that have been determined difficult	Can alert students that they might be off-task, if they lose track of time. Can help them focus on difficult tasks	If the user is working, might interrupt the workflow. Could get annoying after a while	A notification system to check in with students	Track tasks the user answers distracted most frequently, and give most frequent check-ins on those. Give less frequent check-ins on tasks they don't. Allow the user to exclude/emphasise tasks for notifications
Impact on users/community: Adding a daily schedule with a gauge of tasks completed	People can see the tasks they need to accomplish, and set goals accordingly	Might not follow the schedule, making the app's check-in system wrong. Users could stress about empty task gauge.	Schedule and task gauge. Task gauge has easily accessible on/off switch.	Ask users at the start of each scheduled task, "Starting Task. Is this correct?" Give on/off switch for gauge.
Impact on users/community:				

	Positive impact	Possible negative impact	What we'll make	How will we achieve this?
Impact on users/community: Help/Harm them	Help people become less anxious and help them focus on life	Further harming them by giving wrong advice	A research/study conducted on former recipients to determine what kind of advice is helpful	Receive government funds to pay the recipients
Impact on users/community: Extra-Curricular Activities to distract them from their lives	Takes their mind off the stress	Distract to a point in which they don't care about their lives anymore	A schedule to let the recipients focus on both their work and have less stress	Timetables, coordination
Impact on users/community:				

Figure 5-9: Some students were able to fill out more than others in this 15-minute activity, and the depth of students' work varied. Overall, the individual impact matrices were impressive in pinpointing positive and negative impacts.

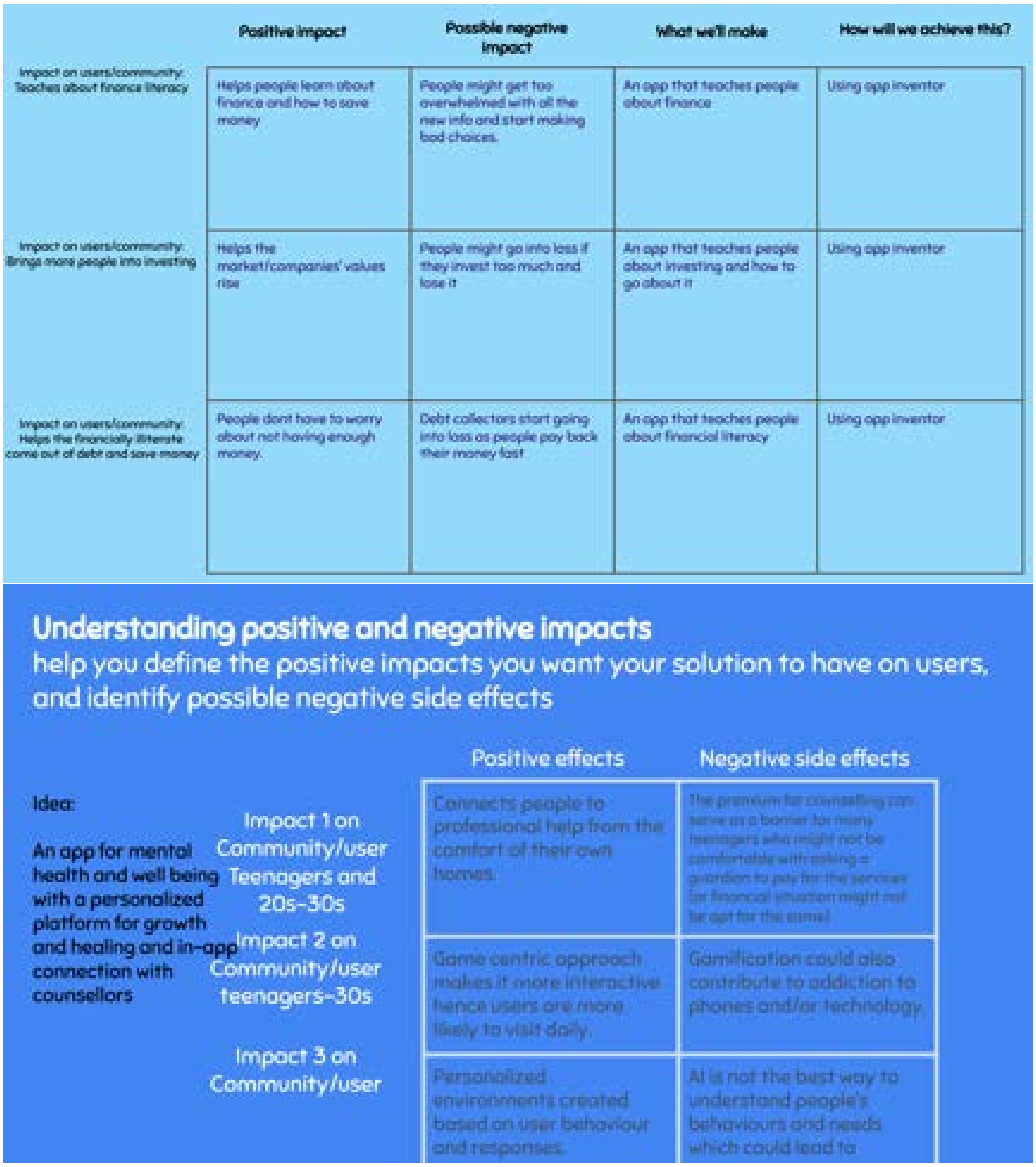


Figure 5-10: Students exceled at listing the positives and negatives, although some tended to tie their solutions mostly to the positive impact.

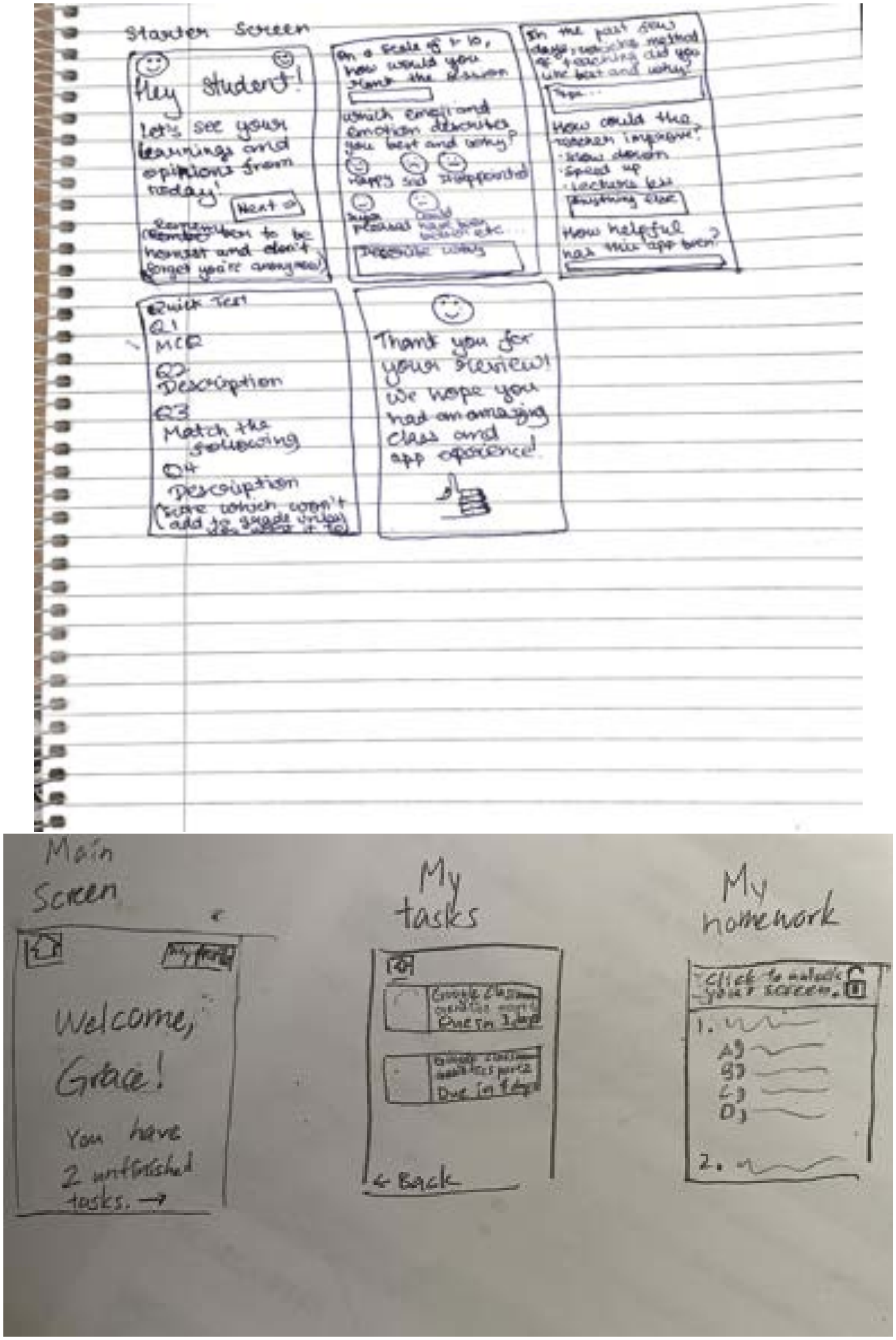


Figure 5-11: Students tended to enjoy sketching their app designs during the workshops.

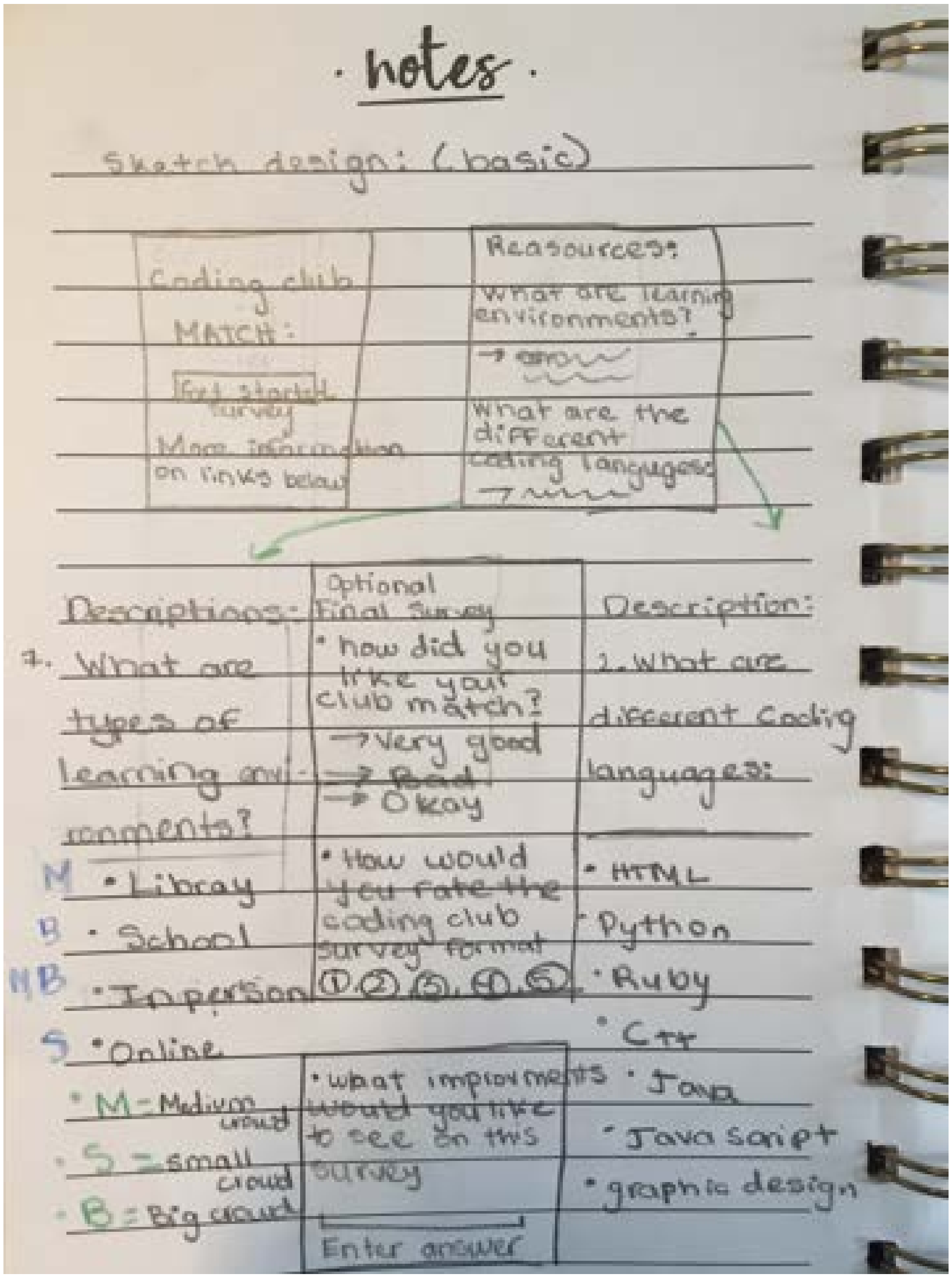


Figure 5-12: Some students were able to go into quite a lot of detail in their app sketches.

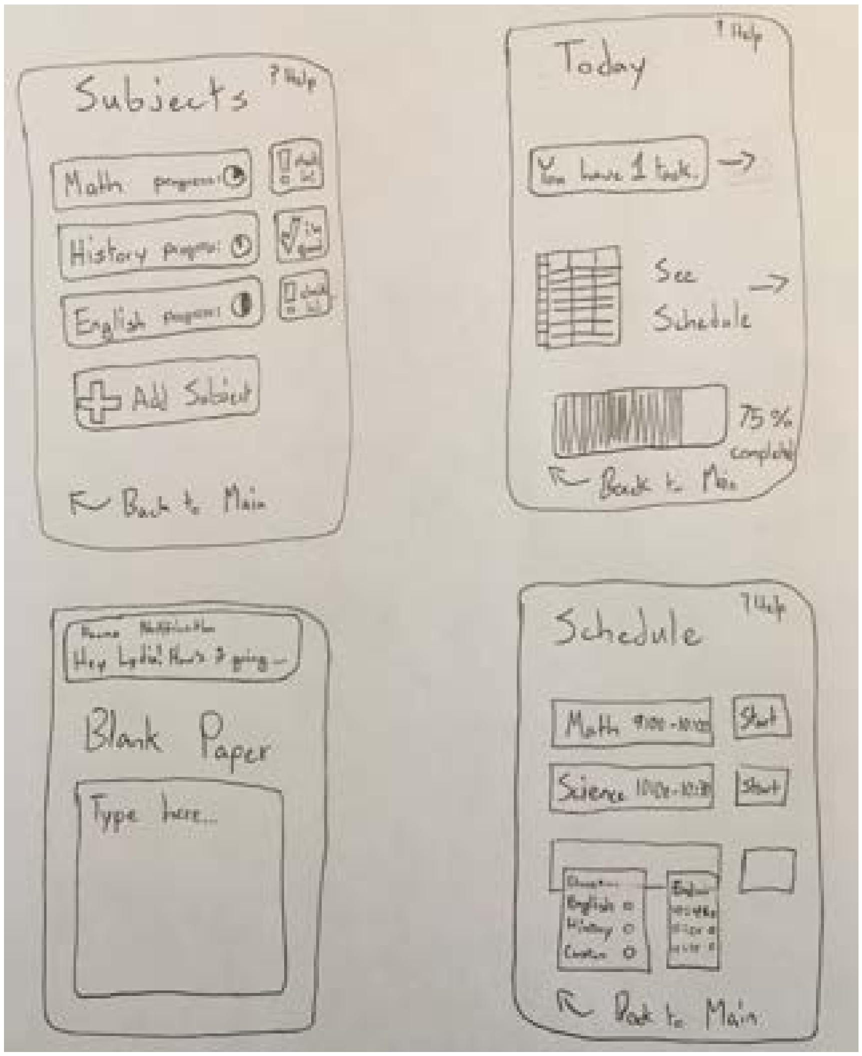


Figure 5-13: Students did well in sketching the main screens of their projects.

Figure 5-14: Prompt for students to think of their project idea.

the post-workshop project idea activity, and 10 students submitted a post-workshop app created using App Inventor. For the project idea, students were asked to fill out a slide with project ideas. The instructions were kept simple in order to measure how students might respond differently pre- and post-workshop to the same high-level prompt. The pre-workshop activity guide provided to participants gave them the prompt is shown in Fig. 5-14. The full coding activity instructions can be viewed in Appendix **??**.

Cohort One

The influence of cohort 1 students' familiarity with aspects of product, design, and engineering processes was most evident in their pre-workshop project ideas. The ideas from students from cohort 1 were more frequently populated with background motivation and sometimes data that appear derived from previous research. Some students used the words "target audience", which is a specific term that is taught in the Technovation Challenge curriculum. In addition, many of the pre-workshop project ideas from cohort 1 listed highly specific app details. There is also a notable

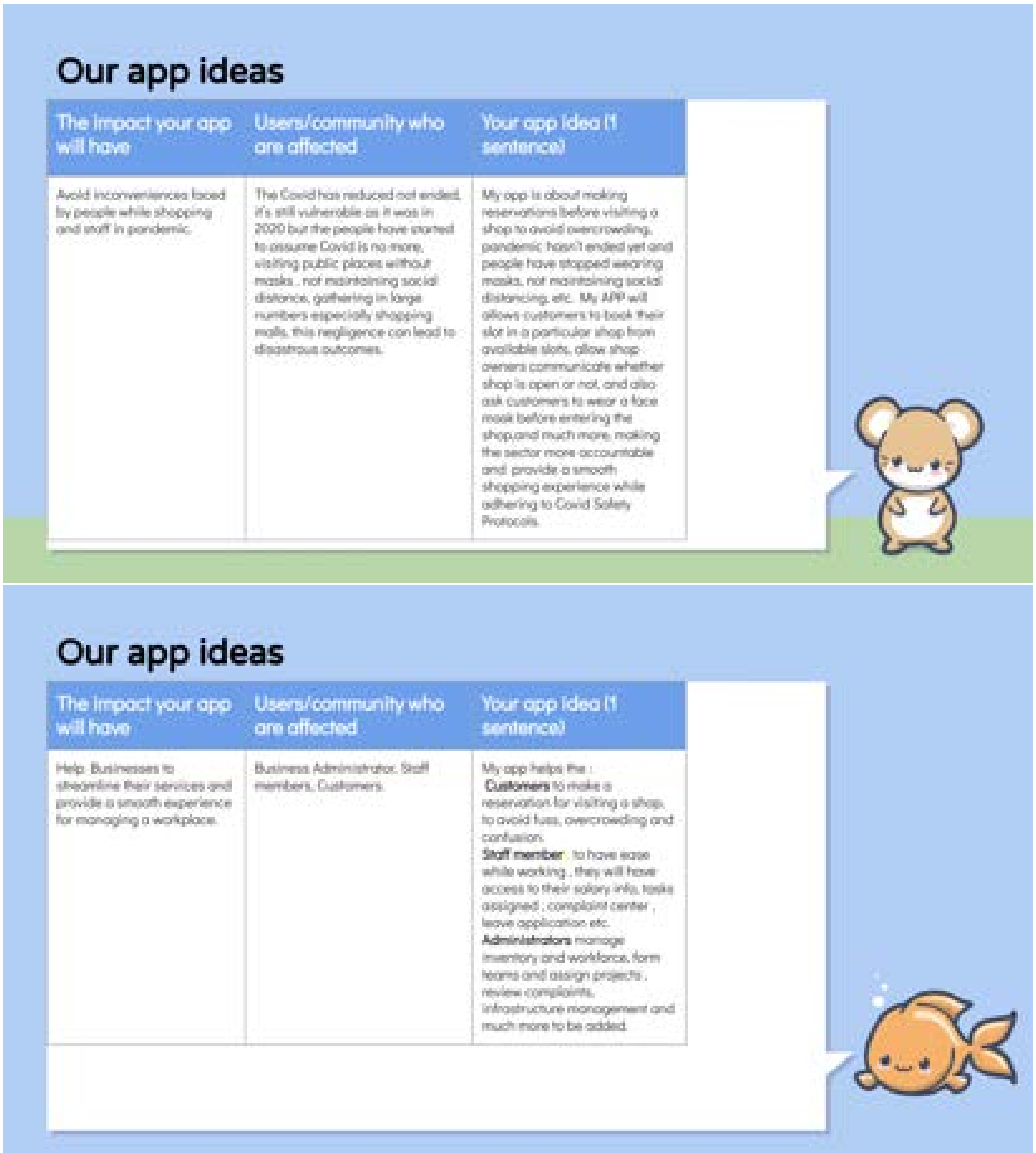


Figure 5-15: Cohort 1: a student's pre-workshop idea (top) and post-workshop idea (bottom). This student's post-workshop idea shows improved consideration of different user groups in their project proposal.

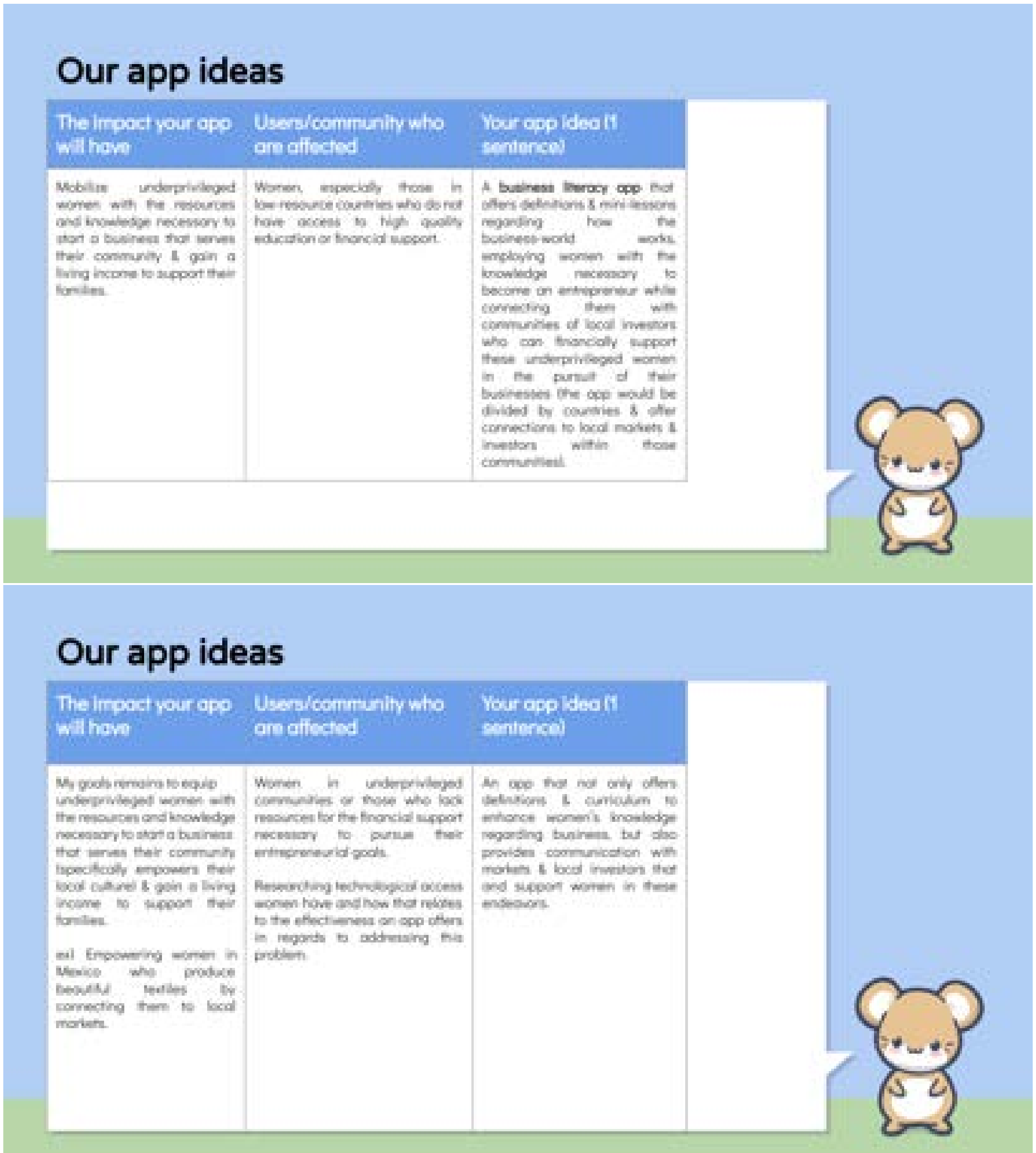


Figure 5-16: Cohort 1: another student's pre-workshop idea (top) and post-workshop idea (bottom). The post-workshop idea shows deeper investigation of impact and users affected.

formal and "business pitch-like" tone to some descriptions, further suggesting that participants used Technovation materials to inform how they filled this out. One also student even asked this question about this activity: "Is it ok if I write about the app I'm coding for Technovation?", a clear indication that they were reusing the project for the workshop.

Since I wanted to compare the value-add of computational action to an established program like Technovation, students were allowed to use any existing projects. Paired results of pre-post app ideas support the hypothesis of the added value of computational action. Some students had a better understanding of distinct user and community groups, as seen in Fig. 5-15. Another student re-framed their project more from the perspective of making responsible impact, as seen in Fig. 5-16.

From the examination of pre-post app ideas, it can be seen that the caliber of the work from students from cohort 1 was already quite high to begin with. Students from cohort 1 indicated in post-survey responses that they felt the computational action workshop was useful for giving them concrete steps to create an impactful project and frameworks for researching users and understanding negative harms. These are illustrative of the value-add that students felt about computational action, even if they were already familiar with engineering design concepts.

Cohort Two

The pre-workshop project ideas submitted by students from cohort 2 are markedly different from those of cohort 1. Unlike cohort 1, most ideas submitted by cohort 2 were not backed by background research or data, which is expected since students have not yet learned the computational action process.

Similarly, none of the pre-workshop project ideas from cohort 2 students had a formal or "business pitch-like" tone, nor used specific technical jargon like "target audience" when describing users and communities. Again, this makes sense and is aligned with expectations. The pre-workshop ideas from cohort 2 included ones that were fun and delightful, however many pre-workshop project ideas were not tied to impact or an understanding of users and communities.

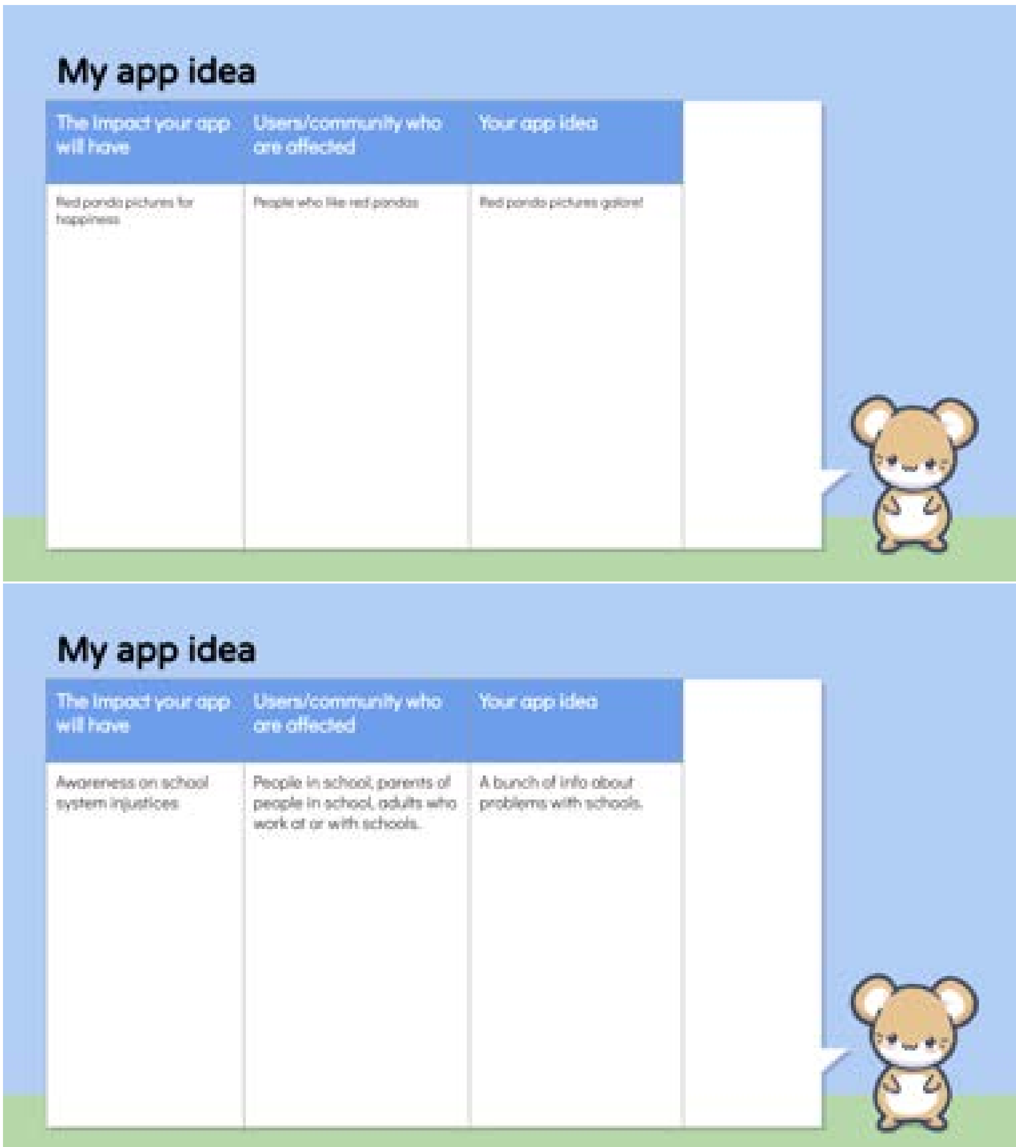


Figure 5-17: Cohort 2: this student's post-workshop idea (bottom) has impact and user/community understanding, compared to their pre-workshop idea (top). The pre-workshop idea is mostly just for fun, but post-workshop idea is tied to impact and communities affected.

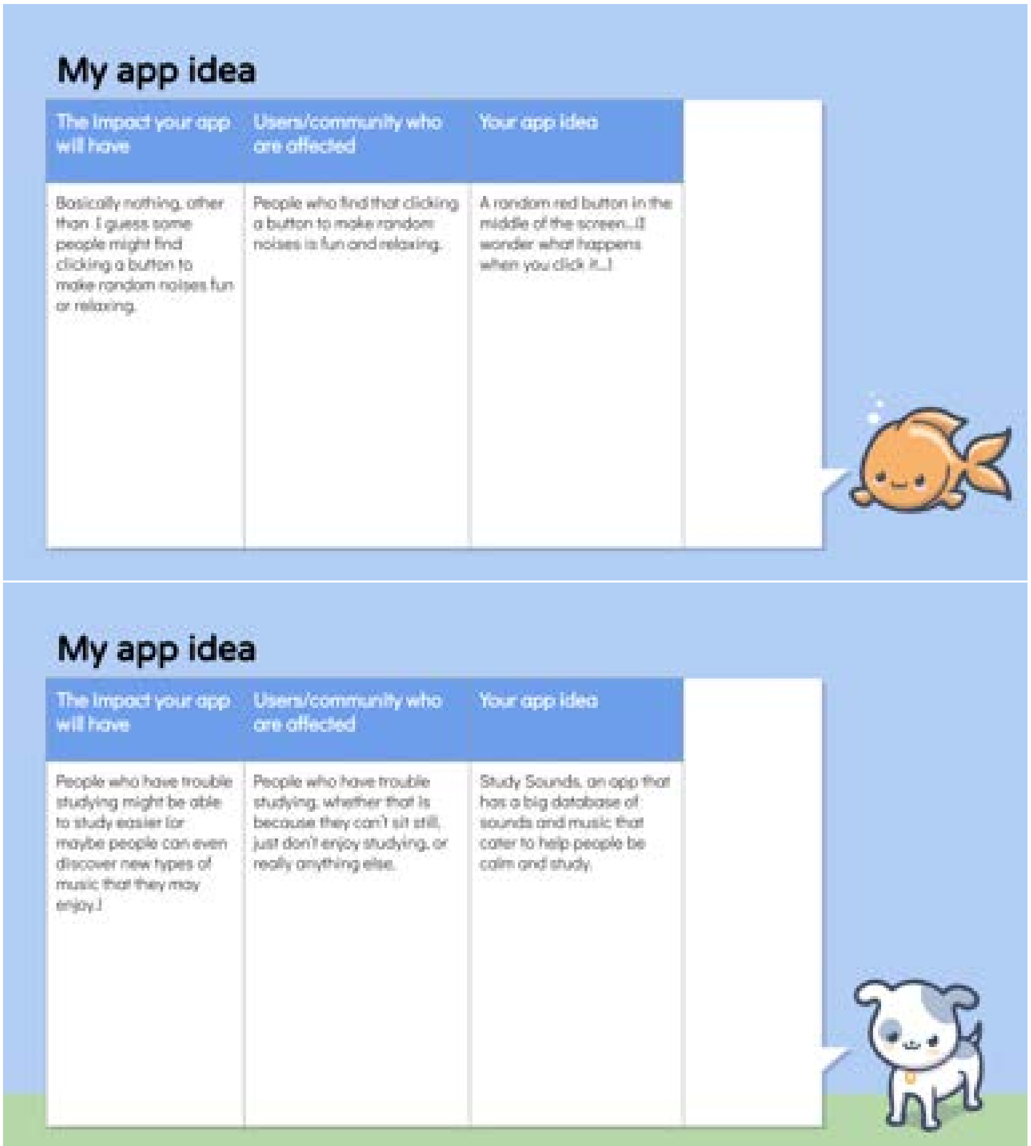


Figure 5-18: Cohort 2: this student's post-workshop idea (bottom) shows improved understanding of impact and users affected, compared to their pre-workshop idea (top).

Figure 5-19: Some more pre-workshop ideas from cohort 2 students. Most pre-workshop ideas were less fleshed out than the students' post-workshop ideas.

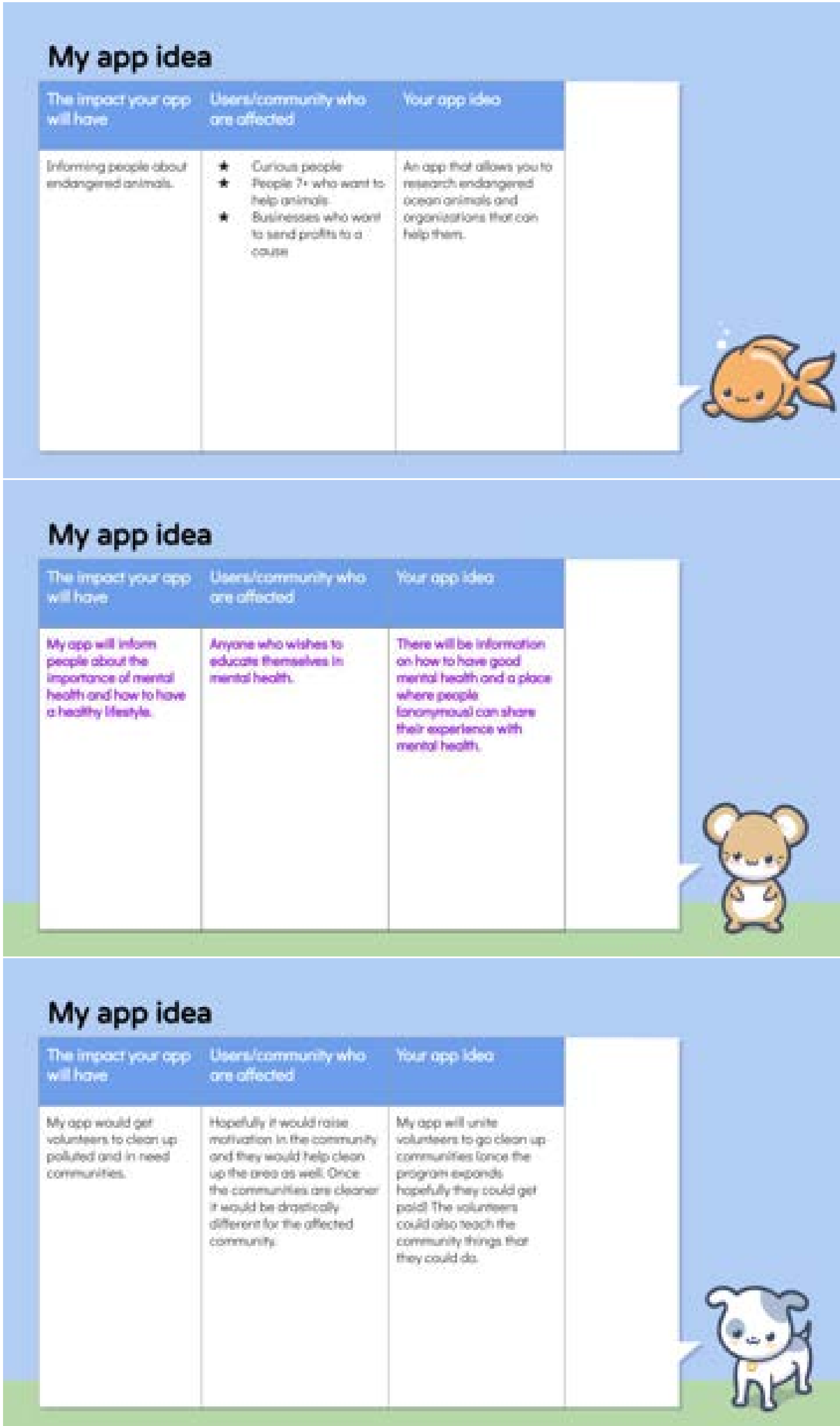


Figure 5-20: Some post-workshop ideas from cohort 2 students. More of the post-workshop ideas are tied to meaningful impact and making a difference in communities.

In contrast, some students' post-workshop ideas changed to quite deep and meaningful subjects. Figure 5-17 shows one student's change: their post-workshop idea (bringing awareness to injustices in a school system) describes a meaningful impact and includes distinct user groups impacted by this issue. Their pre-workshop idea is fun and playful, but not rooted in any real problem or thinking about people affected. Other students from cohort 2 built upon their pre-workshop ideas to flesh out a meaningful post-workshop project idea. In Figure 5-18, one student continued working on the same idea pre- and post-workshop, but noticeably, their post-workshop idea now pinpoints a real-world impact (helping students study better and focus) rather than only describing an cool app idea. This is a great example of students practicing computational action in action: they shift from "just coding" toward identifying real problems in the world that their solutions can affect.

5.2.5 Student-coded Projects

Of the 101 participants from both cohorts, 20 students compelted pre-workshop apps coded in App Inventor, and 9 completed post-workshop apps. 5 students in cohort 1 submitted a pre-workshop app created in App Inventor, and 0 submitted a post-workshop app. 15 students in cohort 2 submitted a pre-workshop app, and 9 students submitted a post-workshop app. The quality and completelness of pre-workshop and post-workshop apps varied from student to student. This was influenced by a student's pre-existing familiarity with coding and block-based programming, as well as the time they had to do each coding activity. However, despite these variables, there are still themes that can be seen in changes between pre-post apps. Pre-workshop apps tended to have less coding, almost always only one screen with some design, and much less developed meaningful impact. The post-workshop apps generally had more coding, more screens, and more functionality. Post-workshop apps also generally demonstrated more ties to real issues. Based on pre-post comparisons of students' coded projects, it seems likely that students used computational action tools (like the impact matrix) to improve their post-workshop app. It also seems very likely that the coding time and help from facilitators during the workshops helped students add more code to their post-workshop apps. Paired pre-post app comparisons show that students not only added functionality, but demonstrated improved grounding in a real-world issue. One student's pre-workshop app, which can be seen in Figure 5-22 consisted of one screen of red pandas pictures and no code. The student seemed to take a lot away from the workshop because their post-workshop app changed a lot: it became tied to deep impact and addressing what people need. Often, a student's pre-app only had one screen, with either little or no code. The post-app tended to have more screens, more design added, and more code (even if code was not fully complete). Some students only submitted a pre-workshop app and were not able to complete a post-workshop app. These pre-study apps usually had more focus on the design aspect and limited coding.

Some students used the App Inventor platform to design their final projects. The post-workshop app in Fig. 5-26 shows sparse coding, but quite detailed frontend design. Another student's pre-study app (Fig. 5-27 was an attempt at displaying an image with a button to clear it, but had no code, and was not functional. The student's post-study app boasted two screens (middle and left) and was more tied to a real problem (marine life conservation). Perhaps due to student's coding level and natural leaning toward design, the post-app also had no code, but did demonstrate getting closer to a functional app.

Overall, students' post-workshop apps tend to be more grounded in real-world problems, which was great to see. In addition, post-workshop apps tend to have more coded functionality, which is likely a testament to the help of the facilitators in breakout room sessions during the workshops.

5.3 Usage of Computational Action Website

The computational action site was available to all students after the workshops. During the research period, the most frequent visits were to the curriculum materials, student projects, and following that, specific student project pages. A breakdown of most visited pages is shown in Fig. 5-28. The average duration of each session

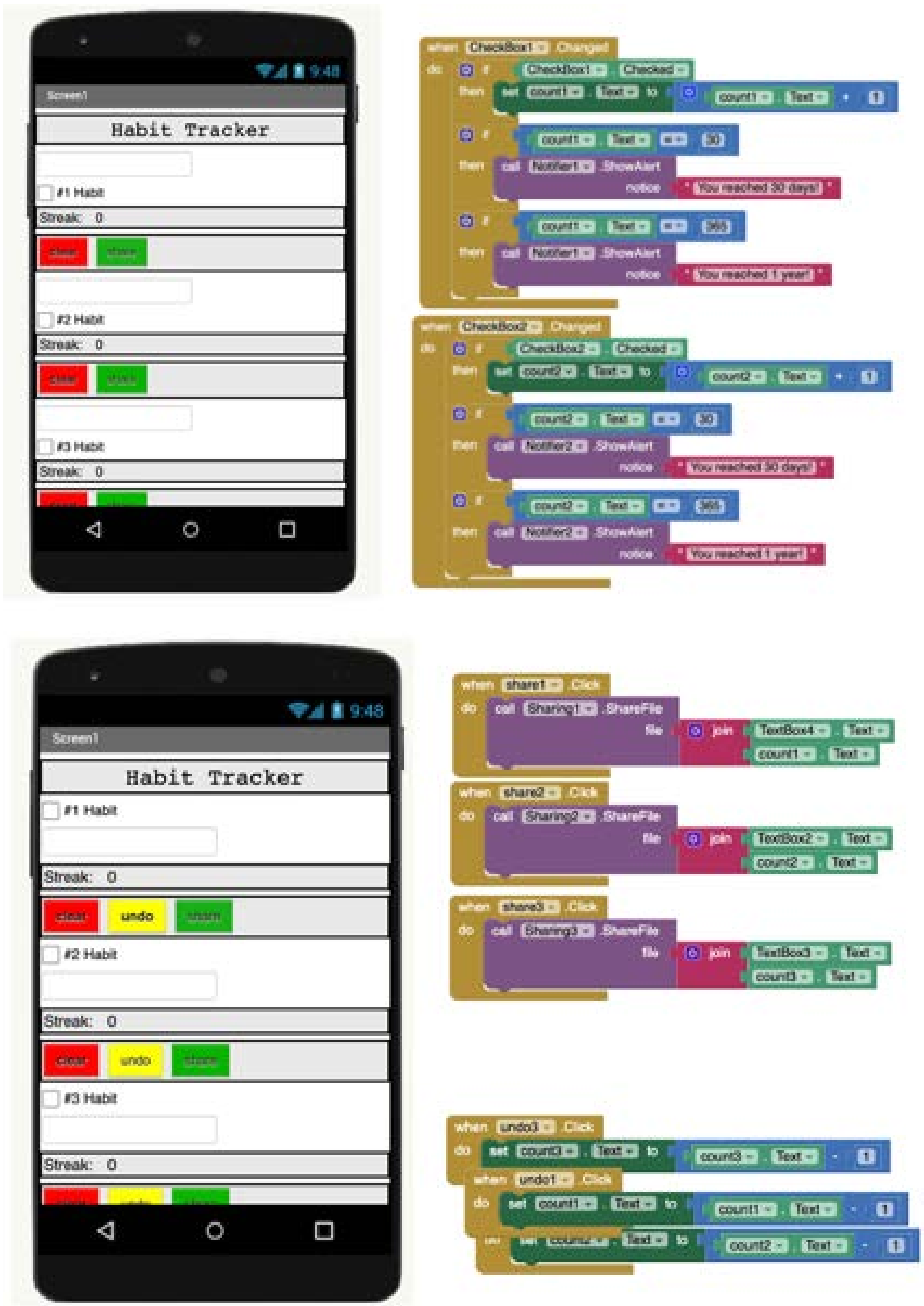


Figure 5-21: This student's pre-workshop app (top) had functioning code blocks and design. Their post-workshop app (bottom) added more functionality - both in design and in code.

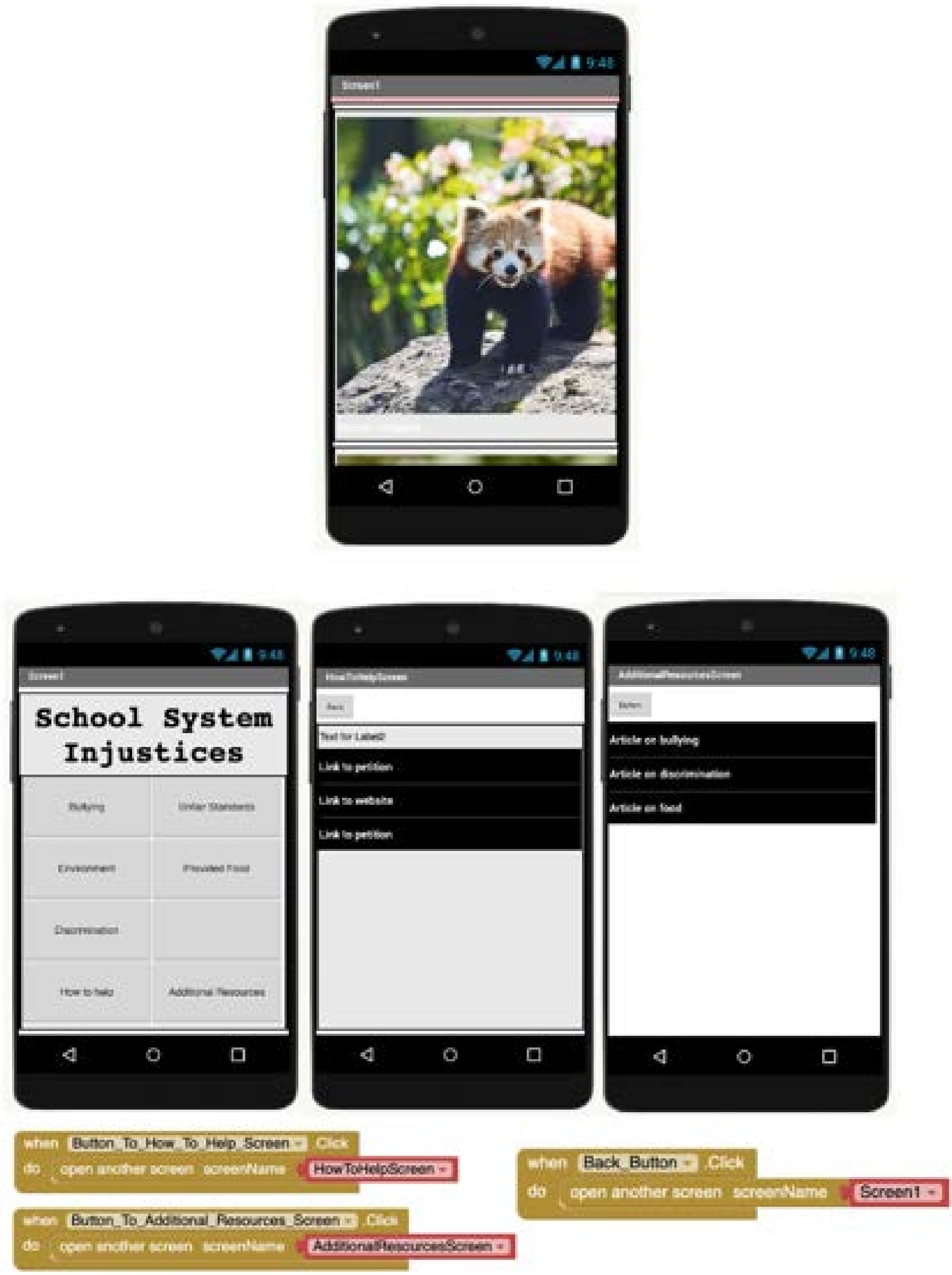


Figure 5-22: This student's pre-workshop app (top) was a collection of photos, with no code. This student's post-workshop app (bottom) had multiple screens and some code, and addresses a different issue.

Figure 5-23: This student's pre-workshop app focused on the frontend design.

Figure 5-24: This student's pre-workshop app had functioning code blocks and design, but not necessarily making an impact on their community.

Figure 5-25: This student's pre-workshop app (top) had one screen and no code. They added multiple screens (7) to their post-workshop app (bottom) and added code.

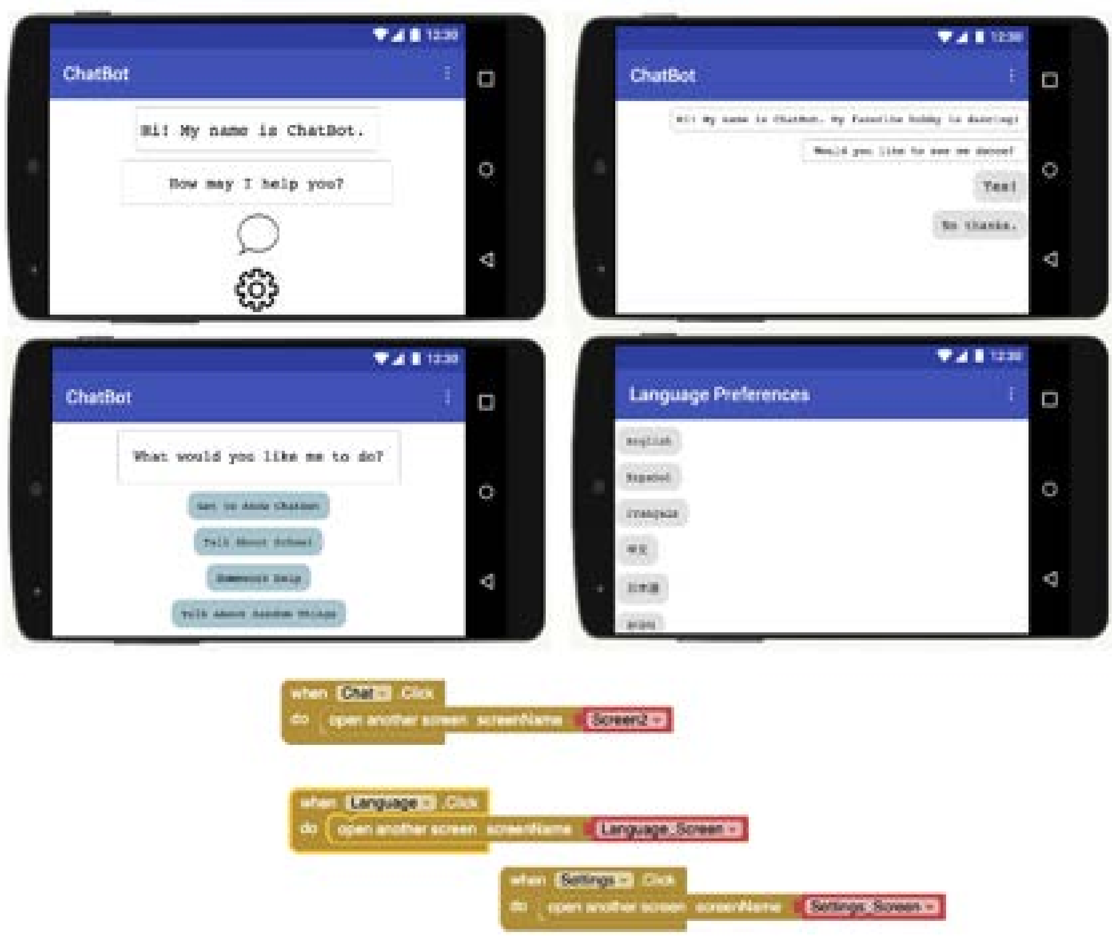


Figure 5-26: This student focused on using App Inventor for designing their app. Their designs for the app's main screens go into detail.

Figure 5-27: This student's pre-workshop app (left) was not working and did not have code. Their post-workshop app (right) features frontend design.

was 4 minutes. Most of the sessions during the research period were from users in the United States (74 sessions), followed by India (5 sessions), and then unique users form Indonesia, Georgia, Philippines, France, Hong Kong, China, and the United Kingdom.

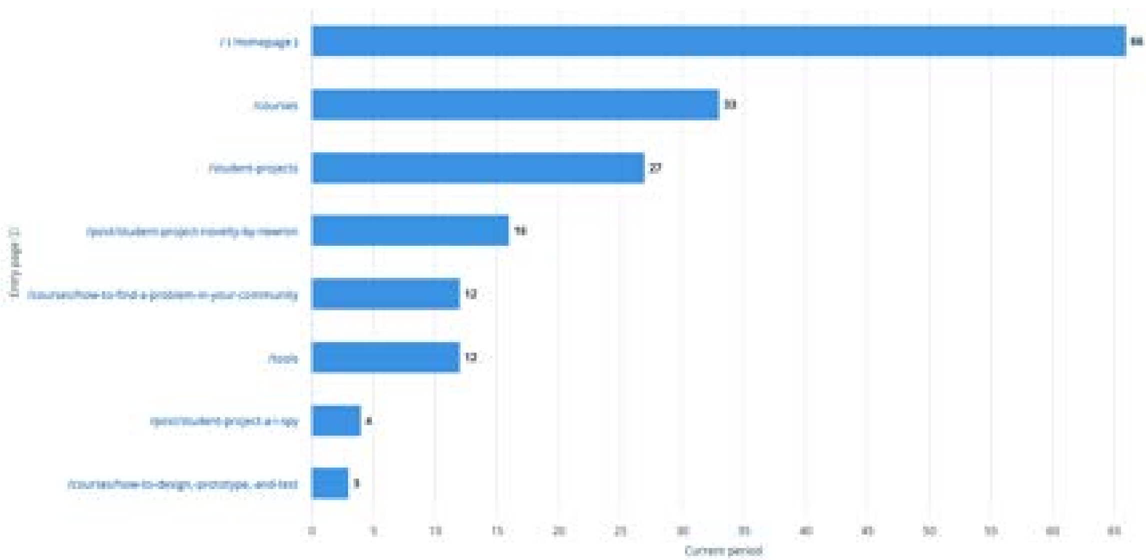


Figure 5-28: Most visited website pages during a 2-month period between Feb 26, 2022 and Apr 26, 2022. Students navigated most to the curriculum pages ("courses"), student project examples ("student-projects", "project-novelty-by-newton", "project-a-i-spy") as well as the toolkit page ("tools").

Chapter 6

Conclusion

6.1 Discussion

In the previous chapters, I discussed the results of quantitative data and analyzed student work from the research workshops. Some of the findings are worth summarizing and highlighting. The computational action process and research study presented in this thesis were created for the purpose of enabling computational action for A.I. literacy and programming education for young people. Since the launch of the first version of the computational action process during the first pilot, student responses to the workshops have been positive. Students in the first pilot wanted to learn the material more quickly to inform the projects they were creating, and after the workshops, they wanted access to more for future projects. These students created impressive projects addressing real issues, from online wildfire prediction to apps for improving mental health, entirely on their own. They didn't just learn app programming and machine learning, but also made projects that addressed problems in the world. The students' projects embodied computational action in action, and their work and feedback were valuable for shaping further improvements to the computational action curriculum, tools, and website.

Students in the final research study were asked to complete pre- and post-workshop activities and surveys so that the effectiveness of the process could be measured. The quantitative pre-post paired results show that students, who were mainly of middle school and high school ages both domestic and international, showed an increase in computational identity, computation skill, digital empowerment, and self-efficacy. In other words, they felt more confident in their programming skill; more able to identify a problem, understand user and community needs, and design socially responsible solutions; more empowered to make something to address a real problem; and more confident in their ability to do this on their own, rather than being told what to do. Students who had previous coding and engineering design experience also showed this increase.

From students' qualitative feedback, these increases in identity, knowledge, empowerment, and self-efficacy were also evident. In written feedback, the majority of students felt that they gained a lot of skills to tangibly make an impact and that they will continue to use computational action for future coding projects. Students felt that learning the process helped them see that making an impact is achievable, and now they know the steps to go about it. Some students qualified this impression of ease by also commenting on the "harder" work that they now realize should go into a coding project: namely, that they will now consider potential negative side effects, interview users, and collect data to inform their project ideas. This is good support for the effectiveness of the computational action process.

Not all of the topics in the computational action process were wholly novel to all participants, which is why it is interesting that students who have had previous engineering design experience also had positive feedback for the curriculum and toolkit. These students gave feedback that the templates were useful and having one place (the website) to reference slides, tools, and examples was also helpful. Some student feedback also pointed to the impact matrix as particularly helpful to think about not just positive but also potential negative impacts of technology, something that they had not learned before.

Digging further into both quantitative and qualitative results shows that students are highly capable of creating, on their own, impressive work that embodies computational action. They can define real-world issues, hone in on a problem that affects their community and is also motivating for themselves, create user research questions and gather data, use this data to discuss meaningful positive and negative impacts of technology, and design and implement functional applications that address these issues. Given that the workshops of the final study covered computational action in only three to four hours, it is all the more impressive that students created such meaningful work in this short amount of time. This is a promising sign for future work of incorporating the computational action process into longer workshops or programs where students have more time to fully plan and implement projects.

6.2 Future Work

The research and results described in this thesis is a promising start for computational action. As seen in the results from the study, students found the curriculum and toolkit helpful to guide them to creating projects that have meaning and solve problems. A goal for future work is to integrate the material and tools more with coding tools, like creating extensions and tutorials inside the App Inventor platform. When computational action is tied more seamlessly into coding or A.I. tutorials, students can benefit from learning about technology and computational action together. The computational action toolkit can be modified to be interactive App Inventor tutorials so students have the option to practice the tools in situ rather than in Google Docs or Slides.

Another goal is to add more reflection and adaptive feedback throughout the computational action process. Reflection has been demonstrated as a powerful tool for student learning, and each section of computational action can be further improved by adding more space for reflection. It is possible that after reflection, a student may change how they approach the next topic of the computational action process. The reflection portion of computational action can include questions on computational identity, digital empowerment, and self-efficacy to further understand the efficacy of the process.

Students come into any technology program with a gamut of different backgrounds and experiences with programming, from little or no experience to quite advanced backgrounds. This was also true of the computational action workshops. Feedback from students on the workshops was generally very positive, but it is clear that in the future, the process can benefit from technical sections that fork for beginner, intermediate, and advanced programming experience. Students of different grade bands can also benefit from curriculum and tools that are better targeted for their education levels. The current computational action curriculum has an emphasis on being playful and colorful, and introduces programming in App Inventor to assume little or no experience with coding. The third and fourth topics in particular would make sense to be more fine-tuned depending on age and coding experience. A set of beginner/elementary school, intermediate/middle school, and advanced/high school compilation of computational action curriculum and tools can also more accurately meet NGSS and CCSS standards, and likely be more effective for different student segments.

Another good area for future work is investigating potentially different needs from U.S. and international young people. The current material is English-based and informed by standards that are most directly applicable to North American K-12 science education, as well as an engineering design process rooted in Western industry. Many of the monthly users of App Inventors are from outside of the U.S., and many of the participants in the research study were also located outside of the U.S. There is a large interest from students outside of North America in both computational action as well as learning programming. It is worth investigating whether computational action topics should be modified depending on the needs of international students to be more beneficial to a global perspective.

Finally, I will contribute more videos teaching each topic of computational action to be added to the computational action website for future programs under the MIT RAISE initiative. Further work on the computational action website will be to include it as an evergreen resource publicly available for all to use, and also integrating it with some of the related programs mentioned in this thesis. It is my hope that the process and tools presented in this thesis will be helpful for all young people interested in using technology to help others. By putting computational action in action, students have already created meaningful applications in communities around the globe while they themselves are only beginning to learn about programming, machine learning, and other technologies. Even as technology changes, the goal of computational action remains relevant, and I hope the process will continue to guide young people around the world step-by-step toward their dreams of making a difference.

Appendix A

Links for Computational Action Process Materials

A.1 Curriculum

1. Topic One: https://docs.google.com/presentation/d/1AiD-r81_abJkJG_mLidS2yribn5ZRH8InP4jOS5-tMc

2. Topic Two: https://docs.google.com/presentation/d/1WU8ACLdrlKZ_NAmcGPlAyXjcWv_UoUAgMqI3Y-Lt18I

3. Topic Three (two parts): https://docs.google.com/presentation/d/1M83unILtzNpwo7bI2XG9GqZ5HIOkIE1AVfJ6KTWShbI, https://docs.google.com/presentation/d/1xDcN4Ag4CLUCxLZLbVlQ01OOD6Bq69JFj6cDVJhtWTk

4. Topic Four: https://docs.google.com/presentation/d/1xqbG04IoYpy-BAi5mJRIH7OZ0D0dhQM70Fa2XOWCilE

5. Topic Five: https://docs.google.com/presentation/d/1rEWWwbxWsU5q1Yaz1WglDkS_4UGelEP1bft-TdIFnfM

A.2 Toolkit

Entire toolkit:

`https://drive.google.com/drive/folders/1aXN1QMVaN72QwUCJOosbzYHnuXRCOG bf`

A.3 Website

Website: `https://www.computationalaction.org`

Appendix B

Computational Action Videos

The following videos were recorded for the first pilot study of the computational action process.

1. Video Playlist: `https://www.youtube.com/watch?v=mKrtp-bUnjw&list=PLwe8i-OmmPusGF4MTZq0i-rooiRM98nUb`
2. Computational Action 101: `https://www.youtube.com/watch?v=RRk-UTh-rsg`
3. Topic One: `https://www.youtube.com/watch?v=wyQoIu-9jg8`
4. Topic Two: `https://www.youtube.com/watch?v=Hj_g2tzdqgw`
5. Topic Three: `https://www.youtube.com/watch?v=mKrtp-bUnjw`
6. Topic Four: `https://www.youtube.com/watch?v=vyATvCMjrIQ`

Appendix C

Pre-Post Paired Results

Survey question	comparison	significance	test	p	test_statistic	mean_pre	mean_post
q1	pre/post	1	wilx	0.02376793	68	3.19230769	3.48076923
q2	pre/post		wilx	0.3657123	12	4.71153846	4.76923077
q3	pre/post		wilx	0.40538056	20	4.71153846	4.76923077
q4	pre/post		wilx	0.08326452	9	4.51923077	4.63461538
q5	pre/post		wilx	0.07091546	54	3.5	3.67307692
q6	pre/post		ttest	0.10193485	-1.6655505	3.15384615	3.40384615
q7	pre/post	1	wilx	0.00477562	104	2.40384615	2.80769231
q8	pre/post	1	ttest	4.7113E-05	-4.4481285	3.65384615	4.13461538
q9	pre/post	1	ttest	3.2384E-05	-4.5595843	3.48076923	4.09615385
q10	pre/post	1	wilx	1.0901E-05	31.5	3.15384615	3.90384615
q11	pre/post		wilx	0.44867213	86.5	4.19230769	4.26923077
q12	pre/post	1	ttest	1.9776E-06	-5.3663484	3.19230769	4
q13	pre/post		ttest			3.51923077	3.90196078
q14	pre/post		ttest	0.19648723	-1.3087463	4	4.13461538
q15	pre/post		ttest	0.75519915	-0.3134739	3.01923077	3.05769231

Figure C-1: All pre-post paired results from all cohorts. Significant results (increases pre-post) can be seen for computational identity (Q1), computational skill (Q7), knowledge/skills and self-efficacy (Q8, Q9, Q10), and digital empowerment (Q12).

Survey question	comparison	significance	test	p	test_statistic	mean_pre	mean_post
q1	pre/post	1	ttest	0.001079	-3.7607	3	3.521739
q2	pre/post		wilx	0.317311	0	4.956522	4.913043
q3	pre/post		wilx	0.317311	0	4.956522	4.913043
q4	pre/post		wilx	0.654721	6	4.73913	4.782609
q5	pre/post	1	ttest	0.049731	-2.07654	3.565217	3.869565
q6	pre/post		ttest	0.802701	-0.25289	3.217391	3.26087
q7	pre/post	1	wilx	0.035637	17	2.217391	2.695652
q8	pre/post	1	wilx	0.000275	0	3.652174	4.304348
q9	pre/post	1	wilx	0.008618	12.5	3.652174	4.26087
q10	pre/post	1	ttest	0.004282	-3.18488	3.043478	3.695652
q11	pre/post		ttest	0.539042	-0.624	4.478261	4.565217
q12	pre/post	1	wilx	0.00258	12	3.434783	4.217391
q13	pre/post		ttest			3.565217	3.954545
q14	pre/post		ttest	0.069477	-1.90837	3.956522	4.26087
q15	pre/post		ttest	0.604116	0.526051	3.565217	3.478261

Figure C-2: All pre-post paired results from cohort 1. These results were analyzed and presented in the Results chapter. This is the raw findings from paired analysis.

Survey question	comparison	significance	test	p	test_statistic	mean_pre	mean_post
q1	pre/post		ttest	0.57282371	-0.5705974	3.34482759	3.44827586
q2	pre/post		wilx	0.20590321	7	4.51724138	4.65517241
q3	pre/post		wilx	0.24821308	13.5	4.51724138	4.65517241
q4	pre/post		wilx	0.05878172	0	4.34482759	4.51724138
q5	pre/post		wilx	0.56370286	18	3.44827586	3.51724138
q6	pre/post		ttest	0.0830606	-1.7974341	3.10344828	3.51724138
q7	pre/post	1	ttest	0.04787618	-2.0691413	2.55172414	2.89655172
q8	pre/post	1	ttest	0.04787618	-2.0691413	3.65517241	4
q9	pre/post	1	wilx	0.00474772	34	3.34482759	3.96551724
q10	pre/post	1	ttest	0.00018929	-4.2957059	3.24137931	4.06896552
q11	pre/post		ttest	0.62555334	-0.4934352	3.96551724	4.03448276
q12	pre/post	1	wilx	0.00195074	12.5	3	3.82758621
q13	pre/post	1	wilx	0.01241933	13	3.48275862	3.86206897
q15	pre/post		ttest	0.44243787	-0.7791316	2.5862069	2.72413793

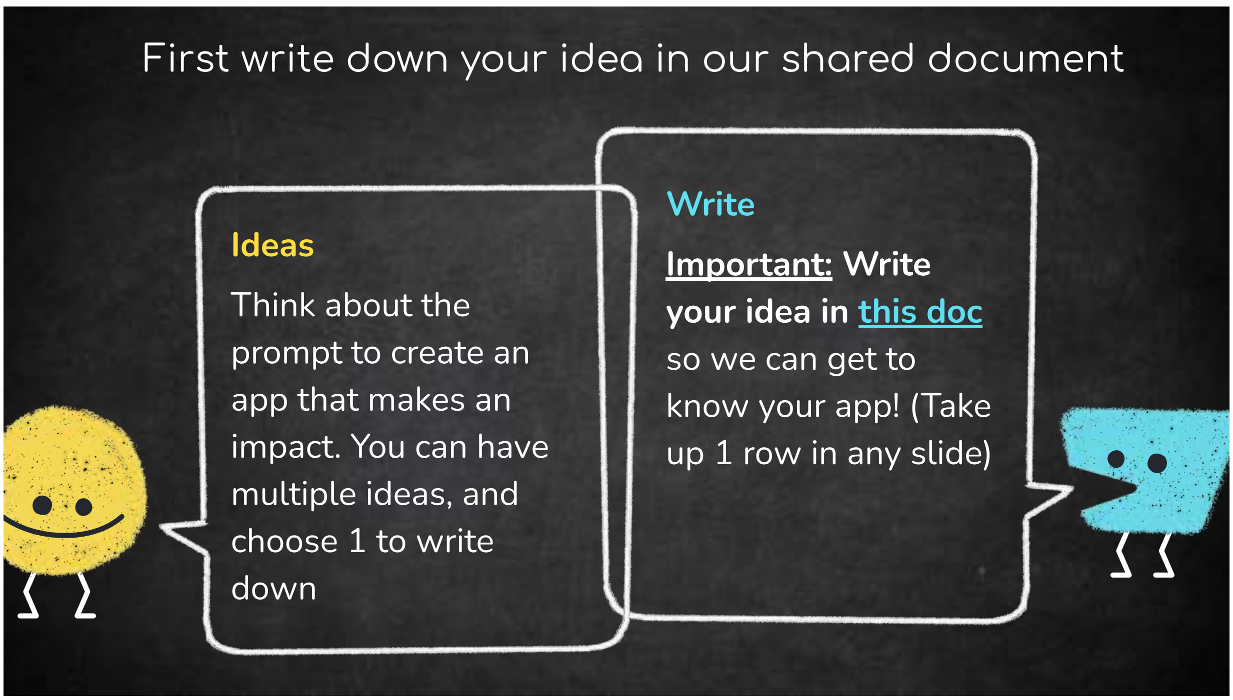
Figure C-3: All pre-post paired results from cohort 2. These results were analyzed and presented in the Results chapter. This is the raw findings from paired analysis.

Appendix D

Pre-workshop App Coding Activity

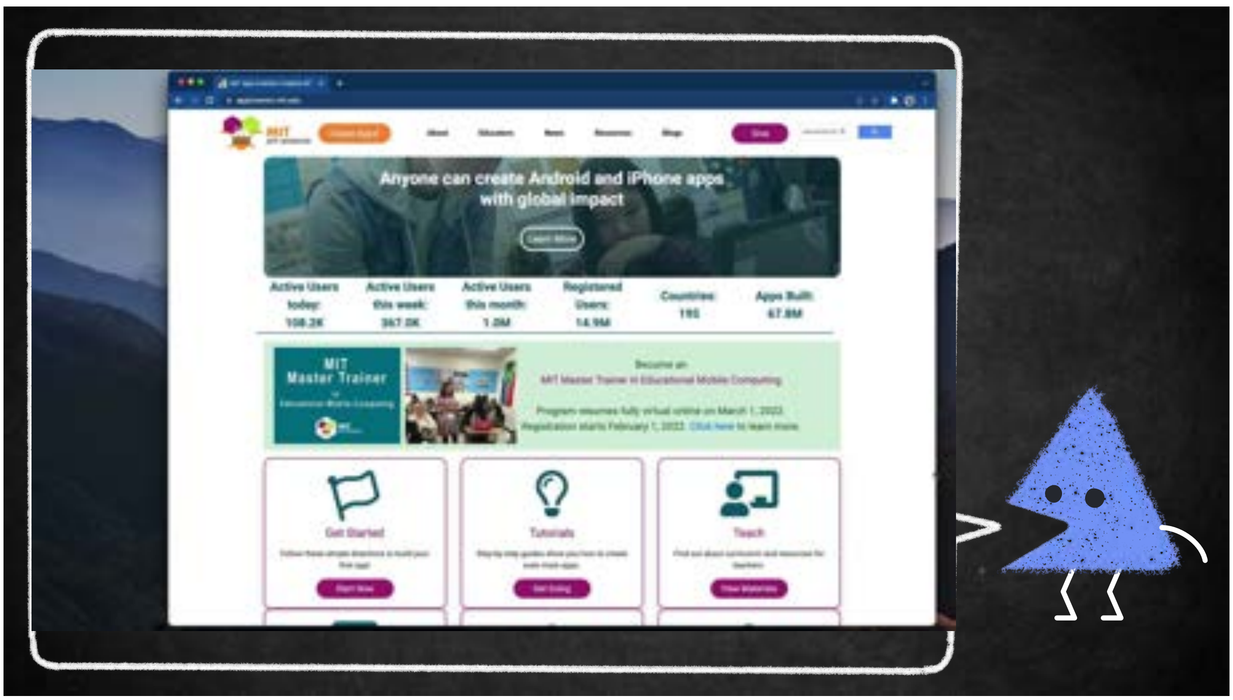

Let’s make an app!


Your prompt:
Create an app that makes an impact in your community
This can be anything that you're interested in, and can be something that affects your family, teachers, siblings, friends, or others in the world around you.



First write down your idea in our shared document
Ideas
Think about the prompt to create an app that makes an impact. You can have multiple ideas, and choose 1 to write down
Write
Important: Write your idea in this doc so we can get to know your app! (Take up 1 row in any slide)

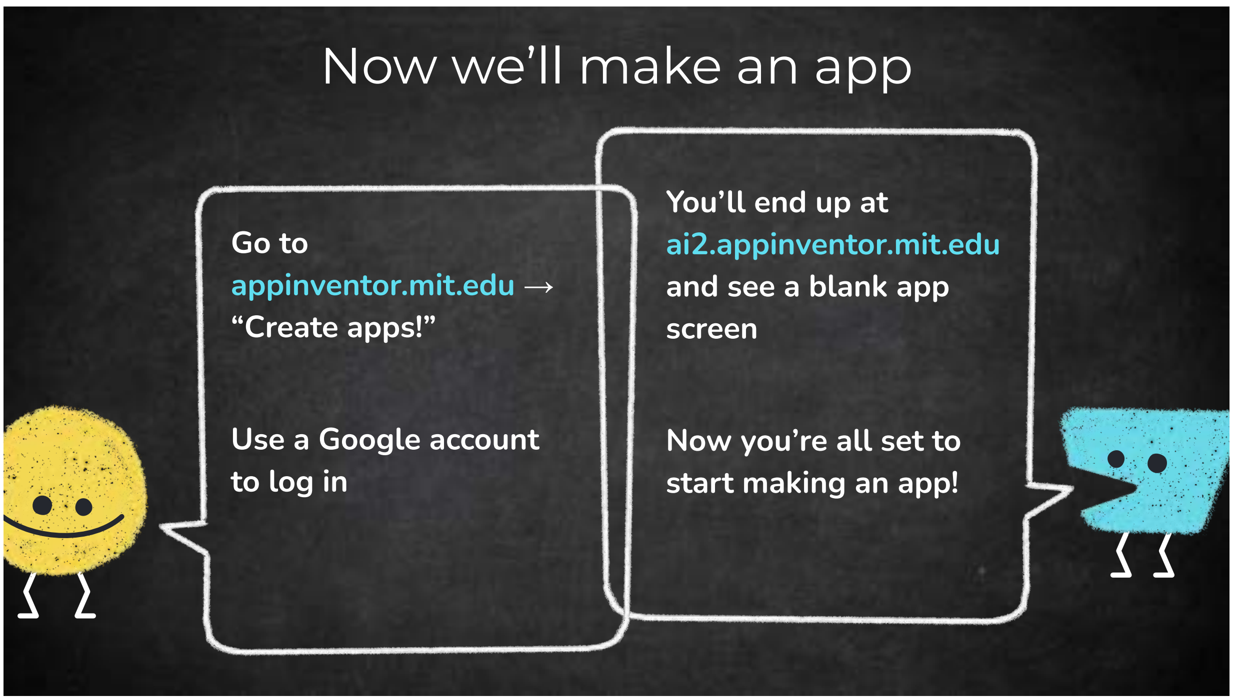

Quick App Inventor demo
We’ll start with a quick demo to show you how
you can make an app in less than 10 min



Anyone can create Android and iPhone apps with global impact
Active Users today:
Active Users this week:
Active Users this month:
Registered Users:
Countries:
Apps Built:
MIT Master Trainer
Get Started
Tutorials
Teach


MIT
Anyone can create Android and iPhone apps with global impact
Active Users today:
Active Users this week:
Active Users this month:
Registered Users:
Countries:
Apps Built:
MIT Master Trainer
Get Started
Tutorials
Teach

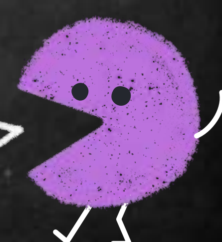

Now you try!

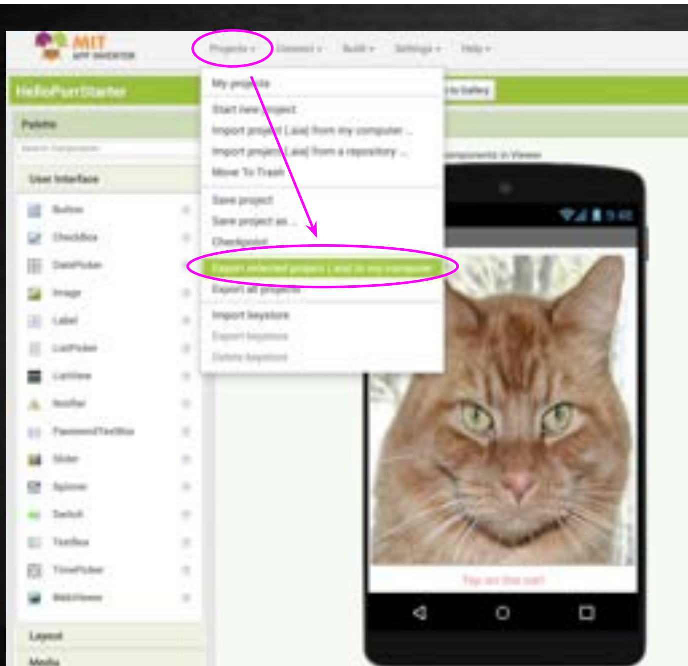

Now we'll make an app
Go to appinventor.mit.edu → "Create apps!"
Use a Google account to log in
You'll end up at ai2.appinventor.mit.edu and see a blank app screen
Now you're all set to start making an app!

How to connect a phone and see your app live!

One awesome part of creating apps in App Inventor is that you can see your changes immediately on an Android phone! There are a few ways to connect. The easiest is to download MIT App Inventor Companion on the Google Play Store if you have an Android phone. You can find easy instructions here:
http://appinventor.mit.edu/explore/ai2/setup-device-wifi

If you don't have an Android phone, not to worry! Follow these instructions to get set up based on the computer you have:
http://appinventor.mit.edu/explore/ai2/setup





Save and share

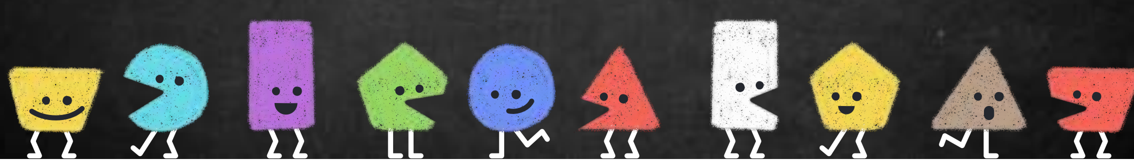
After you're happy with your app, save your project by going to: "Projects" → "Export selected project (.aia) to my computer"

Then upload your downloaded (.aia) file to this link

IMPORTANT: be sure to add your project to the link! (Even if you are not done with your app)

Great job!

Now we'll discuss making an impact with apps and artificial intelligence (A.I.)



Appendix E

Final Study Workshop Schedule

Computational action studies information and timeline

Materials
1. Curriculum slides
2. Worksheets/tools folder
3. Website

Saturday 3/12: 9am-12pm

TIME	**ACTIVITY**	**NOTES**
9-9:10am ET	Students fill out pre survey	Everyone fills out survey, will put link in Zoom chat. Students have received pre-survey in email ahead of time, but everyone is reminded to fill it out if they haven't already. If they already filled it/ while we wait, we'll do a fun intro in the Zoom chat (where they're located & make their animal persona name (fave color + fave animal)
9:10-9:25am ET	Pre App Inventor activity review (5min intro, 10min review or write app ideas)	If time permits (and enough students have finished ideas), we can also make breakout rooms for coding in App Inventor instead.
9:25-9:45am ET	Problem finding & brainstorm exercise (10min lesson, 10min activity time)	Students do this brainstorming activity in breakout rooms and take a photo and send via email (to computationalaction@gmail.com) Nicole will first go over the activity and lead it, then students are encouraged to share (2 or 3 volunteers). We will probably not break into groups, but *may if kids have a lot of questions.*

9:45-9:50 ET	Break	Note: Nicole or co-teacher turns pre-survey off so it stops receiving (to prep for no exit survey confusion)
9:50-10:20am ET	User research (10min lesson, 20min group question writing + practice asking each other questions in break out rooms) Students will be told to **draft 3 questions**. And try to get **3 questions answered** (by facilitators, or maybe by each other - for practice) Put their questions in the chat to receive an answer. Class example: Nicole asks question w/ Sharifa if no student volunteers.	**We will break out into rooms for this activity, led by each facilitator.** Students will each make a copy of this worksheet to write and ask questions. Facilitators will answer to the best of their ability trying to be the user impacted. Students are told that this is *just for practice* asking potential users questions. Students share their practice questions with computationalaction@gmail.com If time permits, students will go on to make a copy of the user persona worksheet and fill this out. Note: very important that students share their practice questions with computationalaction@gmail.com
10:20-10:25am ET	Break	
10:25-10:50am ET	Design (10min lesson, 15min impact matrix activity)	Students go to impact matrix worksheet (make a copy) and fill it out online. After they are done, they will click "Share" and share with this email: computationalaction@gmail.com We *may break out into rooms* if there are a lot of questions. (if so, facilitators should remind students to share with email)

10:50-10:55am ET	Break	
10:55-11:15am ET	5min wireframing lesson + 15min activity	Students are first given lesson on wireframes, then draw wireframe/sketch of their app idea on paper. We may do this together or break out into rooms if there are a lot of questions. We will reconvene to share. Students will take photo and send it to me via email (computationalaction@gmail.com)
11:15-11:50am ET	Post App Inventor activity Nicole demos App Inventor. Students will fill out app ideas + code their app in App Inventor (at least get started)	Facilitators will help students code in App Inventor Very important that students upload their .aia file to this Dropbox link (even if apps are not finished)
11:50-12pm ET	Students fill out post survey	**Very important students fill this out before leaving!**

End of session! Students are reminded that they can continue coding their final app idea in App Inventor in the next few days/over the next week and upload to the Dropbox link. Nicole will send a follow-up email with instructions and reminders.

Sunday 3/13: 1pm-4pm

TIME	**ACTIVITY**	**NOTES**
1-1:10pm ET	Students fill out pre survey	Everyone fills out survey, will put link in Zoom chat. Students have received pre-survey in email ahead of time, but everyone is reminded to fill it out if they haven't already. If they already filled it/ while we wait, we'll do a fun intro in the

		Zoom chat (where they're located & make their animal persona name (fave color + fave animal)
1:10-1:25pm ET	Pre App Inventor activity review (5min intro, 10min break out rooms/ or group share / write app ideas)	Students put ideas in this doc, (this should be done before Sat, but we will breakout into groups to do this if not enough students have). If time permits (and enough students have finished ideas), we can also make breakout rooms for coding in App Inventor instead.
1:25-1:45pm ET	Problem finding & brainstorm exercise (10min lesson, 10min activity time)	Students do this brainstorming activity in breakout rooms and take a photo and send via email (to computationalaction@gmail.com) Nicole will first go over the activity and lead it, then students are encouraged to share (2 or 3 volunteers)
1:45-1:50 ET	Break	
1:50-2:20pm ET	User research (10min lesson, 20min group question writing + practice asking each other questions in break out rooms)	Students get experience working on writing questions, and asking the facilitator in their breakout rooms sample questions. Facilitators will answer to the best of their ability trying to be the user impacted. Students are told that this is *just for practice* asking potential users questions. Students share their practice questions with computationalaction@gmail.com
2:20-2:25pm ET	Break	

2:25-2:50pm ET	Design (10min lesson, 15min impact matrix activity)	Students go to impact matrix worksheet (make a copy) and fill it out online. After they are done, they will click "Share" and share with this email: computationalaction@gmail.com This is done in breakout rooms so facilitators can help answer questions (and remind students to share with email)
2:50-2:55pm ET	Break	
2:55-3:15pm ET	5min wireframing lesson + 15min activity	Students are first given lesson on wireframes, then breakout into activity to draw wireframe/sketch of their app idea on paper. We will reconvene to share. Students will take photo and send it to me via email (computationalaction@gmail.com)
3:15-3:50pm ET	Post App Inventor activity Nicole demos App Inventor. Students will fill out app ideas + code their app in App Inventor (at least get started)	Facilitators will help students code in App Inventor Very important that students upload their .aia file to this Dropbox link (even if apps are not finished)
3:50-4pm ET	Students fill out post survey	**Very important students fill this out before leaving!**

End of session! Students are reminded that they can continue coding their final app idea in App Inventor in the next few days/over the next week and upload to the Dropbox link. Nicole will send a follow-up email with instructions and reminders.

Appendix F

Research Study Consent and Assent Forms

CONSENT TO PARTICIPATE IN NON-BIOMEDICAL RESEARCH
(For parents/guardians of children under 18)

Computational Action Education Workshops and Activities

Your child has been asked to participate in a research study conducted by Nicole Pang, Robert Parks, and Dr. Hal Abelson, Ph.D., from the Electrical Engineering and Computer Science department at the Massachusetts Institute of Technology (M.I.T.) The results of this study will contribute to Nicole Pang's Masters of Engineering thesis.

Your child was selected as a possible participant in this study because you expressed interest in learning about engineering product design and making an impact with technology products through MIT workshops and/or project-building program.

The information below provides a summary of the research. Your child's participation in this research is voluntary and you can withdraw at any time.

- **Purpose**
  The study will investigate changes in students' self-perception of computational identity and digital empowerment before and after computational action educational activities, and how best to teach computational action that incorporates technology like artificial intelligence (AI) or making an app.
- **Study Procedures**
  In this study, participants will engage in workshops over video call (e.g. Zoom or similar), which will be recorded, and which will include learning about computational action, learning about user research and implementation processes, learning about evaluating ethics in technology and AI, discussions, short group activities, filling out surveys, and working toward a final project.
- **Risks & Potential Discomfort**
  You will be using computers and may experience eyestrain and/or other strain related to computer use. If you experience strain, feel free to take a break from using the computer.

You should read the information below, and ask questions about anything you do not understand before deciding whether or not to have your child participate.

- **PARTICIPATION AND WITHDRAWAL**

Your child's participation in this study is completely voluntary and you are free to choose whether you want your child to be in it or not. If you choose for your child to be in this study, you may subsequently withdraw them from it at any time without penalty or consequences of any kind. The investigator may withdraw your child from this research if circumstances arise. You are encouraged to be available to your child for the duration of the research.

- **PURPOSE OF THE STUDY**

This study investigates how K-12 and older students can achieve computational identity and digital empowerment through the intervention of educational activities centered on the topic of computational action. This will be researched through questionnaires, interviews, and website activity logging before and after an educational activity intervention.

The education activites include computational action curriculum workshops, discussions on technology and artificial intelligence (AI), discussing other computational action student examples, using an online checklist of computational action tools, and developing projects through hackathon-like activities. The computational action curriulum includes five workshops: defining a problem, gathering data from users using user research, evaluating ethical designs and prototypes, implementation and managing tasks on a team, and launching and landing a solution.

- **PROCEDURES**

If your child volunteers to participate in this study, we would ask them to do the following things:

1. Engage in recorded video calls (e.g. on Zoom), around a total of around 4 hours (with periodic 15min breaks) over one or a few days, which will involve:
    a. learning from instructors about computational action, which includes design, user research, implementation processes, and creating a viable solution
    b. learning about ethical design involving artificial intelligence (AI)
    c. engaging in discussions and short group activities
    d. presenting your final project or idea
    e. use a computational action resource tool
2. Answer questions (e.g., about their reaction to the workshops, their self-perception of being an engineer, demographics information, etc.) from the researchers through discussion and questionnaires.
3. Participate in a voluntary interview with the researchers after the workshop activities. The interview will last no more than 30 minutes.
4. Note that they may be assigned to different variations of the workshop curriculum (e.g. some online activities vs. some activities over video call (e.g. Zoom)) so that we can study which resource is more effective.

- **POTENTIAL RISKS AND DISCOMFORTS**

Your child will be using computers and may experience eyestrain and/or other strain related to computer use. If they experience strain, they can take a break from using the computer at any time.

- **POTENTIAL BENEFITS**

By participating in this study, your child will likely learn about making a technology product that has a real-world impact. These skills will likely be valuable for your future academic classes, projects, and professional endeavors, because you will likely learn how to investigate a problem, gather real-world data, and develop a validated solution that makes a difference in the lives of people in their community or the world.

Additionally, through this research, written works (e.g., research papers) will be created explaining how computational identity and digital empowerment is affected by computational action workshops, and how people can learn about computational action. This will likely help future educators and researchers develop curriculum and tools to help students create real-world soltuions. In addition, the applications developed through participating in these computational action workshops may likely solve real-world problems, and if participants decide to release their app or products, this could benefit society in general.

- **PAYMENT FOR PARTICIPATION**

You (or your child) will not receive payment for participating in this study.

- **PRIVACY AND CONFIDENTIALITY**

You and your child can opt out of any activity that you would not like to participate in. You and your child can also opt out of having audio and/or video recordings taken during activities and/or interviews.

As a parent and/or guardian, you can elect to attend any and all workshops, activities, discussions and/or interviews conducted by the researchers. You are not expected to attend any of the activities and/or interviews, but are most welcomed to participate at any time should you wish.

The only people who will know that your child ais a research subject are members of the research team which might include outside collaborators not affiliated with MIT. No information about your child, or provided by your child during the research will be disclosed to others without you and your child's written permission, except: if necessary to protect you or your child's rights or welfare, or if required by law. In addition, your child's information may be reviewed by authorized MIT representatives to ensure compliance with MIT policies and procedures.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your child's identity. If photographs, videos, or audio-tape recordings of your child will be used for educational purposes, your child's identity will be protected or disguised. You and your child have the right to review/edit the tapes by contacting the investigators of this study, who will have access to the tapes (see "Identification of Investigators" below). After the usefulness of the tapes has passed, they will be erased.

Data collected in the study will only be made available to researchers directly involved in the study. Online responses to surveys will be downloaded to a password-protected computer. All other data will also be stored on password protected computers. Once the responses are downloaded, the online responses will be deleted. During the analysis, each participant will be assigned a random user ID. This ID will be used to distinguish data between participants. All data with identifying information (e.g. age, gender) will be stored on password-protected computers. After the analysis has been completed, we will perform additional encryption of the data and store it. Data from the study will be retained in an encrypted format for the purposes of future research using the data (for as long as the data is useful for research and system development). After its usefulness has passed, it will be deleted.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact:

- *Principal Investigator:*
  - Harold Abelson
  - Address: Stata, Room 32-G516, 32 Vassar St, Cambridge, MA 02139, USA
  - Daytime phone number: (617) 253-5856
- *Co-Investigator:*
  - Nicole Pang
  - Address: Stata, Room 32-G539, 32 Vassar St, Cambridge, MA 02139, USA
  - Daytime phone number: (650) 283-7222

- **EMERGENCY CARE AND COMPENSATION FOR INJURY**

If you feel your child has suffered an injury, which may include emotional trauma, as a result of participating in this study, please contact the person in charge of the study as soon as possible.

In the event your child suffers such an injury, M.I.T. may provide itself, or arrange for the provision of, emergency transport or medical treatment, including emergency treatment and follow-up care, as needed, or reimbursement for such medical services. M.I.T. does not provide any other form of compensation for injury. In any case, neither the offer to provide medical assistance, nor the actual provision of medical services shall be considered an admission of fault or acceptance of liability. Questions regarding this policy may be directed to MIT's Insurance Office, (617) 253-2823. Your (or your child's) insurance carrier may be billed for the cost of emergency transport or medical treatment, if such services are determined not to be directly related to your child's participation in this study.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

By signing this consent form, I acknowledge my understanding and consent to the collection, storage and transfer (if applicable) of my personal information to the United States.

____
Name of Subject

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Name of Legal Representative (if applicable)

______________________________________ ______________
Signature of Subject Date

_______________________________________ _____________
Legal Representative (if applicable) Date

SIGNATURE OF PERSON OBTAINING INFORMED CONSENT

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____
Name of Person Obtaining Informed Consent

_______________________________________ _____________
Signature of Person Obtaining Informed Consent Date

ASSENT TO PARTICIPATE IN RESEARCH
(For those 17 or younger)

Computational Action Education Workshops and Activities

1. My name is Nicole Pang and I'm a graduate student at MIT.

2. We are asking you to take part in a research study because we are trying to learn more about how people go about *problem-solving using technology* and whether a process called *computational action* can have an effect on this.

3. If you agree to be in this study, you will join workshops and/or using an online learning tool. In a video call (like Zoom), you will learn about *computational action*, discuss with us and other students, do short activities online, fill out surveys, and participate in a short interview with myself after the activities.

4. In the study, you will use a computer, which may put you at risk for eyestrain or other strain related to computer use. We will take breaks during the workshops to try to prevent this, and if you feel any strain or like you need additional breaks, you can let us know any time.

5. By participating in this study, you will likely learn engineering design skills and learn about how advanced technology like AI affects the world. These skills and knowledge will likely be valuable for your future, whether you continue to pursue engineering or computer programming, or you learn that you would rather not work with computers in the future.

6. Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say "yes" you can still decide not to do this.

7. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.

8. You can ask any questions that you have about the study now. If you have a question later that you didn't think of now, you can call me *at +1-650-283-7222* or ask me next time. You can also call the Chairman of the Committee on the Use of Humans as Experimental Subjects at M.I.T. at 1-617-253 6787 if you feel you have been treated unfairly.

9. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

____________________________________ ____________________

Name of Subject Date

CONSENT TO PARTICIPATE IN NON-BIOMEDICAL RESEARCH
(For adults 18 or older)

Computational Action Education Workshops and Activities

You have been asked to participate in a research study conducted by Nicole Pang, Robert Parks, and Dr. Hal Abelson, Ph.D., from the Electrical Engineering and Computer Science department at the Massachusetts Institute of Technology (M.I.T.) The results of this study will contribute to Nicole Pang's Masters of Engineering thesis.

You were selected as a possible participant in this study because you expressed interest in learning about engineering product design and making an impact with technology products through MIT workshops and/or project-building program.

The information below provides a summary of the research. Your participation in this research is voluntary and you can withdraw at any time.

- **Purpose**
  The study will investigate changes in students' self-perception of computational identity and digital empowerment before and after computational action educational activities, and how best to teach computational action that incorporates technology like artificial intelligence (AI) or making an app.
- **Study Procedures**
  In this study, participants will engage in workshops over video call (e.g. Zoom or similar), which will be recorded, and which will include learning about computational action, learning about user research and implementation processes, learning about evaluating ethics in technology and AI, discussions, short group activities, filling out surveys, and working toward a final project.
- **Risks & Potential Discomfort**
  You will be using computers and may experience eyestrain and/or other strain related to computer use. If you experience strain, feel free to take a break from using the computer.

You should read the information below, and ask questions about anything you do not understand before deciding whether or not to participate.

- **PARTICIPATION AND WITHDRAWAL**

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise.

- **PURPOSE OF THE STUDY**

This study investigates how K-12 and older students can achieve computational identity and digital empowerment through the intervention of educational activities centered on the topic of computational action. This will be researched through questionnaires, interviews, and website activity logging before and after an educational activity intervention.

The education activites include computational action curriculum workshops, discussions on technology and artificial intelligence (AI), discussing other computational action student examples, using an online checklist of computational action tools, and developing projects through hackathon-like activities. The computational action curriulum includes five workshops: defining a problem, gathering data from users using user research, evaluating ethical designs and prototypes, implementation and managing tasks on a team, and launching and landing a solution.

- **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

1. Engage in recorded video calls (e.g. on Zoom), around a total of around 4 hours (with periodic 15min breaks) over one or a few days, which will involve:
    a. learning from instructors about computational action, which includes design, user research, implementation processes, and creating a viable solution
    b. learning about ethical design involving artificial intelligence (AI)
    c. engaging in discussions and short group activities
    d. presenting your final project or idea
    e. use a computational action resource tool
2. Answer questions (e.g. on your self-perception as an engineer, your reaction to the curriculum, demographic information, etc.) the researchers through discussion and questionnaires
3. Participate in a voluntary interview with the researchers after the workshop activities. The interview will last no more than 30 minutes.
4. Note that you may be assigned to different variations of the workshop curriculum (e.g. some online activities vs. some activities over video call (e.g. Zoom)) so that we can study which resource is more effective.

- **POTENTIAL RISKS AND DISCOMFORTS**

You will be using computers and may experience eyestrain and/or other strain related to computer use. If you experience strain, feel free to take a break from using the computer.

- **POTENTIAL BENEFITS**

By participating in this study, you will likely learn about making a technology product that has a real-world impact. These skills will likely be valuable for your future academic classes, projects, and professional endeavors, because you will likely learn how to investigate a problem, gather real-world data, and develop a validated solution that makes a difference in the lives of people in their community or the world.

Additionally, through this research, written works (e.g., research papers) will be created explaining how computational identity and digital empowerment is affected by computational action workshops, and how people can learn about computational action. This will likely help future educators and researchers develop curriculum and tools to help students create real-world soltuions. In addition, the applications developed through participating in these computational action workshops may likely solve real-world problems, and if participants decide to release their app or products, this could benefit society in general.

- **PAYMENT FOR PARTICIPATION**

You will not receive payment for participating in this study.

- **PRIVACY AND CONFIDENTIALITY**

You can opt out of any activity that you would not like to participate in. You can also opt out of having audio and/or video recordings taken during activities and/or interviews.

The only people who will know that you are a research subject are members of the research team which might include outside collaborators not affiliated with MIT. No information about you, or provided by you during the research will be disclosed to others without your written permission, except: if necessary to protect your rights or welfare, or if required by law. In addition, your information may be reviewed by authorized MIT representatives to ensure compliance with MIT policies and procedures.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. If photographs, videos, or audio-tape recordings of you will be used for educational purposes, your identity will be protected or disguised. You have the right to review/edit the tapes by contacting the investigators of this study, who will have access to the tapes (see "Identification of Investigators" below). After the usefulness of the tapes has passed, they will be erased.

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____
Name of Subject

____
Name of Legal Representative (if applicable)

______________________________________ Signature of Subject	______________ Date
______________________________________ Legal Representative (if applicable)	______________ Date

SIGNATURE OF PERSON OBTAINING INFORMED CONSENT

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

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Name of Person Obtaining Informed Consent

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Signature of Person Obtaining Informed Consent Date

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