**STEAM Workshop Development**

Aiding the Design Museum of London in its efforts to motivate student engagement in STEAM fields through digital design workshops

An Interactive Qualifying Project Report

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**Abstract**

The United Kingdom has increasingly marginalized the design and technology curriculum, leading to a dramatic decrease in the number of engineers and designers entering the workforce. Our project aided the Design Museum of London in its efforts to motivate student engagement in design and technology through digital design workshops. We researched educational practices, interviewed education professionals, and surveyed students to evaluate the effectiveness of existing workshops. To motivate students to engage more with design and technology, we recommended lesson plan updates, created pre- and post-visit modules for each workshop, and developed a proposal for a new workshop focused on how designers use computer code to create user interactions.

**Executive Summary**

STEAM education is an interdisciplinary teaching method that combines science, technology, engineering, the arts, and mathematics and encourages students to interact with traditional STEM (science, technology, engineering, and mathematics) education in an innovative way. Ideally, STEAM increases students' creativity and innovation, and stimulates student interest in STEM by "utilizing the arts as a fulcrum through which sciences, mathematics, structural and technological design learning can be explored and experienced" (Harris & Bruin, 2018).

The United Kingdom implemented STEAM education through two subjects: art and design, and design and technology. However, due to a lack of government funding, schools in the UK have increasingly marginalized design curricula, and in some cases cut it entirely (D&T Association, 2016; see also Adams, 2019). The lack of stimulating design curricula within classrooms contributed to a 10% decrease in interest in design among students years seven to nine from 2008 to 2010 (Hutchinson & Bentley, 2011).

The Design Museum of London is a privately owned museum working to "build public awareness of design by connecting design with people's lives and passions" (The Design Museum of London, 2016). The Design Museum offers three digital design workshops - graphic design, 3D printing, and app design - to motivate student engagement in STEAM fields. However, the Design Museum believes its current workshops could be more effective in a variety of ways. Thus, the Design Museum commissioned this IQP to identify specific areas to improve and suggest ways to do so.

The goal of this project was to aid the Design Museum in its efforts to motivate student engagement in STEAM fields by updating current digital design workshops and developing a new workshop. The team completed this goal by:

1. Developing an evaluation framework for workshop effectiveness according to stakeholder views.
2. Assessing the effectiveness of the Design Museum's current workshops: app design, graphic design, and 3D printing.
3. Updating lesson plans and creating pre- and post-visit modules for the Design Museum's current workshops.
4. Creating a proposal for a new workshop according to the evaluation framework.
5. Piloting and assessing the new workshop based on the evaluation framework.

To accomplish our first objective, the team utilized the Expero Framework to assess the effectiveness of the Design Museum's current digital design workshops. The Expero Framework is made up of two sections: desired outcomes and existing outcomes. The desired outcomes, informed by data collected from the stakeholders (students, teachers, and Design Museum educators and members of the learning team), are what stakeholders want the program to accomplish. The existing outcomes, informed by observational research, are what the lessons currently accomplish, and may or may not align with the desired outcomes. The team defined five desired outcomes through interviews and surveys with stakeholders:

1. Workshops should focus on design and the design process rather than technical skills.
2. Workshops should combine technical skills with students' passions.
3. Workshops should provide a real-world, practical application of what students learn in school.
4. Workshops should inspire students to ask questions and continue learning after the workshop ends.
5. Workshops should be unique to the Design Museum.

We identified existing outcomes for the three existing workshops based on observational research, surveys, and by participating in the workshops when we could not observe students. Utilizing the adapted Expero Framework, we then determined which existing outcomes did not match the desired outcomes so that we could provide recommendations to increase the alignment between the two.

*App Design Workshop Recommendations*
The app design workshop aligns with the first four desired outcomes; to align with the fifth, we recommend that instructors show students an example of a digital user interface related to the museum, and discuss its design choices with the students to tie the workshop back to the museum. This user interface might be the Design Museum's website, the city mapper app on display in one of the museum's permanent exhibits, etc.

*Graphic Design Workshop Recommendations*
The graphic design workshop aligns with the first three desired outcomes, but not the final two. Therefore, we recommend that the Design Museum include physical posters from its collection with which students can interact. Additionally, the post-visit module should contain additional posters for students to analyze, along with some thought-provoking questions that will prompt students to consider the design choices made when creating the included posters.

*3D Printing Workshop Recommendations*
The 3D printing workshop aligns with the first, third, and fifth desired outcomes, but not with the second. We were unable to gather enough data to determine if the workshop met the fourth objective. The team recommends that the Design Museum shorten the technical background discussed in the lecture section. Additionally, we recommend including more objects from the 3D printing wall in Designer, Maker, User (one of the museum's permanent exhibits), and highlighting different design-related applications of 3D printing and its materials during the lecture section.

*Proposed Coding Workshop*
Responding to the Design Museum's request and student demand, we created a proposal for a brand-new workshop that focuses on how designers use computer code to create user interactions within the digital world by integrating sensors and design. We created this workshop based on the desired outcomes the team determined. We designed the workshop for students ages

7 to 18 to explore the definition of design in this context, utilizing sample objects from the Design Museum's collection.

*Pre- and Post-Visit Modules*

Based on the third objective, the team created pre- and post-visit modules for the three current workshops. The pre-visit modules provide introductions to the workshops with questions to motivate students' thinking in design, while post-visit modules provide tutorials to strengthen and enhance students' skills and knowledge gained during each workshop.

All of our changes, if implemented, may improve the effectiveness of the Design Museum's digital design curriculum. A stronger digital design curriculum at the Design Museum may inspire students visiting the museum to learn more about the importance of design in their own lives and how they can use design and technology as a tool to pursue their passions. Teaching students about the relevance of design may result in an increased number of students feeling engaged by their school curriculum, which might cause an increase in classroom participation, student learning, and, eventually, the number of well-rounded designers and engineers entering the UK workforce.

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**1. Introduction**

STEAM education is an interdisciplinary teaching method that combines science, technology, engineering, the arts, and mathematics and encourages students to interact with traditional STEM (science, technology, engineering, and mathematics) education in an innovative way. Ideally, STEAM increases students' creativity and innovation, and motivates student engagement in STEM by "utilizing the arts as a fulcrum through which sciences, mathematics, structural and technological design learning can be explored and experienced" (Harris & Bruin, 2018).

The United Kingdom implemented STEAM education through two subjects: art and design, and design and technology. The UK Department for Education created these subjects as both are necessary for educating future innovators as they provide students with numerous methods with which to solve challenging problems (Department for Education, 2014). However, due to a shortage of government funding, schools have increasingly marginalized design curricula, and in some cases cut it entirely (D&T Association, 2016; see also Adams, 2019). The lack of stimulating design curricula within classrooms contributed to a 10% decrease in interest in design among students years seven to nine from 2008 to 2010 (Hutchinson & Bentley, 2011). The combination of curriculum marginalization and the challenges of teaching a new educational method resulted in educators struggling to deliver stimulating STEAM-related content in UK schools. (Boy, 2013). As a result, educational partners such as museums have increased their number of hands-on activities revolving around principles of STEAM education.

The Design Museum is a privately owned museum located in Kensington, London, working to "build public awareness of design by connecting design with people's lives and passions" (The Design Museum of London, 2016). The museum offers multiple exhibits for a wide range of visitors, as well as three digital design workshops - app design, graphic design, and 3D printing - to motivate student engagement in STEAM fields. The museum utilizes technology as a tool to shape students' overall image of design. However, the museum finds it challenging to deliver workshops that result in productive and original student output due to diversity in students' age range, educational background, and learning ability. Therefore, the learning team at the museum would like updated lesson plans that may engage a wider variety of students.

The goal of this project was to aid the Design Museum in its efforts to motivate student engagement in STEAM fields by updating current digital design workshops and developing a lesson plan for a new coding workshop. Our team achieved this goal by developing an evaluation framework for workshop effectiveness according to stakeholder views, assessing the effectiveness of the Design Museum's current workshops, updating lesson plans and creating pre- and post-visit modules for the Design Museum's current workshops, creating a proposal for a new workshop, and piloting and assessing the new workshop based on the evaluation framework.

## 2. Background

In this chapter, we will introduce the state of STEM education within the United Kingdom, along with the national curriculum and current implementation of STEAM within the UK, as well as information about the Design Museum's digital design workshops. This chapter discusses associations between age range and the fields of science, technology, engineering, the arts, and mathematics. Then, we present various learning and teaching styles to explore suitable and engaging approaches to implement STEAM into education curriculum for varying age ranges.

### 2.1 State of STEM Students in the United Kingdom

According to the 2018 Engineering UK Report, approximately 650,000 students in the United Kingdom pursue secondary education. Less than 50% of those students pass their math and science courses each year, and out of the 300,000 students remaining, only 10% pursue higher level math and science. This leaves 30,000 students still pursuing STEM-related fields. Only 10,000 of those students pursue engineering degrees, and just 9,000 of them pursue engineering careers. The United Kingdom has an immense gap between the number of engineers needed and the number of engineers available: the 2018 Engineering UK Report states that UK companies will require 56,000 engineers and technicians by the year 2020. Therefore, with an annual output of just 9,000 engineers, 46% of engineering employers reported that they had recruitment difficulties (Engineering UK 2018).

### 2.2 The Benefits of STEAM Education

To bridge this gap, schools are changing the way they teach STEM - a curriculum based on providing students with a technical education rich in science, technology, engineering, and math - to engage more students in these fields (Hom, 2014). Some educators, concerned that a pure STEM education harms their students' creativity, are incorporating the arts into their curricula, transforming STEM into STEAM. STEM education and the arts may seem diametrically opposed at first glance: the former demanding technical knowledge, memorization, and quantitative analysis, while the latter focuses on creativity, self-expression, and qualitative analysis. By combining them, however, students may be able to apply the technical knowledge of STEM more effectively, leading to increased innovation within the workplace. While some might think that engineering involves minimal creativity, "today's engineers have more opportunity to be creative than most" (Simmons, 2015). The sheer number of engineering sub-disciplines allows engineers ample opportunities to create innovative new products for users (Simmons, 2015; see also NESTA, 2010).

In addition to promoting innovation, STEAM affirms students' individual identity and increases their engagement (Cooper, 2014). Student engagement within the classroom is declining: researchers from the Programme for International Student Assessment found that one-fourth of 15-year-old students have a low sense of belonging at school, and one-fifth have low levels of participation (Willms, 2003). Therefore, schools around the world are transitioning into incorporating STEAM education into all levels of their curriculum (Kim, Y., 2012). An example

lesson, located in Appendix A, involves using Rube Goldberg machines to teach students engineering principles such as pulleys and transfer of momentum, while combining separate elements of the machine to accomplish a task in a creative way.

**2.3 STEAM-Related National Curriculum of the United Kingdom**

The National Curriculum of the United Kingdom defines the subjects and the standards for primary and secondary schools, and contains five STEAM-related subjects: mathematics, science, art and design, computing, and design and technology. The aim of the National Curriculum is to raise students' interest in "human creativity and achievement" (Department for Education, 2013). The department utilizes the term "Key Stage" (KS) to define the scope of the curriculum. Each Key Stage contains a block of years, where students share analogous subjects and standards. The UK national curriculum consists of four Key Stages (KS1 through KS4) and twelve subjects (Department for Education, 2013).

During Key Stages 1 and 2, students familiarize themselves with the number system, as well as the usage of multiplication and division in mathematics. The expectation in science classes is that students will develop basic scientific understanding through the introduction of representative examples such as plants, lights, and force. For design and technology, students have the opportunity to learn about complex structures, mechanical and electrical systems, computing, and the skills of the designing and making process, and create sketchbooks using various tools and materials (Department for Education, 2013). During Key Stage 3, teachers expect students to practice and develop the knowledge and application skills they gained in earlier Key Stages (Department for Education, 2014).

During Key Stage 4, the UK Department for Education decreases the number of compulsory subjects as a result of student need to prepare for exams in the General Certificate of Secondary Education (GCSE). Though schools must provide design, technology, and the arts as STEAM-related subjects from which students may choose, they are no longer mandatory for students. In compulsory subjects, such as mathematics, teachers expand theories and applications based on knowledge students gained in earlier Key Stages. This method allows students to apply, prove, and solve mathematics problems in multiple subjects including real world finances. In biology, chemistry, and physics, students ideally not only continue learning scientific concepts and expand upon their knowledge, but additionally develop new lab-based skills that allow them to apply their learning (Department for Education, 2014).

Not included in the UK National Curriculum, Key Stage 5 consists of students ages 16 to 18 and is optional. While students may choose to enter an apprenticeship at the conclusion of Key Stage 4, the majority take General Certificate of Education Advanced Level (A Level) classes, as part of Key Stage 5, and continue their education in college or university (St. John Baptist Church in Wales High School, 2019). The Office of Qualifications and Examinations Regulation defines A Level as a set of exams aiming to assess students' achievement in chosen subjects - which includes over 20 STEAM-related subjects out of 38 provided - and also aims to increase student preparation for entrance into higher institutions (The Office of Qualifications and Examinations Regulation, 2017).

**2.4 Learning and Teaching**

To promote teachers' ability to encourage student engagement and effectively teach STEAM education, it is important for teachers to understand their students' abilities and how they differ based on age and background. "Students learn in many ways - by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing; and drawing analogies and building models" (Learning and Teaching Styles, 2002). In order to learn new information more effectively, learners benefit from first reviewing their prior knowledge related to the new topic (Rosenshine, 2012). Reviewing material on a regular basis allows students to strengthen connections among previously learned material, as well as strengthen their ability to receive information (Rosenshine, 2012). A framework commonly utilized to ensure that teachers effectively apply this idea is Bloom's Taxonomy, a pyramid organizing knowledge in a series of steps from beginner to master: remember, understand, apply, analyze, evaluate, and create. Teachers' use of Bloom's Taxonomy can help ensure that students can complete what their teacher asks of them (Campagna et al, 2013). Figure 2.4 shows this framework in graphic form.
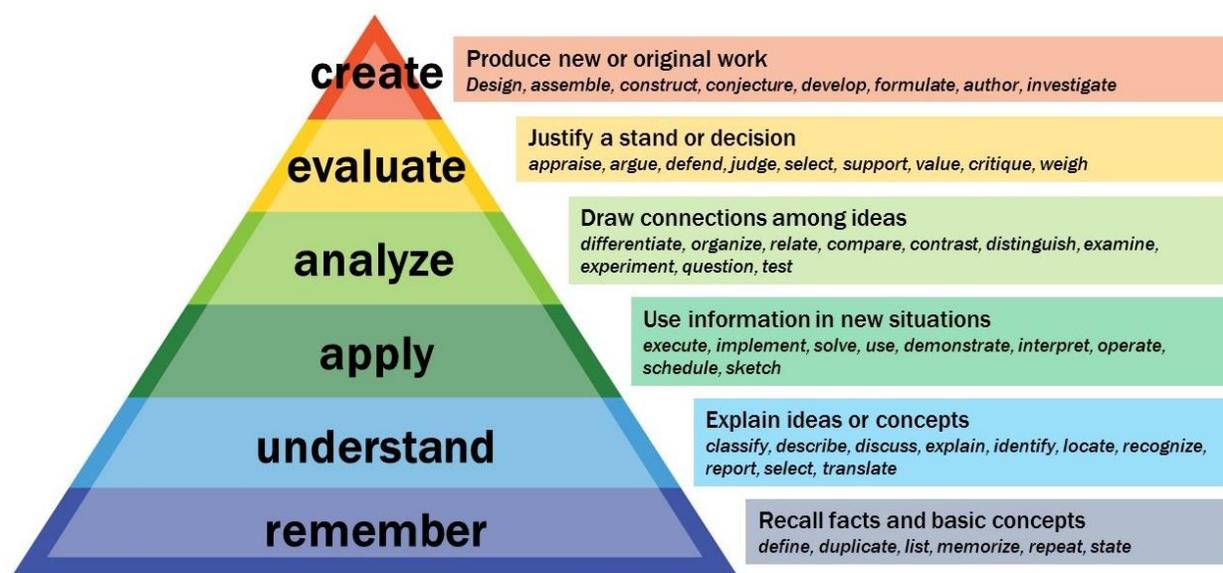


**Figure 2.4 Bloom's Taxonomy**

Source: Research Guides: Learning Outcomes: Bloom's Taxonomy. (n.d.). Retrieved from https://lib.guides.umd.edu/c.php?g=598357&p=4142337.

A demonstrated approach to convey new information to students effectively is through instructional observation. According to "Principles of Instruction: Research-Based Strategies that all Teachers Should Know," students learn well from instructed observation that involves interaction with their teachers. An example would be a teacher working step-by-step through a math problem on a whiteboard, and then proposing a similar problem to students. "Worked examples allow students to focus on the specific steps to solve problems and thus reduce the cognitive load on their working memory" (Rosenshine, 2012, 15). This approach allows

education professionals to check for student understanding, may increase student willingness to ask questions, and encourages students to process material fully.

Instructional observation is tailorable for use in any classroom format, ranging from one-on-one learning to cooperative group environments, which refers to "a group of students that requires cooperative efforts" (Woods & Chen, 2010, 2). Although learners in a cooperative group environment participate in activities with one another, they are always responsible for their own individual achievements, which makes group environments a productive way for students to process information effectively (Budden, 2008). However, this method can pose a challenge when adapting materials for classes with mixed abilities.

Students generally are more creative and learn best when lessons involve an interdisciplinary style (Harris & Bruin, 2018). Interdisciplinary lessons combine multiple distinct subjects to create a lesson; this style allows educators to present information in a meaningful way to different types of learners: visual, auditory, and kinesthetic (Harris & Bruin, 2018). Educators often combine interdisciplinary teaching styles with an approach known as student-centered learning, in which the primary role of the teacher is to coach and facilitate student learning and overall comprehension of material (*Teaching Methods,* 2018).

There is evidence that student-centered learning and interdisciplinary teaching allow students to become more engaged in their learning (Harris & Bruin, 2018). "Designly Thinking" is an example of a framework to apply the principles of student-centered learning, which involves four key parts:

- Discover, where designers generate as many new ideas as possible
- Define, where designers consider the feasibility and complexity of each idea and filter through the ideas they wish to expand upon
- Develop, where designers generate solutions or physical prototypes of their ideas
- Deliver, where designers finish, launch, and present their project

This process allows students to direct their own learning and utilizes multiple academic disciplines to solve a problem (Design Council, 2015; see also *Teaching Methods,* 2018).

**2.5 Lesson Planning**

Lesson planning is a critical element of teaching, as writing a lesson plan provides a detailed description of the lesson and its objectives. Lesson plans are especially important when teaching in an interdisciplinary style, where connecting topics is critical to the flow of the lesson. Lesson plans should begin with an objective, stating precisely what the students should learn within a session. Then, educators choose activities to help the students meet the necessary learning objectives (Richards, 2002).

A useful framework for structuring a lesson plan consists of four stages: opening, inquiry, instruction and activity, and debrief (Bertrand, 2010). The opening and inquiry stages are important to STEAM because they allow the instructor to stimulate student thinking about the various aspects of the activity (Bull Glen, et al., 2017). The instructor then asks questions of the students, ensuring that they make connections between multiple subjects and perspectives (Richards, 2002). In the activity phase, students should work with one another on a student-

centered project in order to increase individual engagement (Cooper, 2014). Lastly, a debrief where students are able to reflect on what they learned can help further solidify new information (Richards, 2002). For an example of a lesson plan based on this framework, see Appendix B.

To adapt educational material for any group of students, guidance suggests that educators should become familiar with the type of students within their learning environment (Learning and Teaching Styles, 2002). If an educator is going to present a lesson to a group of students who may be less experienced on a specific subject, they may do so by rewriting the lessons to contain more familiar words, phrases, and concepts (Budden, 2008). However, for stronger learners, educators may adapt the same material to include more challenging exercises and less-familiar information (Learning and Teaching Styles, 2002).

**2.6 Assessment of Lessons**

Evaluators should base a lesson assessment on learning outcomes that are both specific and measurable (Hussey & Smith, 2008). Additionally, it is important to determine that these learning outcomes are reasonable expectations of a student relative to their base level of knowledge (Campagna et al, 2013). Shown in Figure 2.4, Bloom's Taxonomy is a commonly used hierarchy of learning that evaluators use to determine if a learning outcome is reasonable by ensuring that students have the prerequisite skills to achieve the learning outcome. Educators may then more effectively assess a lesson, considering the necessary understanding required to complete the lesson (Campagna et al, 2013).

Evaluators conducting the assessment may consider the visions of the stakeholders, people interested in the success of the lesson, which may include students and teachers. The Expero model, created by the European Commission for Vocational Schools, analyzes the quality of learning outcomes through systematically collecting data from stakeholders. The Expero model consists of two sections: "should," which refers to the desired outcomes, and "is," which refers to the existing outcomes. The desired outcome category contains the stakeholders' vision for the lesson, while the existing outcome category represents its actual state (Cervai, Cian, Berlanga, Borelli, & Kekäle, 2013). Once evaluators complete the framework, existing outcomes that align with the desired outcomes remain unchanged; teachers then change the aspects that do not align so that the existing outcomes align with the desired outcomes (Cervai et al., 2013). For an example of hypothetical data, see Figure 2.6.
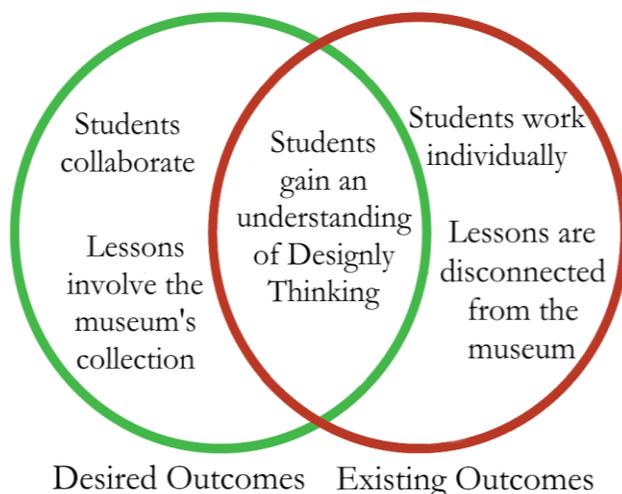
**Figure 2.6 Hypothetical Evaluation Framework based on the Expero Model**

### 2.7 The Design Museum's Digital Design Workshops

The Design Museum is currently questioning the effectiveness of its digital design workshops. Located in Kensington, London, the museum works to increase public awareness and understanding of design by intertwining design with the lives and passions of the people. The museum serves over 60,000 learners per year (The Design Museum of London, 2016). Currently, the Design Museum offers three different 90-minute digital design workshops: app design, graphic design, and 3D printing. These workshops aim to expand upon STEAM subjects in the UK's national curriculum. For a detailed description of these workshops, see Appendix C. According to David Houston, the Learning Producer at the Design Museum, the three sessions are "designed to give school groups the opportunity to explore hands-on relevant digital tools and take the experience back to their classrooms where they can practice" (Houston, 2017).

### 2.8 Conclusion

As students progress through Key Stages, they have the opportunity to learn STEM subjects; however, they may disengage. By adding the arts into STEM, STEAM education may motivate students' engagement in class (Harris & Bruin, 2018). Additionally, this interdisciplinary teaching method also enables students to gain the lasting benefits of leadership, communication, engineering principles, and creative thinking by combining science, technology, engineering, the arts, and mathematics into exciting and effective lessons. Students can learn the content of these lessons in a multitude of ways, which may range from observation to action. Therefore, teachers might teach in a way that affirms individual student identity, accounting for all students' interests, whether that is science, the arts, or another subject. STEAM approaches may help motivate students' engagement in STEM and help fill the gap between the number of engineers the UK requires and the number that are available.

**3. Methods**

The goal of this project was to aid the Design Museum in its efforts to motivate student engagement in STEAM fields by updating current digital design workshops and developing a lesson plan for a new coding workshop. The team completed this goal by:

1. Developing an evaluation framework for workshop effectiveness according to stakeholder views.
2. Assessing the effectiveness of the Design Museum's current workshops.
3. Updating lesson plans and creating pre- and post-visit modules for the Design Museum's current workshops.
4. Creating a proposal for a new workshop according to the evaluation framework.
5. Piloting and assessing the new workshop based on the evaluation framework.

**3.1 Develop Evaluation Framework**

The team utilized the Expero Framework to assess the effectiveness of the Design Museum's current digital design workshops. The Expero Framework is made up of two sections: the desired outcomes and the existing outcomes (Cervai, Cian, Berlanga, Borelli, & Kekäle, 2013). The desired outcomes, informed by data collected from the stakeholders, are what stakeholders want the program to accomplish. The team determined that the stakeholders relevant to the lesson assessment consist of students, teachers, and Design Museum educators and members of the learning team. The existing outcomes, informed by observational research and surveys, are what the lessons currently accomplish.

To gather data about the desired outcomes, the team interviewed four Design Museum staff members, three workshop facilitators, and one workshop content creator. Each interview lasted approximately fifteen minutes and consisted of questions about what they believed students should get out of their experience at the Design Museum, what should make the sessions unique to the museum, and how they should learn when at the museum, along with some individualized questions that pertained to the expertise of the interviewee. For a general interview guide, see Appendix D1.

The team also collected survey data from a group of students who participated in the Design Museum's app design workshop. Distributed at the conclusion of the workshop, the student survey consisted of questions about how much they enjoyed the workshop, how much they learned from the workshop, and how interested they were in continuing to learn about app design. For the student survey questions, see Appendix D2.1.

Additionally, the team developed two surveys for education professionals: one for those visiting the Design Museum with their students and another for a general audience of UK teachers which we posted on the Design Museum's Twitter page. We were unable to use a more targeted method due to time constraints. The survey for the education professionals visiting with their students consisted of five questions and took each educator under five minutes to complete. The survey posted to the Design Museum's social media consisted of six questions and took approximately one minute to complete. The survey we distributed online consisted of more closed-ended questions and required less time to complete in an attempt to increase participation.

This survey focused more on the ideal length and monetary value of a workshop rather than learning objectives. For the survey questions for educators, see Appendix D2.2.

To identify the desired outcomes, the team used two approaches. First, we categorized responses to questions in each interview based on similar themes between responses. This categorizing, also known as coding, allowed the team to identify common themes as well as stand-alone ideas amongst the interviewed stakeholders. Second, we identified ideas shared by multiple survey respondents and incorporated these ideas into the desired outcomes. The team then used Bloom's Taxonomy to remove any desired outcomes that were unreasonable to expect from students.

**3.2 Evaluate Current Curriculum**

In order to determine the workshops' existing outcomes, the team gathered data in three ways. First, we observed a class of students participating in the Design Museum's app design workshop. To categorize observations, the team utilized a framework for assessing student engagement developed by the International Center for Leadership in Education; for this framework, see Appendix D3. Second, team members participated in each of the Design Museum's other digital design workshops. Our participation allowed each team member to make preliminary observations by putting themselves into the mindset of a young learner. The team then coded all observations based on common themes such as student engagement, collaboration, and perceived understanding. Third, the team surveyed both the students who participated in the workshop and their accompanying education professional. Completed at the conclusion of the digital design workshop, the survey consisted of eight questions and took students less than five minutes to complete. The survey, conducted immediately following the workshop, consisted of questions to determine what students believe they gained from the workshop and how much they enjoyed their experience. The team then identified common ideas among responses and included them in the existing outcomes.

After coding the data, the team filled in the desired outcomes section of the framework, and then determined the overlap between the desired outcomes and the existing outcomes, thus completing the framework. For our completed framework, see Appendix F.

**3.3 Update Lesson Plans and Create Pre- and Post-Visit Modules**

After we finished assessing the current lessons, the team updated the existing lesson plans and created pre- and post-visit modules for the three workshops: app design, graphic design, and 3D printing. To update the lesson plans, the team identified underperforming aspects of the lessons, and suggested changes to make the workshops better align with the desired outcomes. Additionally, based on requests from our sponsor, the team created pre- and post-visit modules for each of the three workshops.

To determine the focus of the pre-visit modules, the team analyzed the learning objectives and the desired outcomes for each lesson in order to create corresponding questions to stimulate student thinking. For post-visit modules, the team researched resources that used the same tools in each workshop in order to allow students to continue learning by themselves.

### 3.4 Create Proposal for New Workshop

Prior to the team's arrival, our sponsor informed us that there is high demand for a coding workshop at the Design Museum, but the museum does not currently offer one. Therefore, our team recommended software and developed a lesson plan that incorporates the desired outcomes that we previously identified. The team created the lesson plan after assessing and updating the three current digital design workshops, which allowed us to incorporate previous assessment findings.

### 3.5 Pilot and Assess New Workshop

The team piloted the new workshop three times: first we conducted a 30-minute pilot session; we then revised the lesson and conducted two more 60-minute sessions. During the pilot sessions, the team acted as instructors and taught the practical portion of the lesson. We conducted these pilot sessions with students ages 15 to 18. The team utilized the same data collection techniques described in section 3.2 to determine a new set of existing outcomes, and then placed these new existing outcomes into the framework to evaluate the pilot sessions. To determine the progress made by our revisions, the team compared the difference in overlap between the existing and desired outcomes from the first pilot to the second pilot.

**4. Findings**

      In this chapter, we describe the five desired outcomes of the digital design workshops that we identified from data gathered from various stakeholders through interviews and surveys. The data we collected aided our team in the development of our evaluation framework, which we developed to help the Design Museum identify underperforming areas of its workshops. The team listed each stakeholder's desired outcomes and evaluated whether or not each desired outcome aligns with each workshop's existing outcomes. Due to low workshop enrollment, the team was unable to obtain enough data to evaluate the specific existing outcomes for the graphic design and 3D printing workshops.

**4.1 Desired Outcomes**

      To determine the workshops' desired outcomes, we gathered data from stakeholders through interviews and surveys. These stakeholders consisted of students, teachers, and Design Museum educators and members of the learning team. The stakeholders formed their opinions from their unique individual experiences learning about and teaching design. Our team then identified five desired outcomes to which all of the workshops should align.

**4.1.1 Workshops should emphasize teaching design rather than technical skills.**

      According to Tzveta Dinova, a freelance content creator for the Design Museum, workshops should focus on design and build on the museum's available resources. Additionally, Sevra Davis, Head of Learning at the Design Museum, believes that workshops should focus on the process of creating the product rather than the final product itself. She also believes that the workshops should use digital methods to facilitate design rather than exclusively teach technical skills. David Houston, the Learning Producer for Schools and Further Education, also stated that the workshops should advance students' knowledge of design. The team also observed two hands-on workshops, in which students interact with design through experiential, tactile learning outside of the digital realm. As a result of interview responses and observations made during the hands-on workshops, the team determined that the Design Museum intends for workshops to focus on design and the design process rather than technical skills. This desired outcome means that although students may walk away with strengthened technical skills, the primary focus of the lesson should be design.

**4.1.2 Workshops should combine technical skills with students' passions.**

      The team determined from student surveys and interviews with Tzveta, Sevra, and Komal (the Learning Producer for Young Audiences) that workshops should fill the gap between technical skills and students' passions. In our interview with Tzveta, she said that the Design Museum should use its resources to help students integrate their passions with design and technical knowledge. We believe this perspective is valuable as it aligns with the museum's mission statement: "To build public awareness of design by connecting design with people's lives and passions" (The Design Museum of London, 2016). Additionally, Sevra said that the workshops should focus on ensuring that young people receive skills relevant to the future of work, while also focusing on design. Sevra and Komal both mentioned that while schools

already teach technical skills, the Design Museum should build upon those skills in a way that foster students' passions. Sevra's statement is important because engaging students' passions in technical skills may lead to an increase in students' motivation to engage in STEAM fields (Cooper, 2014). When the team asked the seven students who participated in the app design workshop what excited them, five indicated that they enjoyed the freedom to incorporate their passions: one student said, "I liked that I could integrate my own ideas into my app." The team believes that this perspective is valuable because the student's testimony aligns with what other stakeholders stated. Therefore, the team concluded that one desired outcome is that workshops should combine technical skills with students' passions.

### 4.1.3 Workshops should provide a practical application of what students learn in school.

The team determined that workshops should be relevant to the real world. David Houston, stated that students should receive a real-world, practical application of what they are learning in the classroom. We believe that this perspective is important because students may have few chances at school to experience practical applications due to the marginalization of design curricula (D&T Association, 2016). By combining literature with practical applications, the team believes that workshops at the Design Museum may help students broaden their knowledge and may increase their engagement in relative fields. Additionally, a teacher who brought his students to the Design Museum said that workshops show real-world applications of the design skills developed within the classroom (Appendix E2). Based on this data, the team concluded that workshops need to provide real-world applications of skills learned within the classroom.

### 4.1.4 Workshops should inspire students to ask questions and continue learning.

Workshops should also encourage students to want to learn more about the subject of the workshop after leaving the Design Museum. Joe Hoole, a freelance educator, wants students to leave asking questions, and according to Komal, students should be amazed at all the possibilities for potential applications of the knowledge they gained in the workshop. These comments are important because one aim of the workshop is to inspire students to continue learning about design after they leave the museum (The Design Museum of London, 2016). If students leave the workshops asking questions, the team believes it shows that students are likely to express interest in continuing their learning. The Design Museum wants the focus of the workshops to be not on the final product, but rather the journey along the way. While this approach may result in an incomplete final product, the Design Museum would rather that students express interest in continuing their learning once they leave the workshop and finish the product on their own.

### 4.1.5 Workshops should be unique to the Design Museum.

According to David Houston, it is fundamental that the workshops offer a unique experience that students can only find at the Design Museum. We split the way that the workshops may accomplish this desired outcome into two parts:

First, workshops should not be able to exist without the Design Museum. David said that when students visit the Design Museum to participate in workshops, the experience should be one that they can only find at the Design Museum itself. He also noted that the workshops should be unable to function outside of the context of the Design Museum. This desired outcome is vital to our sponsor since students may lose interest in the workshops if they do not offer a unique experience. From this recommendation, the team determined that if it is possible to deliver a Design Museum workshop outside of the Design Museum, the Design Museum should remove it from its curriculum.

Second, workshops should involve the Design Museum's collections and exhibitions. According to an interview with Komal, the content of the workshops should be specific to the exhibitions, yet still accessible outside of the Design Museum. This perspective is important because connecting lessons to the exhibits provides students with a unique experience from the museum. The team also determined that the software utilized throughout these workshops must be free of charge and readily available to all students so that they may continue to exercise the design and technical skills they acquired during the lesson.

## 4.2 Existing Outcomes

The team developed existing outcomes for each workshop based on observational research, surveys, and when necessary, participating in the workshops. We then determined which existing outcomes matched the desired outcomes so that we could make necessary recommendations.

## 4.2.1 Existing Outcomes of the App Design Workshop

Through observational research and surveying, the team determined that the app design workshop aligns with the first four of the five desired outcomes. The workshop aligns with the first desired outcome (workshops should emphasize teaching design rather than technical skills) because facilitators ask students to focus on defining a user, a problem, and the role of the designer in creating an effective interaction. Additionally, in this workshop, students consider a type of user and design an app that would appeal to this type of user. The workshop also allows students to explore the design process through app design while encouraging them to incorporate their own passions.

The team observed that the workshop facilitator asked students to use the skills gained in the lecture to create an app related to one of their passions. Having students create something they are passionate about aligns with the second desired outcome (workshops should combine technical skills with students' passions). One student created an app incorporating her interest in stationary, and another highlighted his passion for fitness by creating an app to track his running. Based on these observations, the team determined that the app design workshop aligns with the desired outcome.

The app design workshop aligns with the third desired outcome (workshops should provide a real-world, practical application of what students learn in school). The workshop achieves this outcome by building upon the national curriculum's aim to "build and apply a

repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users" (Department for Education, 2013). In the app design workshop, the team observed students acquiring new skills and designing an app based on a student-defined user. Thus, the team found that the workshop aligns with this desired outcome.

We determined that the app design workshop aligns with the fourth desired outcome (workshops should inspire students to ask questions and continue learning after the workshop ends) based on student surveys. Six out of the seven students we surveyed after they completed the app design workshop rated their interest in continuing to learn about app design as 4 or 5 out of 5:

On a scale of 1 to 5, how interested are you in continuing to learn about and/or work with app design after leaving the Design Museum?
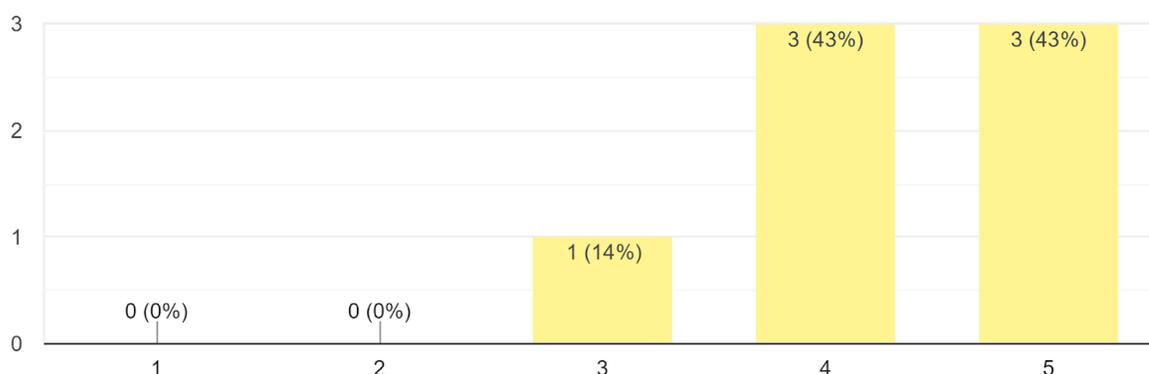


**Figure 4.2.1 Data From App Design Survey**

Additionally, when the workshop ended, students continued to ask questions about the capabilities of the app design software. Based on the surveys and observations, the team determined that the app design workshop aligns with the fourth desired outcome.

The app design workshop does not align with the fifth desired outcome (workshops should be unique to the Design Museum). The app design workshop has the fewest ties to the Design Museum of any of the current workshops and would be just as effective if taught elsewhere. The software utilized is freely accessible outside of the workshop, but lacks any incorporation of the Design Museum's exhibitions and fails to involve any objects from the museum's collection with which students can interact. Based on the lack of integration of the museum's collection, the app design workshop fails to meet the final desired outcome.

**4.2.2 Existing Outcomes of the Graphic Design Workshop**

In its current form, the graphic design workshop aligns with the first three desired outcomes, but not the final two. While it effectively teaches design, allows students to

incorporate their passions, and is applicable to the real world, it fails to inspire students to continue learning about graphic design, and would be just as effective if taught outside of the Design Museum.

Based on our observations, the team believes that the workshop successfully teaches students about design by instructing students to define a problem and create an interaction between an object (the poster), and a user (people with an interest in the subject of the poster). The lesson encourages students to think about possible design choices that might draw the attention of people who see the poster. Additionally, we observed that the workshop provides ample opportunities for students to link their passions and the skills the workshop teaches, as the students have complete creative control over the subject of the poster. The team observed this when one student chose to focus their poster on climate change and another on campaign finance. Furthermore, graphic design is relevant to multiple important professional fields. Creating effective logos, websites, and advertisements demands significant knowledge of graphic design, and all three are necessary components of many businesses. Therefore, we found that the graphic design workshop aligns with our first three desired outcomes.

However, the workshop fails to inspire students to continue learning. We observed that the workshop spends more time encouraging students to think about the issue the poster protests rather than teaching graphic design. While this outcome is a positive one, it fails to encourage students to ask questions about design, which is the goal of the workshop. Additionally, the workshop lacks a strong tie to the Design Museum. Instead, the team observed that the lesson focuses on food labels, advertisements, and only includes a single poster from the Design Museum's collection. Thus, the workshop fails to align with our fourth and fifth desired outcomes.

### 4.2.3 Existing Outcomes of the 3D Printing Workshop

The team found that the 3D printing workshop meets the first desired outcome (workshops should emphasize teaching design rather than technical skills). However, we believe that the workshop should contain more lecture content and design-related handling objects. The team observed that during the lecture section of the workshop, the instructor discussed more of the history of 3D printing and its technical applications rather than its role in designing products. Additionally, during the practical section, students with little to no prior experience spent the majority of their time learning how to use the software instead of designing their 3D model. We believe this workshop aligns with the first desired outcome as it allows students to explore design by altering a digitized object from the museum's collection. It focuses on solving a problem a potential user might encounter when using the object while advancing student knowledge of design through the technical lens of 3D modeling.

However, this workshop fails to accomplish the second desired outcome (workshops should combine technical skills with students' passions). We observed that the facilitator spent much of the lesson on the history of 3D printing, which did not leave enough time for the hands-on section. The workshop provided students with knowledge of how to use 3D printing to develop their passions. However, the prompt for the activity restricted students' ability to

implement their passions since students can only create 3D-printed modifications for an existing object in the Design Museum's collection.

The 3D printing workshop successfully accomplishes the third desired outcome (workshop should provide real-world, practical application of what students learn in school). The workshop offered students an opportunity to learn a 3D modeling software and apply it through their design of real-world products, such as chairs, lighting equipment, and a lemon juicer. Since the national curriculum states that students should "develop the creative, technical and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world," this workshop aligns with our third desired outcome (Department for Education, 2013).

As we did not have the chance to observe students participating in the 3D printing workshop, the team was unable to determine whether or not the workshop meets the fourth desired outcome (workshops should inspire students to ask questions and continue learning after the workshop ends).

This workshop aligns with our fifth desired outcome (workshops should be unique to the Design Museum) since it offers an experience unique to the Design Museum. We observed that instructors provided students with the opportunity to consider multiple factors when designing an improvement to an existing object from the Design Museum's collection, including the age of the user, the purpose of the object, and convenience. Due to the uniqueness of the museum's collection and the experience students would get from designing a product using 3D modeling, we found that students would get an irreplaceable experience from this workshop.

**4.3 Workshop Length**

The team conducted an online survey of teachers distributed through the Design Museum's Twitter account from 13 May to 27 May, 2019 and received 10 responses. We asked teachers how long they wished workshops to take; 5 out of 10 respondents preferred 2 - 3 hours, while four preferred 1.5 hours (the current length).

Please select your ideal workshop length:
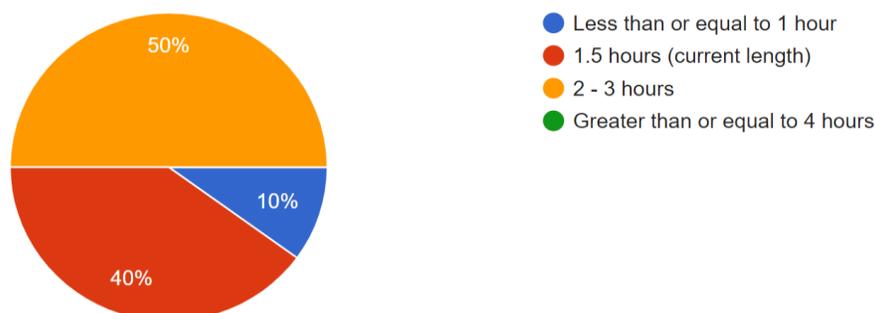


**Figure 4.3 Data From Online Teacher Survey**

We also asked respondents how much they would be willing to pay for a workshop. 5 indicated willingness to pay £100 or more for workshops with up to 30 students (the current rate), while 3 were willing to pay £5 per student or more. The team therefore concluded that there is demand for longer workshops, even at higher prices.

**4.4 Conclusion**

By comparing the desired outcomes with the existing outcomes, the team summarized the aspects of each workshop that require improvement. Due to limited workshop participation, the team had the opportunity to observe only the app design workshop. We then participated in the 3D printing and graphic design workshops to complete our evaluation. The app design workshop contains few connections with the Design Museum's collections and exhibitions, and students in this workshop lack any interaction with physical objects. The graphic design workshop fails to provide an encouraging environment that prompts students to ask questions or further explore on their own, and also has few physical objects with which students can interact. The team concluded that both of these workshops can exist without the Design Museum. In addition, the 3D printing workshop fails to foster students' passions, and also fails to combine technical skills with said passions. Based on the above shortcomings, the team then provided suggestions that may change the workshops to align with the desired outcomes.

**5. Recommendations and Deliverables**

Based on our findings and literature review, the team developed recommendations for improving the Design Museum's three digital design workshops, built pre/post visit modules for each, and created a proposal for a new workshop focused on the use of computer code in design. After creating a draft proposal for the new coding workshop, the team piloted the workshop to three groups of students and revised the proposal based on feedback to ensure that it fulfills all of the desired outcomes.

**5.1 Recommendations for App Design Workshop**

We recommend that the instructors who teach the app design workshop show students an example of a user interface (UI) related to the museum, and discuss its design choices with the students. We recommend this because the app design workshop includes few connections with the Design Museum's collection, and would be just as effective when taught outside the museum. To connect the app design workshop to the museum, instructors might note specific elements of its UI such as color, button placement and style, etc., and ask students to consider why the designer made those decisions. We constructed this recommendation based on our literature review of guided examples, located in section 2.4.

Additionally, the team recommends using the Design Museum's website as an example of digital design to ensure that the app design workshop is unique to the museum. While apps and websites require slightly different design decisions and will most likely result in a less effective example, the fact that the Design Museum already has a website means that this suggestion will be significantly easier to implement. Websites and apps both involve similar aspects of design, and while not exactly the same, would certainly be relevant information for students to have.

**5.2 Recommendations for Graphic Design Workshop**

The team proposes two potential solutions so the graphic design workshop may meet the desired outcomes. First, the team recommends including posters from the Design Museum's collection in order to strengthen the connection between the Design Museum and the workshop, as well as increase the interaction between students and physical objects. Instructors can place posters around the classroom prior to the workshop, and provide students with questions prompting them to think about the design process such as asking them to identify the poster's target audience. Students may then walk around the room and examine each poster. The team suggests choosing posters with a variety of different concepts that pertain to students' educational backgrounds. Potential posters may include:

**Figure 5.2 Potential Posters for Graphic Design Workshop**

Sources: *Your beauty up in smoke* (poster). (2015). Mccann Healthcare Worldwide Japan, INC.
*Sony microvault* (poster). (2005). Sony Corporation.

## 5.3 Recommendations for 3D Printing Workshop

The team proposes four changes in order for the 3D printing workshop to achieve all of the desired outcomes outlined in the evaluation framework. First, the team recommends that the Design Museum shorten the technical background of the lecture section and incorporate more applications of 3D printing in relation to design. The purpose of this recommendation is not to detract from the importance of the technology's history, but rather to redistribute the focus of the workshop towards how technical skills enhance the design process.

Second, in order to improve how instructors teach the design process (desired outcome 1), we recommend that students receive an additional prompt encouraging them to consider the type of material they might use to carry out their design. Throughout the lecture portion of the workshop, students learn about the different applications of 3D printing, but do not have the opportunity to implement this knowledge. This addition would allow the Design Museum to incorporate an additional step of the design process into their lesson, and highlight a physical application of the technical skills gained from the workshop.

Third, the team proposes that the Design Museum incorporate additional handling objects into this workshop and then prompt students to consider how the designer utilized the design process to create each one. Handling objects serve two purposes: first to provide students with unique and diverse examples of 3D printed objects in order to spark inspiration when it comes to the creation of their own object. Second, to increase the workshop's focus on the design process through the use of experiential and tactile examples. These handling objects may include objects from the 3D printing wall located in the DMU exhibit:

**Figure 5.3 3D Printed Objects from DMU**

The team also recommends a fourth adjustment related to the individual skill level of each group of participating students. For students that enter the workshop with low to no technical skills or 3D modeling exposure, the prompt for the workshop will remain as is: asking them to choose one of select objects from the museum's collection and create a modification or adjustment for it. For students that enter the workshop with moderate to high technical skills, the prompt for the workshop may increase in difficulty, such as asking them to fill in the blanks in "A [user] needs an object to [purpose]," and instructing them to follow the design process to design a prototype of such an object. The purpose of this recommendation is for workshop facilitators to direct their lessons to their specific audience, whatever the skills of those incoming students may be.

### 5.4 Recommendations for Workshop Length

We recommend that the Design Museum offer its digital design workshops in longer, more expensive sessions instead of the current workshop length and price. Surveyed teachers indicated that they would be willing to spend more on a longer workshop, and that a longer workshop would be able to go more in depth with its material, increasing students' understanding of design and practical experience related to the software utilized.

**5.5 Coding Workshop Deliverable**

One primary objective of our project was to create a proposal for a coding workshop. Thus, we designed a 90-minute coding workshop that meets all of the desired outcomes identified in our findings chapter; for the full proposal, see Appendix G1. This proposal focuses on how designers create user interactions within the digital world by integrating coding, sensors, and design. We designed the workshop for students to explore the definition of design in this context, utilizing sample objects from the Design Museum's collection. Instructors will prompt students to consider each object's intended user, and think critically about how the design affects the object's function. Next, students will receive an introduction to programming framed as a method used by designers to facilitate interaction. Facilitators will teach students basic technical programming skills, which students can use to design an Internet of Things (IOT)-like device. Before they begin building their device, students should determine a problem and a user, and visualize their product idea via a drawing. They will then use the programming skills they gained throughout the lesson to create such a device utilizing a microcontroller. Once the students finish, they will present their device to the group, along with their initial user, problem, and drawing for the device's appearance.

The recommended workshop responds to the first and second findings (workshops should emphasize teaching design rather than technical skills and workshops should combine technical skills with students' passions). Students will define a user and a problem and then use the programming knowledge they gained within the workshop to design a user-object interaction. The students then consider how they might develop this interaction by designing the physical appearance of the device. This approach incorporates three levels of design: code, the microcontroller sensor package, and the appearance of the device. Incorporating three levels of design places the focus of the workshop on design rather than technical skills, and provides a practical outlet for students to apply the knowledge they learn in their design and technology classes. Additionally, current teaching methods place a focus on how each aspect of the code is applicable to design. Our workshop accomplishes this goal by providing the class with deconstructed sample code of a well-designed IOT device and then reconstructing it as a guided example. The instructor will explain how each element of the code creates an interaction. The team utilizes this method to align with the best practices for teaching. The coding workshop effectively responds to these desired outcomes by teaching students technical skills in a way that emphasizes their role in design and allows them to work through the design process and apply what they are learning in their classrooms.

To incorporate the third and fourth desired outcomes (workshops should provide real-world, practical application of what students learn in school and workshops should inspire students to ask questions), our workshop's design brief is open-ended, allowing students to utilize the newly developed skills by designing for a problem and user of their choice. By utilizing an open-ended design brief, the workshop encourages students to create a device related to what they are passionate about. By engaging students' passions, the proposed coding

workshop encourages students to leave the workshop asking questions about how programming might enhance their passion and how they might further develop their programming skills.

In order to align with the fifth desired outcome (workshops should be unique to the Design Museum), the team developed a curriculum that utilizes one of the museum's permanent exhibits and teaches design through the lens of programming. First, students learn about user-object interaction from a section of Designer, Maker, User (DMU): the Internet of Things Wall. During the workshop, facilitators ask students to think about how a designer creates a user interaction. This question is the main theme of the workshop, and should advance student knowledge of design by prompting students to think critically about this theme and asking them to iterate through the design process. The proposed workshop cannot exist outside the Design Museum because of this intentional focus on design and inclusion of one of the museum's permanent exhibits.

**5.6 Pre- and Post-visit Modules Deliverable**

Based on our third objective, the team created pre- and post-visit modules for the three existing workshops. The pre-visit modules provide introductions to the workshops with potential questions asked to motivate students' thinking in design. Since the Design Museum would like the workshop to focus on the education of design rather than technical skills, the pre-visit module may help students deepen their design thinking during the workshop by leading them through the thinking process beforehand. The post-visit modules provide additional information as well as similar or more advanced projects for students to work on after the workshop. We expect that students could improve their skills on the software learned and express interest in further study in relative fields.

*App Design Workshop Pre-Visit Module*

The pre-visit module begins with the definition of app design. This module prompts students to think about a poorly designed app, then consider who would download the app and what tasks it helps users accomplish. These questions may lead students to consider the design of their app from the users' perspective. We then ask students to redesign four different screens of their chosen app using pen and paper. The team expects this module to provide students with basic app design experience before coming to the workshop. For a complete pre-visit module for the app design workshop, see Appendix H1.

*Graphic Design Workshop Pre-Visit Module*

The pre-visit module begins with a definition of graphic design. The module then asks students to analyze a piece of graphic design and consider what message the piece is trying to portray, how it is drawing the users' attention, and how it influences the user. The module then prompts students to redesign a poster in a different style. The team expects that students who complete this activity will gain a basic understanding of graphic design prior to participating in the workshop. For a complete pre-visit module for the graphic design workshop, see Appendix H3.

*3D Printing Workshop Pre-Visit Module*

The pre-visit module defines 3D printing, introduces different 3D printing materials used and encourages students to locate an object around them for which they can create a 3D-printed modification. The worksheet instructs students to draw their ideas on paper, and then, if possible, create their modification from cardboard. This module also prompts students to consider which material would be best to use when actually printing their object. The team expects that this module may offer an adequate amount of background knowledge for students so that they may have more time creating the 3D model during the workshop. For a complete pre-visit module for the 3D printing workshop, see Appendix H5.

*Post-Visit Modules*

The post-visit modules provide tutorials to each workshop. In order to refresh students' memory in regards to the workshop, we included tutorials that have the similar difficulty as which students complete during the workshop. To prompt students to explore design through software utilized at the workshop, the team also provided tutorials with higher level of difficulty so that students may gain more skills on utilized software and, therefore, continue their learning. For complete post-visit modules for the app design, graphic design, and 3D printing workshops, please see Appendices H2, H4, and H6, respectively.

**6. Conclusion**

Our sponsor, the Design Museum, offers three digital design workshops that utilize two subjects (art and design, and design and technology) from the national curriculum in order to stimulate student interest in STEAM subjects. In addition to promoting innovation, STEAM education affirms students' individual identity and increases their academic engagement. However, while the workshops expose students to design, they fail to stimulate students' interest adequately. Our team offered suggestions for how the museum may change its current workshop curriculum to increase student engagement while maintaining a unique experience that only the Design Museum can offer. Our team also suggested multiple objects in the Design Museum's collection and permanent exhibitions to incorporate into each workshop. Additionally, in response to high demand, we developed a proposal for a new workshop that teaches students how designers use computer code to create interactions between users and objects and encourages students to use code to design a device of their own. Our proposed workshop also aims to inspire students to apply their technical and design skills outside of the classroom.

All of our changes, if implemented, may improve the effectiveness of the Design Museum's digital design curriculum. A stronger digital design curriculum at the Design Museum may inspire students visiting the museum to learn more about the importance of design in their own lives and how they can use design as a tool to pursue their passions. We hope that students who participate in the Design Museum's digital workshops will not only gain an understanding of design and its applications, but will also learn how to solve problems creatively, allowing them to become better prepared for success in their future careers. Furthermore, teaching students about design may result in increased classroom participation, student learning, and eventually, the number of well-rounded designers and engineers entering the United Kingdom's workforce. Combined, we hope that our efforts will contribute towards meeting the UK's desired output of 56,000 qualified engineers by the year 2020.

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## 8. Appendices

**Appendix A: Sample STEAM Lesson**

  One proposition for incorporating STEAM principles in elementary schools or their international equivalents is through the use of Rube Goldberg machines. Aiming to "design the most complicated mechanism to solve the simplest problem," Rube Goldberg machines are ideal for combining STEM principles with creative thinking (Kim, Y., 2012). An instructor can design each individual component of the machine to teach an engineering principle, and by combining components, students can accomplish a task in highly creative ways. Yilip Kim and Namje Park, two Korean elementary school teachers, use Rube Goldberg machines in their classrooms to build students' communication skills and teamwork capabilities, all while teaching essential engineering principles such as the transfer of energy, pulleys, and momentum.
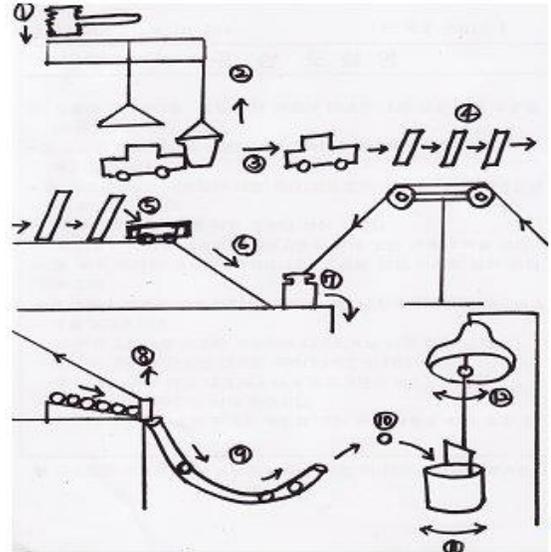


**Figure A - Example Components in a Rube Goldberg Machine (Kim, Y)**

  Figure A gives an example segment of a Rube Goldberg machine containing a loop demonstrating the concepts of momentum and conservation of energy. The educational benefits of incorporating Rube Goldberg machines into curricula can extend beyond the activity itself. By incorporating team-building into the creation of the machines, students can gain the lasting benefits of leadership, communication, and creative thinking, in addition to engineering principles (Allan, 2017).

**Appendix B: Lesson Plan Example**
This is a sample lesson plan that our team referenced when developing our proposal for a new workshop. At the request of our sponsor, the team adapted this format to include a brief, bulleted outline.

Richards, J. C. (2002). *Methodology in language teaching* (1. publ. ed.). Cambridge [u.a.]: Cambridge Univ. Press. Retrieved from http://www.loc.gov/catdir/description/cam021/2001025746.html.

Lesson Planning                                    **37**

| Step | Time | Tasks (Teacher) | Tasks (Pupils) | Interaction | Purpose |
|---|---|---|---|---|---|
| 2 | 5–7 mins | T distributes handout on sports schedule from the newspaper. | Ss read the handout and answer the questions. | T ⟷ Ss | Focus attention of Ss on the concept of skimming for general gist with authentic materials. |
|  |  | T asks Ss to read it quickly and answer the true/false questions that follow it within 3 minutes. | Ss call out their answers to the T. | Ss ⟷ T |  |
|  |  | T goes over the answers and shows Ss how he or she found the answers based on key words in the article. | Ss check their answers. |  |  |
| 3 | 15 mins | T tells Ss that they just practiced skimming to get the general meaning or gist of a passage. | Ss read the handout and answer the questions. | T ⟷ Ss | Getting Ss to read passage quickly to get the overall meaning. |
|  |  | T gives another handout on sports from the textbook (*New Clue*). T asks Ss to read and answer the true/false questions written on the paper within 5 to 7 minutes. T asks Ss for answers and writes them on the board. T explains how key words can give the answers. | Ss call out their answers to the T. | Ss ⟷ T (S ⟷ S possible also) |  |
|  |  |  | Ss check their answers. | T ⟷ Ss |  |
| 4 | 5 mins | T summarizes the importance of reading a passage quickly first in order to get the gist. | Ss listen. | T ⟷ Ss | To remind Ss what they have just done and why – to develop pupil metacognitive awareness. |
|  |  | T gives homework of reading the next day's newspaper's front-page story and writing down the gist of the story in 4 sentences. |  |  |  |
|  |  | **Follow-up:** Next lesson: To teach the students to find the main idea of the passage by scanning. |  |  |  |

Key: Interaction: T ⟷ Ss means teacher interacts with the whole class.

**Appendix C: Current Workshops at the Design Museum**

Currently, the Design Museum offers three different 90-minute workshops aimed to expand upon the UK's National STEAM Curriculum. According to David Houston, the Learning Producer at the Design Museum, the three sessions are "designed to give school groups the opportunity to explore hands on relevant digital tools and take the experience back to their classrooms where they can practice." The current three workshops are 3D printing, app design, and graphic design (Houston, 2017).

The 3D printing and rapid prototyping workshop uses a Fused Deposition Modeling (FDM) 3D printer and its companion 3D modeling software to assist in meeting the national curriculum programing for KS3 and KS4 students (Ritman-Smith, 2018a). The workshop aims to teach students to become responsible, competent, confident, and creative users of information and computing technology by using the 3D modeling software TinkerCAD to execute the double diamond design process (*The Design Process: What is the Double Diamond?* 2015).

In the app design workshop, students work to create a working prototype of a mobile application. This workshop teaches students part of the national curriculum GCSE Design Technology. The respective objectives are to "develop realistic design proposals as a result of exploration of design opportunities and users' needs" (Ritman-Smith, 2018b). To achieve these objectives, students will work in pairs using Proto.io - a free, in-browser mockup application - to create their app (Houston, 2017).

In the third workshop, graphic design, students create a poster related to a widespread issue. This workshop was built to meet the objectives of the National Curriculum Art and Design programs of study and is intended to teach students "about the history of art, craft, design and architecture, including periods, styles and major movements from ancient times up to the present day" (Ritman-Smith, 2017). In this workshop, students work in pairs to create a poster using Sketchbook, a free pixel-based software. For examples of good design, students will use posters from the museum's collection (Houston, 2017).

Each current workshop that the Design Museum offers has one lesson plan while facing diverse Key Stages of students. Therefore, the Design Museum needs to update the contents in lesson plans so that students are "able to go away and create their own work at school" (Houston, 2019). To make lesson plans more suitable and involved for different age range, it is vital to incorporate different teaching techniques and learning styles (Richards, 2002).

**Appendix D: Interview, Survey, and Observation Guide**
The team utilized the following interview guide when interviewing stakeholders. Each stakeholder was asked each question.

**D1. Interview Guide**

1. What is your name?

2. What is your position at the Design Museum?

3. What do you enjoy about working at the Design Museum?

4. In your opinion, what should students learn when they visit the Design Museum?

    a. General goals

    b. Most valuable lesson the Design Museum teaches

5. What makes these sessions unique to the Design Museum?

6. What should a visit to the Design Museum feel like for students?

**D2. Survey Questions**

**D2.1 Surveys for Students**
The team surveyed students participating in the workshops by asking them the following questions. These questions aided our team in gathering numerical data, and data related to individual student experience.

App Design:

1. On a scale of 1 to 5, how much did you know about app design prior to completing this workshop?
2. On a scale of 1 to 5, how much do you know about app design after completing this workshop?
3. On a scale of 1 to 5, how much did you enjoy this workshop?
4. On a scale of 1 to 5, how interested are you in continuing to learn about and/or work with app design after leaving the Design Museum?
5. What is your favorite thing that you learned from this workshop?
6. Did any part of the workshop excite you (when did you have a "wow moment")?
7. Did any part of the workshop bore you (when did you lack engagement)?
8. If you could attend a workshop at the Design Museum in any design and technology field, what field would that be?

Pilot Session:

1. On a scale of 1 to 5, how much did you know about coding prior to completing this workshop?
2. On a scale of 1 to 5, how much do you know about coding after completing this workshop?
3. On a scale of 1 to 5, how much did you enjoy this workshop?
4. On a scale of 1 to 5, how interested are you in continuing to learn about coding after leaving the Design Museum?
5. On a scale of 1 to 5, how much about robotics did you learn?
6. What did you think of the worksheet (did you find it helpful)?
7. What is your favorite thing that you learned from this workshop?
8. Did any part of the workshop excite you (did you have a "wow" moment)? If so, when?
9. What about this workshop can be improved?
10. Additional comments?

**D2.2 Surveys for Educators**

This is the survey distributed to educators on the design museum twitter page. Our findings about workshop length and price are based in part on the data collected from these questions.

Online Teacher Survey:

1.  At what institution do you currently teach?
2.  Are you aware that the Design Museum offers digital design workshops?
3.  Would you bring your students to a digital design workshop at the Design Museum?
4.  Based on your response to the previous question, why or why not?
5.  Please select your ideal workshop length:
    $[] \leq 1$ hr        [] 1.5 hrs (current length)      [] 2 - 3 hrs      $[] \geq 4$ hrs
6.  How much would your institution be willing to pay for an up-to-30-student workshop of your ideal length?
7.  To be entered into the competition, please provide your email below:

Visiting Teacher Survey:

This is the set of survey questions given to educators who brought their students to the digital design workshops. The team used the data collected from these questions to help inform the desired outcomes and the existing outcomes

1.  Would you bring your students to another workshop at the Design Museum?
2.  Why did you choose to bring your students to the Design Museum?
3.  How does a Design Museum workshop add value to your curriculum?
4.  Which part(s) of the workshop, if any, do you think can be improved?
5.  Please select your ideal workshop length:
    $[] \leq 1$ hr        [] 1.5 hrs (current length)      [] 2 - 3 hrs      $[] \geq 4$ hrs
6.  How much would your institution be willing to pay for a 30-student workshop of your ideal length?

**D3. Observations - Student Engagement Walkthrough Checklist**
The team utilized this checklist when recording workshop observations. The data collected from these observations aided our team in determining the workshops' existing outcomes.

International Center for Leadership in Education. (2012). *Student engagement walkthrough checklist.*

Student Engagement Walkthrough Checklist

OBSERVATIONS

| | Very High | High | Medium | Low | Very Low |
|---|---|---|---|---|---|
| Positive Body Language | [] | [] | [] | [] | [] |

Students exhibit body postures that indicate they are paying attention to the teacher and/or other students.

| | | | | | |
|---|---|---|---|---|---|
| Consistent Focus | [] | [] | [] | [] | [] |

All students are focused on the learning activity with minimum disruption.

| | | | | | |
|---|---|---|---|---|---|
| Verbal Participation | [] | [] | [] | [] | [] |

Students express thoughtful ideas, reflective answers, and questions relevant or appropriate to learning.

| | | | | | |
|---|---|---|---|---|---|
| Student Confidence | [] | [] | [] | [] | [] |

Students exhibit confidence and can initiate and complete a task with limited coaching and can work in a group.

| | | | | | |
|---|---|---|---|---|---|
| Fun and Excitement | [] | [] | [] | [] | [] |

Students exhibit interest and enthusiasm and use positive humor.

| | | | | | |
|---|---|---|---|---|---|
| Overall Level of Student Engagement | [] | [] | [] | [] | [] |

**Appendix E: Survey and Interview Data**

**E1. App Design Survey Responses**
The team surveyed students participating in the app design workshop and received the following data. These responses aided our team in gathering numerical data, and data related to individual student experience.

On a scale of 1 to 5, how much did you know about app design prior to completing this workshop?
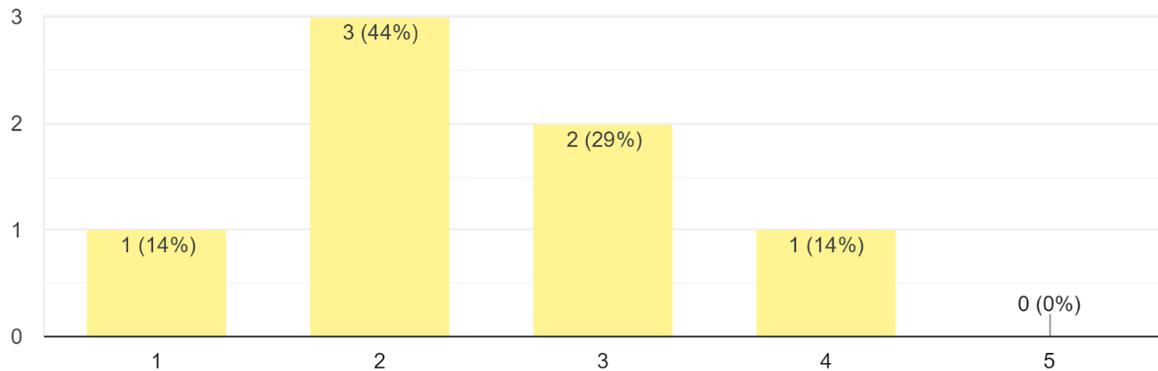


On a scale of 1 to 5, how much do you know about app design after completing this workshop?
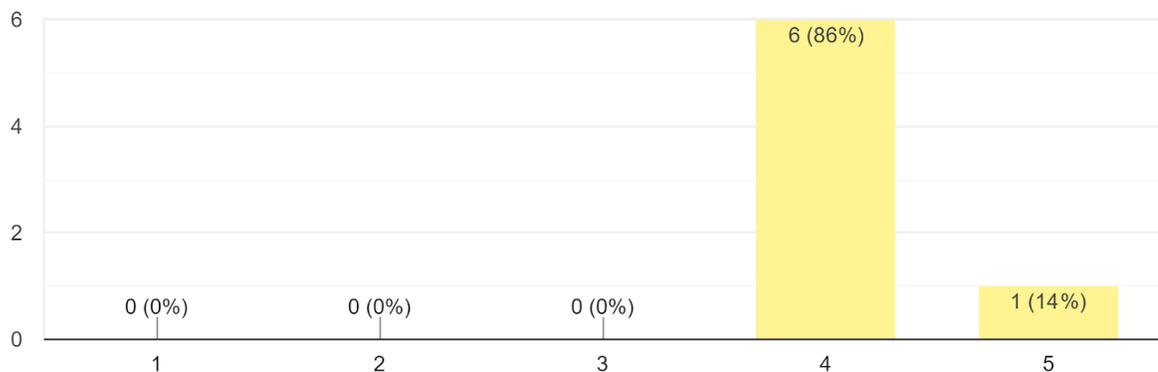
On a scale of 1 to 5, how interested are you in continuing to learn about and/or work with app design after leaving the Design Museum?
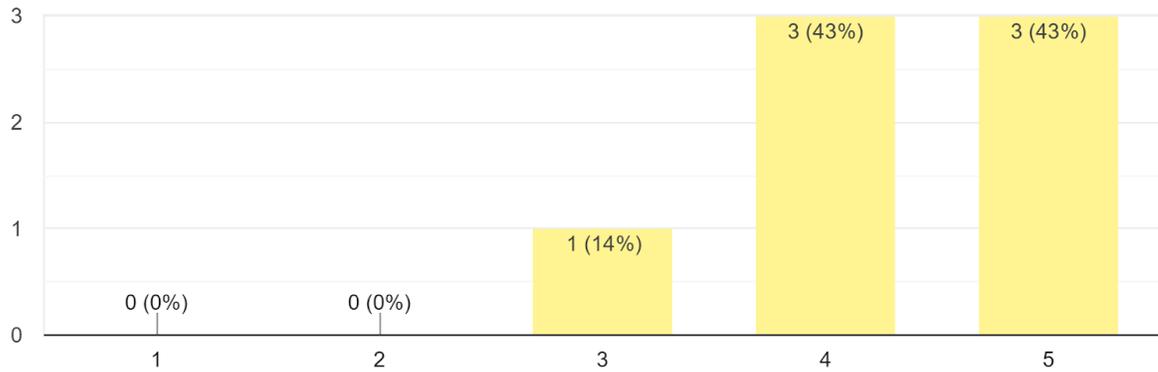


On a scale of 1 to 5, how much did you enjoy this workshop?
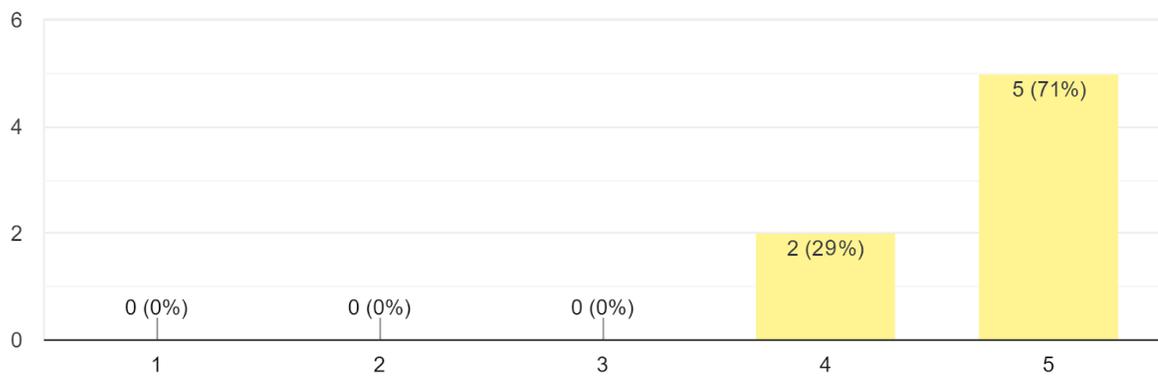
## What is your favorite thing that you learned from this workshop?

Informational Architechture (IA)

How there were 2 parts of code design, front end and back end.

How to use a new software to create an app

I could see the results of what we done so far, also the whole finding out and use new tools and software was a fun itself.

I liked that I could integrate my own ideas into my app. My favourite thing that I learnt is how to easily design an app.

How to create a mobile app

## Did any part of the workshop excite you (when did you have a "wow moment")?

During the design time

when we were able to start designing the app

when we were being taught about using Marvelapp

When what I made began interactive and it started to come in form.

To me, the part where I personally designed my app excited me.

The transitions of the app functioning correctly

## Did any part of the workshop bore you (when did you lack engagement)?

No

The introduction

no part of it bored me.

Maybe in the explanation but it was short so I was not bored of it.

Not particularly

N/A

If you could attend a workshop at the Design Museum in any design and technology field, what field would that be?

Software Design

app design

coding/designing apps and websites

Animation

app designing

AI and machine learning basics

## E2. Online Teacher Survey Responses

| Timestamp | At what institution do you currently teach? | Are you aware that the Design Museum offers digital design workshops? | Would you bring your students to a digital design workshop at the Design Museum? | Based on your response to the previous question, why or why not? | Please select your ideal workshop length: | How much would your institution be willing to pay for an up-to-30-student workshop of your ideal length? | To be entered into the competition, please provide your email below: |
|---|---|---|---|---|---|---|---|
| 5/13/2019 17:22:40 | Primary school | Yes | Yes | It would be a great hands on experience | Less than or equal to 1 hour | Not sure | bkserex@gmail.com |
| 5/13/2019 17:23:19 | School | No | Yes | For up to date subject content. | 1.5 hours (current length) | £100 | Tapley@guilsborough.northants.sch.uk |
| 5/13/2019 19:51:36 | Walthamstow School for Girls | No | Yes | I think the students would enjoy the experience | 1.5 hours (current length) | £150 | shealy@wsfg.waltham.sch.uk |
| 5/14/2019 6:02:30 | New Cit College Epping Forest | No | Yes | Digital design is the future and this will open up potential career opportunities for them | 1.5 hours (current length) | £7-£10 per student but as we are an FE college we would probably have to ask the students to contribute | Rpearce@efc.ac.uk |
| 5/15/2019 13:35:27 | Trinity School, Newbury | No | Yes | It's great to get expertise from professionals outside of school. Engaging for students to be doing elsewhere outside of normal environment. | 2 - 3 hours | £75 | landerson@trinity.newburyacademytrust.org |
| 5/15/2019 21:44:13 | Horsforth School | No | Yes | Great place for inspiration and research | 2 - 3 hours | £5 per student (ideally free as trains cost so much) | Milnert01@horsforthschool.org |
| 5/23/2019 11:30:09 | Larbert High School | No | Yes | Digital learning is at the heart of some many areas in teaching these days. Helps motivate and engage pupils. | 2 - 3 hours | £300.00 | juliemartin01@hotmail.com |
| 5/23/2019 14:55:42 | Offham Primary School | No | Yes | They would learn so much to support their learning and get to visit an iconic institution. | 2 - 3 hours | £300 | tsalter@offham.kent.sch.uk |
| 5/25/2019 19:32:56 | London Design and Engineering | Yes | Yes | It is important for learners to experience design in a real world context. Working with designers amd design institutions. | 2 - 3 hours | £300 | Sharon.morgan@ldeutc.co.uk |
| 5/27/2019 22:17:28 | The St Michael Steiner school | No | Yes | They love the museum | 1.5 hours (current length) | £5 -£10 each | Juliawallace@stmichaelsteiner.hounslow.sch.uk |

**E3. Survey Responses for the 60-minute Pilot Session of Coding Workshop**
The team surveyed students participating in the 60-minute pilot session of the proposed coding workshop and received the following data. These responses aided our team in gathering numerical data, and data related to individual student experience.

On a scale of 1 to 5, how much did you know about coding prior to completing this workshop?
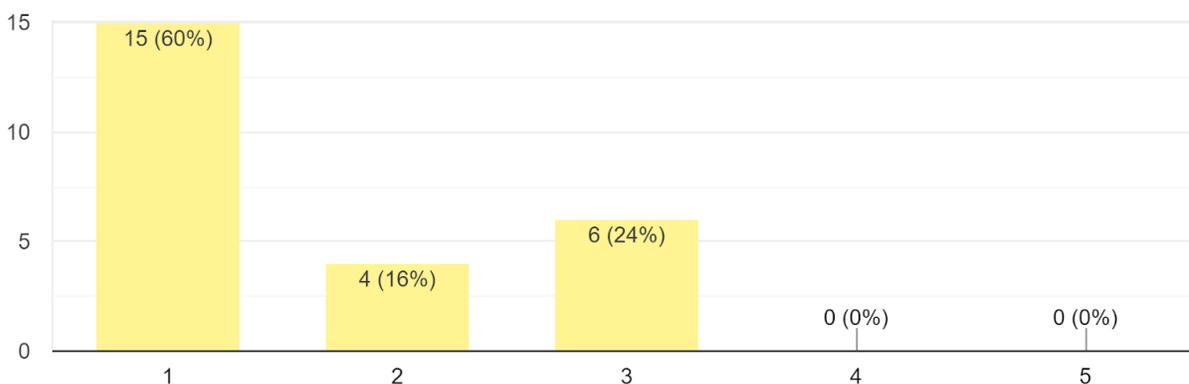


On a scale of 1 to 5, how much do you know about coding after completing this workshop?
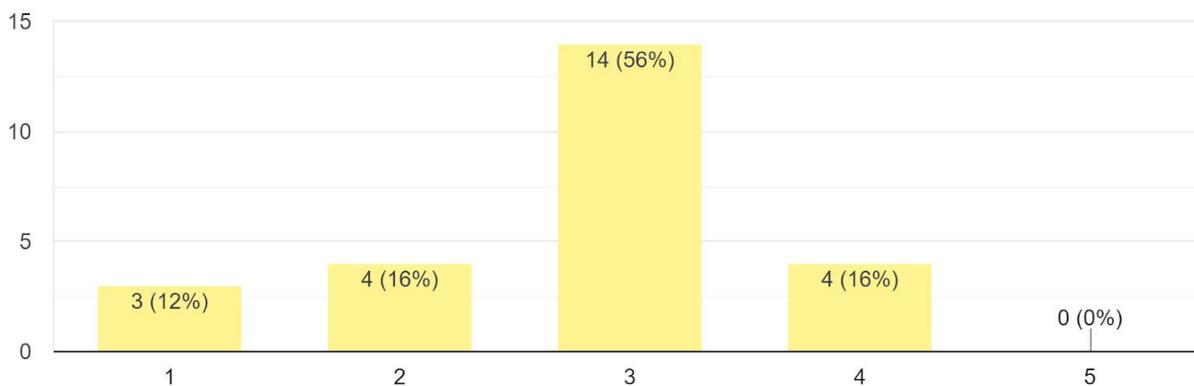
On a scale of 1 to 5, how much about robotics did you learn?
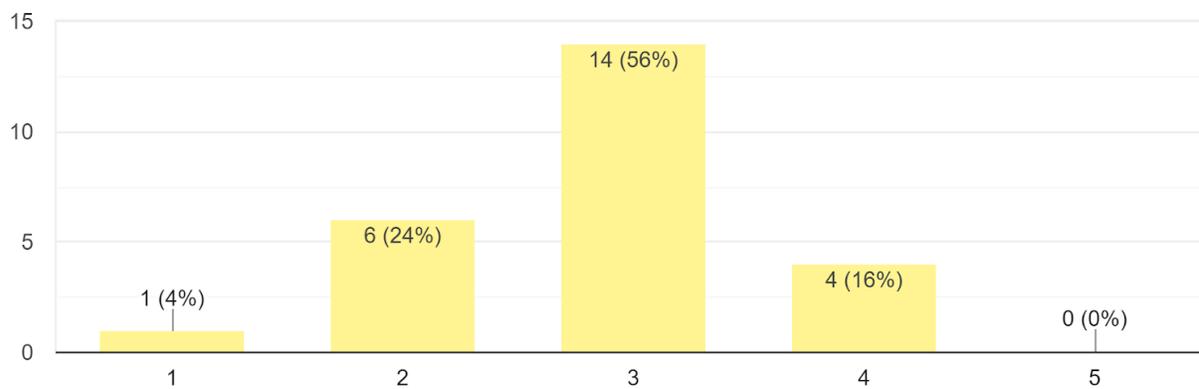


On a scale of 1 to 5, how interested are you in continuing to learn about coding after leaving the Design Museum?
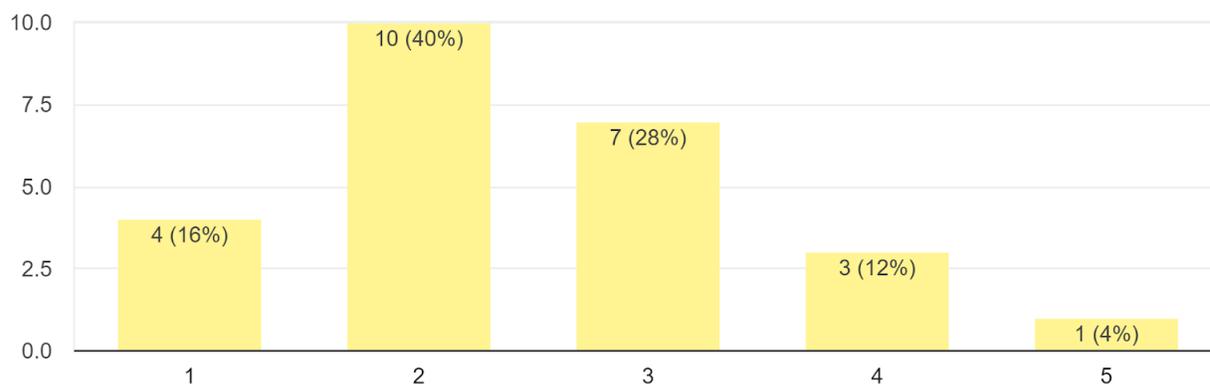
# What did you think of the worksheet (did you find it helpful?)

yes

I didnt really read it sorry

was very interesting

not really

it was interesting

yes very helpful and very colourful

yes, i find it helpful

Yes, very colourful

yes, but more time would've been helpful

was okay

Was really helpful

superb

didn't use it.

A little

helpful

page 2 and 3 good, page 1 confusing, too crammed

I didn't read it

the colours and shapes make it easy to understand the process

yes for basics and it was informative

didn't use it

little crammed

I have not had another time to yous it cause they explained very good

did not use it

# What about this workshop can be improved?

everything was nice :)

music

everything was nice

nothing

the presentation

could be a little bit slower

the sound/music

robots

a littel bit slower

More help and more time for the program

More time, maybe a whole day

I think it was pretty good

More things to show

computer work could be a bit longer

smaller groups, more fashion/Start with fashion examples. explain better why we do this. what is the use.

playing sounds on the devices

more time to experiment with the programme

second part of workshop too fast, maybe give a little more time

it was gr8

robots!!!!!

(our English haha)

its cool

more time for dog toy

for the time we had it was perfect

# What is your favorite thing that you learned from this workshop?

coding

making hearts (icons via basic coding)

microbit

easy programming steps

the programming

to see how roboter are programmed

that a washing machine is also a robot

playing with coding

The microbic

washing machines are robots

that there are obviously easier ways of programming

coding

corresponding functions

the sounds

making a code

how input can be translated that easy into led signals

what is a robot

the lights were fun

robots are dumber than humans

programming

what is possible, for fashion

the weird dog toy

how to program leds

robots are everywhere

# Did any part of the workshop excite you (did you have a "wow moment")? If so, when?

no

when the heart appeared

I did not have one

when false then... when true then...

when the code was displayed on the microbic

when it started blinking

when it worked and my name was shown on the microbic

when we found out that washing machines are robots and when the microbic did what we told it to do

coding

When the microbit played our program

See the light blinking

when we saw that it does not has to be that complicated

not really

yes, when the music started playing, that was a very joyful moment

how fast the code loads on the device.

that everybody can do that with the computer at home on their own with the right programs.

how easy the makecode editor works

more things are robots than expected

when the program worked and lit up

nope

when the LED's turned on

THE WEIRD DOG TOY

the robot

## E4. Interview Coding

The coded interview data below aided our team in determining the workshops' desired outcomes.

| Name | Position at the DM | Favorite parts of working at DM | What should students learn? | What makes these sessions unique to DM? | What should make these sessions unique? | What should a visit to the DM feel like for students? |
|---|---|---|---|---|---|---|
| David Houston | Learning Producer - Schools and Further Education | Diversity: work on projects with a wide range of people | Real-world: Real-world, practical applications | Nothing: Not unique | DM: shouldn't function outside the context of the museum; should involve collections/exhibits | Goal: keep the main goal in mind, and information relevant |
| | | Exhibits: offer easy access to new information | Design: advance students' knowledge of design | Heritage: | Education: | |
| | | Children: offer an interesting perspective | | Resources: | Focus: | |
| | | People: Working with young people who offer an interesting perspective | | | | |
| Tzveta Dinova | Freelance Educator - Workshop Creator | Diversity: work with interesting people | Real-world: | Nothing: | DM: | Goal: foster student's passions |
| | | Exhibits: diverse collection, a lot of heritage to build off of | Inspire: inspire students, school curriculum does not always align with student interest | Heritage: primary focus on design | Education: take students outside the limitations of school | |
| | | Children: | Design: | Resources: targeting students who don't think they are capable of creativity | Focus: | |
| | | People: | | | | |
| Sevra Davis | Head of Learning | Question not asked | Real-world: Relevant to future society & technology | Question not asked | DM: ensure that the workshops are not replicating workshops elsewhere | Goal: DM should fill the gap in the latter between skills and passions |
| | | | Inspire: Focus more on fostering passions than teaching skills; schools do the latter already | | Education: youth should gain forward-looking skills | |
| | | | Design: more focus on process than result | | Focus: focus on the design process | |
| Joe Hoole | Freelance Educator for Digital Design Workshops | Diversity: | Real-world: | Nothing: not much | DM: do not integrate too much, it may seem too "product placement-y" | Goal: students should ask a lot of questions, pique their interest in design |
| | | Exhibits: | Inspire: Pique interest in design, ask a lot of questions | Heritage: | Education: ideally implement 2 hr sessions, so the students can go more in depth | |
| | | Children: flexibility, working with all student age groups | Design: | Resources: | Focus: get students to expand their creativity and think outside the box | |
| | | People: | | | | |

| Name | Position at the DM | Favorite parts of working at DM | What should students learn? | What makes these sessions unique to DM? | What should make these sessions unique? | What should a visit to the DM feel like for students? |
|---|---|---|---|---|---|---|
| Tom Wilson | Head of Collections and Research | Diversity: | Real-world: | Nothing: Unsure | DM: Bridge the gap between what is digital and what is physical | Goal: not sure |
| | | Exhibits: very practical, need to think about what we have and the practicality of it | Inspire: | Heritage: | Education: recognize the difference between good vs. bad design with exhibit examples | |
| | | Children: | Design: | Resources: | Focus: encourage the students to see objects through the designer's perspective | |
| | | People: | | | | |
| Komal Khetia | Programme Producer: Young Audiences | Question not asked | Real-world: Learn through making, gain skills at DM and then actually make somewhere else | Nothing: Allow the sessions to remain accessible outside of the Design Museum | DM: Keep content specific to the exhibitions, but still make it accessible outside the DM | Goal: Provide a brand-new experience, amaze students with what they can accomplish |
| | | | Inspire: Be amazed at what they can do with that knowledge (learned in the workshop) | Heritage: | Education: learning should be fun, but must have a point | |
| | | | Design: | Resources:- keep the content specific to the exebtions | Focus: | |
| Sally Jones | Freelance Educator for Hands-on Design Workshops | Diversity: | Real-world: Teach something that is relevant to their lives that isn't taught in school | Question not asked | Question not asked | Goal: gain insight on the design process, offer a unique interactive experience |
| | | Exhibits:- | Inspire: | | | |
| | | Children: enjoys working with kids | Design: Offer insight into the design process | | | |
| | | People: everyone is welcoming and friendly | | | | |
| Haidée | Freelance Educator for Hands-on Design Workshops | Question not asked | Real-world: A sense of how design has impacts on their everyday lives | Question not asked | Question not asked | Goal: Tools to understand how they interact with design |

## Appendix F: Completed Evaluation Frameworks

### F1. Evaluation Framework for the App Design Workshop
The modified Expero Framework below aided our team in determining the effectiveness of the existing app design workshop.

| Desired Outcomes | | Existing Outcomes (App Design) |
|---|:---:|---|
| **Education** | **Education** | **Education** |
| Should not focus on technical learning as the main objective of each session | ✓ | Students gained understanding of app design |
| Should combine technical skills with students' passions | ✓ | Combines technical knowledge with students' passions: students are able to design an app for a user they define |
| Should take students outside the limitations of school | ??? | The team is unable to answer this question |
| Should complement the education students are receiving in school | ✓ | If the learning targets stated in the outline are correct, then the workshop fufills this desired outcome |
| **Real-World** | **Real-World** | **Real-World** |
| Should provide a real-world, practical, application of what students are learning in school | ✓ | Encourages students to design for the real world |
| Should be relevant to the future of design and technology | ✓ | App design is relevant to the (immediate) future of design and technology |
| **Inspiration** | **Inspiration** | **Inspiration** |
| Should inspire students to go out and further explore design and technology on their own | ✓ | Students left asking questions on how to continue learning about app design after leaving the DM |
| Should focus on fostering students' passions | ✓ | Fostered students' passions through the lens of design and technology, whether these passions were tech focused or not |
| Should cause students to leave asking questions | ✓ | Students left asking questions on how to continue learning about app design after leaving the DM |
| **Design Museum** | **Design Museum** | **Design Museum** |
| Should not be able to exist without the context of the Design Museum | X | The presentation did not relate to the museum and can be delivered elsewhere with the same impact |
| Should involve collections/exhibits, build off the heritage of the Design Museum | X | The presentation did not relate to the museum's collection and can be delivered elsewhere with the same impact |
| Should involve physical objects for students to interact with | X | The presentation did not offer physical objects for the students to interact with |
| **Design** | **Design** | **Design** |
| Should advance student knowledge of design | ✓ | Advanced students knowledge of design |
| Should focus on the design process | ✓ | Focused on the design process |

**F2. Evaluation Framework for the Graphic Design Workshop**
The modified Expero Framework below aided our team in determining the effectiveness of the existing graphic design workshop.

| Desired Outcomes | | Existing Outcomes (Graphic Design) |
|---|---|---|
| **Education** | **Education** | **Education** |
| Should not focus on technical learning as the main objective of each session | ✓ | Focused mainly on a potential protest issue |
| Should combine technical skills with students' passions | ✓ | Students utilised the skills they learned to create a poster that incorporated something they are passionate about |
| Should take students outside the limitations of school | ✓ | Students have the ability to freely express what they are passionate about |
| Should complement the education students are receiving in school | ✓ | Complements school curriculum by having students think critically about exemplifying social issues through design |
| **Real World** | **Real World** | **Real World** |
| Should provide a real-world, practical, application of what students are learning in school | ✓ | Grapic design skills learned are transferable to other graphic applications in school, as well as the real world |
| Should be relevant to the future of design and technology | ✓ | Graphic design is relevant to the future of design and technology |
| **Inspiration** | **Inspiration** | **Inspiration** |
| Should inspire students to go out and further explore design and technology on their own | X | Fosters student interest in the social issue they describe in their poster, not necessarily in design and technology |
| Should focus on fostering students' passions | ✓ | Allows the students to express what they are passionate about |
| Should cause students to leave asking questions | X | Does not leave students asking questions |
| **Design Museum** | **Design Museum** | **Design Museum** |
| Should not be able to exist without the context of the Design Museum | X | The presentation can stand alone outside of the DM with the same impact |
| Should involve collections/exhibits, build off the heritage of the Design Museum | ✓ | The Obama Hope poster is the only poster in the museum's collection that is included in the presentation |
| Should involve physical objects for students to interact with | X | The presentation did not offer physical objects for the students to interact with |

## F3. Evaluation Framework for the 3D Printing Workshop
The modified Expero Framework below aided our team in determining the effectiveness of the existing 3D printing workshop.

| Desired Outcomes | | Existing Outcomes (3D Printing) |
|---|---|---|
| **Education** | **Education** | **Education** |
| Should not focus on technical learning as the main objective of each session | X | The majority of this lesson focuses on the technical skills 3D printing requires |
| Should combine technical skills with students' passions | X | Students are provided with criteria that limits their ability to integrate what they are passionate about |
| Should take students outside the limitations of school | ✓ | Students gain Tinkercad and 3D modeling experience, which is most likely not offered at their institution |
| Should complement the education students are receiving in school | ✓ | If the learning targets stated in the outline are correct, then the workshop fufills this desired outcome |
| **Real World** | **Real World** | **Real World** |
| Should provide a real-world, practical, application of what students are learning in school | ✓ | Students are solving real-world problems for real-world users |
| Should be relevant to the future of design and technology | ✓ | 3D Printing is relevant to the (immediate) future of design and technology |
| **Inspiration** | **Inspiration** | **Inspiration** |
| Should inspire students to go out and further explore design and technology on their own | ??? | The team is unable to answer this question |
| Should focus on fostering students' passions | X | Students are provided with criteria that limits their ability to integrate what they are passionate about |
| Should cause students to leave asking questions | ??? | The team is unable to answer this question |
| **Design Museum** | **Design Museum** | **Design Museum** |
| Should not be able to exist without the context of the Design Museum | ✓ | Utilises the design process to design and create an object |
| Should involve collections/exhibits, build off the heritage of the Design Museum | ✓ | Includes objects from the museum's collection |
| Should involve physical objects for students to interact with | ✓ | Students interact with objects made from different 3D-printed materials, as well as objects from the DM collection |
| **Design** | **Design** | **Design** |
| Should advance student knowledge of design | ✓ | Advanced student knowledge of design through the lens of 3D printing |
| Should focus on the design process | ✓ | Students utilise the design process to solve a problem for a user |

## F4. Evaluation Framework for the 30-minute Pilot Session

The modified Expero Framework below aided our team in determining the effectiveness of the 30-minute pilot session for the proposed coding workshop.

| Desired Outcomes | | Existing Outcomes (Programming) |
|---|:---:|---|
| **Education** | **Education** | **Education** |
| Should not focus on technical learning as the main objective of each session | X | The *pilot session* focuses on the practical portion of the lesson |
| Should combine technical skills with students' passions | ✓ | Allows students to define their own problem within the bounds of the prompt |
| Should take students outside the limitations of school | ✓ | Presents students with materials that may not be accessible at their institutions |
| Should complement the education students are receiving in school | ✓ | Complements the programming education students are receiving in school |
| **Real World** | **Real World** | **Real World** |
| Should provide a real-world, practical, application of what students are learning in school | ✓ | Students learn how to apply basic coding knowledge to a real-world situation |
| Should be relevant to the future of design and technology | ✓ | IOT is relevant to the (immediate) future of design and technology |
| **Inspiration** | **Inspiration** | **Inspiration** |
| Should inspire students to go out and further explore design and technology on their own | ✓ | Students left asking questions on how to continue learning about coding after leaving the DM |
| Should focus on fostering students' passions | ✓ | There is a semi-open prompt that allows students to create something that incorporates what they are passionate about |
| Should cause students to leave asking questions | X | Prompts students to ask questions related to code, not design |
| **Design Museum** | **Design Museum** | **Design Museum** |
| Should not be able to exist without the context of the Design Museum | X | The *pilot session* has minimal ties to the museum |
| Should involve collections/exhibits, build off the heritage of the Design Museum | ✓ | Utilises objects found on the IOT wall in DMU |
| Should involve physical objects for students to interact with | ✓ | The students are interacting with (micro:bits) mini versions of sensors that can be found in IOT-like devices |
| **Design** | **Design** | **Design** |
| Should advance student knowledge of design | X | The *pilot session* has minimal focus on design |
| Should focus on the design process | X | The *pilot session* has minimal focus on the design process |

## F5. Evaluation Framework for the 60-minute Pilot Session

The modified Expero Framework below aided our team in determining the effectiveness of the 60-minute pilot session for the proposed coding workshop.

| Desired Outcomes | Education | Existing Outcomes (Programming) |
|---|---|---|
| **Education** | | **Education** |
| Should not focus on technical learning as the main objective of each session | ✓ | Primarily focuses on the interaction between a user and an object and how it is accomplished through programming |
| Should combine technical skills with students' passions | ✓ | Students utilise the skills they learn to create something they are passionate about |
| Should take students outside the limitations of school | ✓ | The lesson allows students to think about real-world problems outside of schools |
| Should complement the education students are receiving in school | ✓ | For schools teaching the national D&T curriculum, this lesson complements the students' education |
| **Real World** | **Real World** | **Real World** |
| Should provide a real-world, practical, application of what students are learning in school | ✓ | Students are solving real-world problems for real-world users, utilising design tools they've learned in the classroom |
| Should be relevant to the future of design and technology | ✓ | Programming is relevant to the future of design and technology |
| **Inspiration** | **Inspiration** | **Inspiration** |
| Should inspire students to go out and further explore design and technology on their own | ✓ | Students left asking questions on how to continue learning about programming after leaving the DM |
| Should focus on fostering students' passions | ✓ | Aims to foster students' passions through the lens of design and technology |
| Should cause students to leave asking questions | ✓ | Students left asking questions on how to apply programming after leaving the DM |
| **Design Museum** | **Design Museum** | **Design Museum** |
| Should not be able to exist without the context of the Design Museum | ✓ | Each section of the lesson focuses on either, the design process or creating an object-user interaction |
| Should involve collections/exhibits, build off the heritage of the Design Museum | ✓ | Focuses on the design process and includes objects from the museum's collection |
| Should involve physical objects for students to interact with | ✓ | The workshop provides handling objects (sensors) for students to interact with |
| **Design** | **Design** | **Design** |
| Should advance student knowledge of design | ✓ | Explains the effect design has on an object-user interaction |
| Should focus on the design process | ✓ | Focuses on the design process |

**Appendix G: Proposal for the Coding Workshop - Deliverable**

**G1. Outline for the Proposed Workshop**

**Summary:**

This potential workshop integrates coding, sensors, and design, focusing on how designers create user interaction within the digital world. Students will explore the definition of design in this context utilizing example objects from the Design Museum's collection, including the Internet of Things wall. These objects will prompt students to consider the user of each object, and to think critically about the impact the design has. Students will also consider the impact design has on their own lives. Next, students will receive an introduction to programming as a method used by designers to facilitate interaction. Students will then be taught basic technical programming skills. From these base-level skills, students will design an Internet of Things (IOT)-like device. To do this, students will define a user, a problem, and visualize a product idea via drawing. They will then use the programming skills they learned throughout the lesson to create such a device. Once the students finish creating their devices, they will then present them to the group, along with their initial user, a problem, and their drawing for the physical device.

**Learning Outcomes:**
1. Students should be given the tools to interact with design in their lives.
2. Students should learn how designers utilize sensors and programming to design user interaction.
   a. Designer, Maker, User
3. Students should learn the basics of computer programming.

**Handling Objects:**
Pass around sensors and pieces of IOT-like devices to physically show the students the technical side behind the physical design.
- Ultrasonic sensor
- Potentiometer
- Photoresistor

**Workshop Breakdown:**
- Introduction: a list of quick facts about sensors.
  - Teachers should encourage their students to think about where they may find these devices in their everyday lives.
  - Images: Show pictures of the Internet of Things wall from DMU
  - Handling objects: pass around sensors and pieces of IOT-like devices to physically show the students the technical side behind the physical design.

**Start of workshop: 90 minutes**
This document is intended to aid workshop facilitators in the facilitation of the lesson once they gauge the age range and expertise of the participating students. The instructor may split the students into groups and begin the lesson.

Introduction: 10 minutes
- ○ What is a designer?
  - ■ What do they do?
  - ■ Why do they design?
    - ● Users (Designers design for people)
  - ■ The designer's role is to create an interaction between a user and an object
  - ■ What are other examples of well-designed human and object interaction in your (the students) lives?
- ● How does a designer create an interaction between the physical world and the digital world?
  - ■ To create interactions in the digital sphere, designers use a variety of tools and methods:
    - ● Programming
    - ● Sensors
- ○ Transition into technical coding lesson
  - ■ To utilize these tools, a designer must have technical knowledge, which often includes an understanding of programming, materials, and how sensors work and when to use them
- ○ Provide brief outline for the rest of the workshop to the students to incentivise listening to a brief lecture
  - ■ Learning programming fundamentals (see powerpoint)
  - ■ Applying these skills to design a product based on a specific user profile
- ○ Pass out laptops to each student
- ● Teaching: 20 minutes
- ● MakeCode Editor - micro:bit online block programming language
  - ○ Introduce each topic using the nest code as a guided example
    - ■ Start with triggers, explain what they do and where to find them
      - ● On start, forever, on shake
    - ■ Conditionals
      - ● If statements, how it utilizes a true false block
      - ● Else
      - ● Else if
    - ■ True/false blocks and numbers
      - ● numbers
        - ○ explain that they can be integers and sensor input variables

- ● True/false blocks
  - ○ What they are, where they are found, how are they used
  - ○ Inequalities, and/or
- ■ Loops
  - ● While loop, how it utilizes true/false blocks to determine if it runs the code
  - ● For loop, runs code the amount of times specified
- ■ Sensors: where to find them and what they do
- ■ Give students 5 minutes to explore makecode, have them modify the example they created with the instructor
- ● Hands-on setup: 10 minutes
  - ○ Provide scenarios about home automation based on the aspect of human interaction design and some examples of user stories (Scenario 1 and 2 are considered using micro:bit and its built-in brightness, temperature sensors)
    - ■ Scenarios (All KS: display variables. KS4/KS5: additionally, adjust variables)
      - ● Scenario 1: Light sensing - Display the brightness of the room and adjust brightness on command. It will most likely not be possible to have students actually adjust the brightness of the room, but they should show that their code *can* change the brightness.
      - ● Scenario 2: Temperature sensing - same as above, but with temperature
    - ■ Have the student groups think about a problem and who's affected by that problem (the user). Brainstorm solutions to this problem using the micro:bit
  - ○ Transition into hands-on session, letting students write code based on their user stories
- ● Hands-on: 35-40 minutes
  - ○ Maintain same groups
  - ○ Ask all students to:
    - ■ Determine the user, the problem, and some potential solutions
    - ■ Draw what the final product might look like
      - ● Ask students to think critically about how the programming of the micro:bit might be utilized to support a user-object interaction.
    - ■ Inform the students that if they are unable to fully code their device, that is OK!
      - ● The students should be able to explain what they want their device to do, which sensors to utilize, and why.

- ○ KS2 students
  - ■ Provide students with pre built "function blocks" that they can configure to send outputs
  - ■ Ask students if, based on the previous lesson, they can explain how the function blocks work
  - ■ Students can then combine function blocks to create code that can be used on the micro:bit to assist the object the team has designed
- ○ KS3 students
  - ■ Give students textual directions (or perhaps pseudocode) to put blocks together, as well as brief explanations of the blocks involved. Then allow them to put the blocks together themselves.
- ○ KS4-5 students
  - ■ For students with no prior coding experience, teach them variables, conditionals, loops, etc. in the block coding environment, MakeCode Editor. Then, students may explore the language environment themselves.
  - ■ For students who already know Python (or another mid-to-high level language), they can alternatively be given instructions on how to control the micro:bit with Python.
  - ■ Hands-on time: more time should be left for students to code in their groups (provide reminders of the instructions as necessary)
- ● Present & Conclude: 10-15 minutes
  - ○ Have the students/groups each present their project. Present their devices to the group along with their initial user story and the drawing for the physical device.

Worksheet:
- ● KS4:
  - ○ Pseudocode that represents the basic goal, but students need to fill in the exact code
  - ○ Reminders for conditions, loops and variables in coding
- ● KS5:
  - ○ Instructions or hints on the logic of the coding that achieve basic goal
  - ○ Reminders for conditions, loops and variables in coding

**G2. Proposed Workshop Slides**

# The User



# Internet of Things Wall
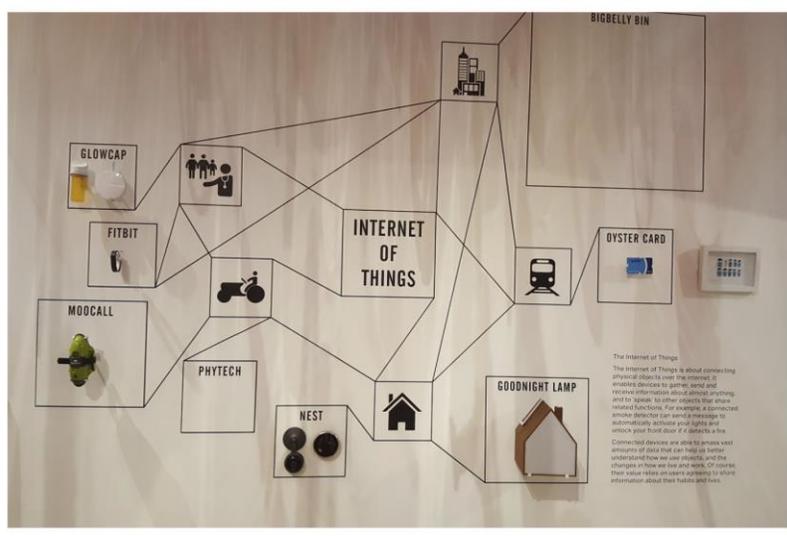
What is this?

What does it do?

Who uses this?

How does it work?



What is this?

What does it do?

Who uses this?

How does it work?

What is this?

What does it do?

Who uses this?

How does it work?



## User-Object Interaction

Programming:
the way humans tell
computers what to do



Sensors: a tool computers use to
gather data about the world

## Potential Nest Code

A Nest temperature sensor continuously checks temperature.

- If it's too cold, turn on the heat
- If it's too hot, turn on the air conditioner
- If it's the proper temperature, display a smiley face
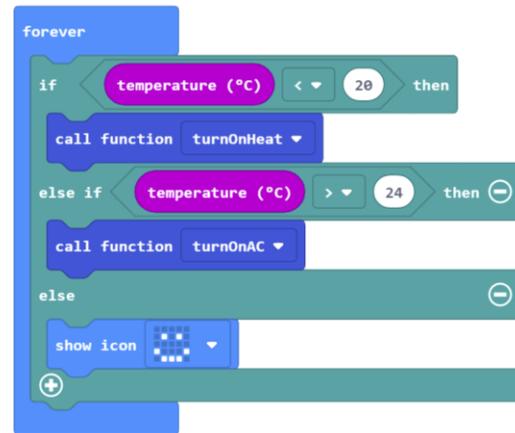


## Create a user-object interaction



Solve a problem by creating a user-object interaction with a micro:bit and either a temperature sensor, light sensor, or accelerometer.

# Brainstorm

What is the problem?

Who is the user?

How can your sensor solve that problem?

**G3. Proposed Workshop Worksheet**

# MakeCode Editor

MakeCode Editor is a block coding environment for micro:bit.
The following are various data types and their corresponding functions.

### True/False Block

A statement that is either true or false.
These True/False blocks are generally used for a comparison:
    - if two numbers are equal or not
If a value in the MakeCode Editor is in a pointed block, it is a True/False block.
*Found under "Logic"

true ▼

false ▼

temperature (°C) > ▼ 20

### String

"Hello!"

"1234 ABCD"
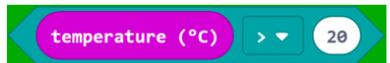
Text that is displayed on the screen. Strings are always contained inside quotation marks, the MakeCode Editor will do this for you.
*Found under "Basic"

4

light level

### Number

Any numerical value. Contained inside a rounded block without quotation marks. Sensor values are also often numbers.
*Found under "Basic"

### Trigger

Includes:
- on start
- on shake
- on button press, etc.

When one of these actions occurs, the code inside the block is executed.
*Found under "Basic" and "Input"

on start

on button A ▼ pressed

on screen down ▼

on shake ▼
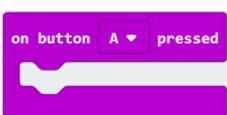
### Output

Displays a number, word, or picture on the LED screen.
*Found under "Basic"

show icon ▼

show number 0

show string "Hello!"

2
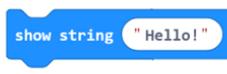
| Loop: | Utilised to run the same block or blocks multiple times. | |
|---|---|---|
| **Forever** | Executes the code inside the loop forever, starts when the micro:bit is turned on. *Found under "Basic" | forever |
| **While** | Executes the code inside the loop as many times as indicated. *Found under "Loops" | repeat 4 times do |
| **Repeat** | Executes the code inside the loop as long as the True/False Block is true. *Found under "Loops" | while true do |

| Input Variables: | Also known as the sensors on the Micro:bit. | |
|---|---|---|
| **Light Level (brightness)** | Number: a value from 0 (dim) to 255 (brightest) | light level |
| **Temperature** | Number: degrees Celsius | temperature (°C) |
| **Button/Pin (on & off)** | True/False: whether or not Button A is pressed | button A is pressed |
| **Accelerometer** | Number: the acceleration of the micro:bit | acceleration (mg) x |
| **Compass Heading (degrees)** | Number: changes in compass bearing | compass heading (°) |
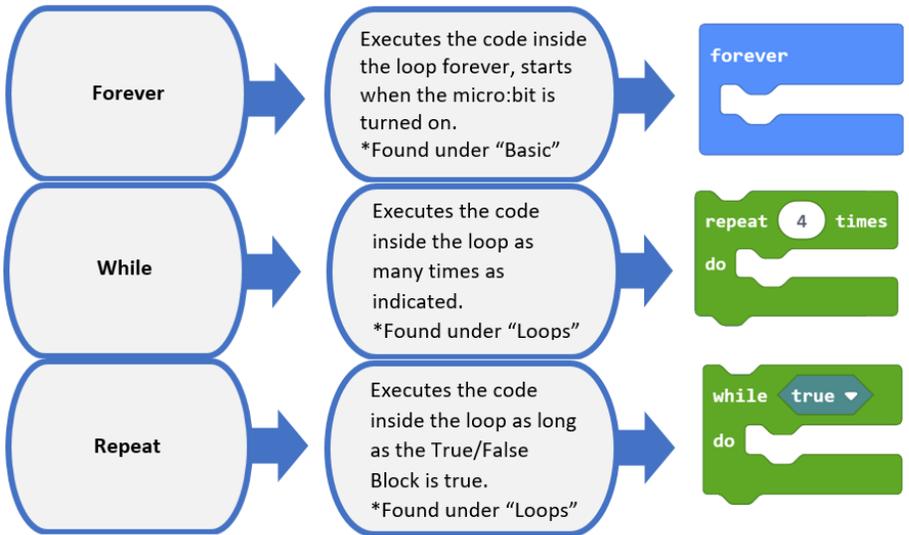
**Conditions (Logic):**

| | | |
|---|---|---|
| **If** | If the True/False block is true, then execute the code |  |
| **If** **Else** | If the True/False Block is true, then execute the code inside the first section. Otherwise, then execute the code inside the second section. |  |
| **If** **Else If** **Else** | If the first True/False Block is true, then execute the code inside the first section. If the first True/False Block is false and the second True/False Block is true, then execute the code inside the second section. Otherwise, then execute the code inside the third section. |  |

4

# Examples

Frameworks are useful for designing code.

As a [*who*], I want to [*what*] so that I can [*why*].

1.  As a [*security guard*], I want to [*know when the safe is shaken*] so that I can [*tell if somebody is trying to open it*].
    - This example utilises the <u>accelerometer</u> in the micro:bit.

| Pseudocode | Code |
|---|---|
| When the safe is shaken {<br>   While (true) {<br>      Show an "X" on LED screen<br>      Wait 1 second<br>      Clear LED screen<br>      Wait ½ second<br>   }<br>  } |  |
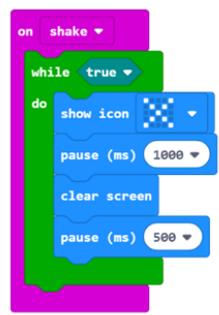
2.  As a [*security guard*], I want to [*know if the brightness within the safe changes*] so that I can [*tell if somebody is trying to open it*].
    - This example utilises the <u>brightness sensor</u> in the micro:bit.

| Pseudocode | Code |
|---|---|
| Forever {<br>  If the brightness is greater than 180<br>   {<br>     Show an "X" on LED screen<br>     Wait 1 second<br>     Clear LED screen<br>     Wait ½ second<br>   }<br> } |  |
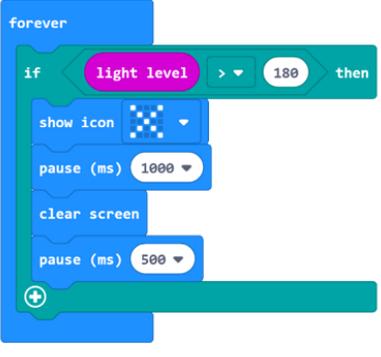
**Appendix H: Pre- and Post-Visit modules**

**H1. App Design Pre-Visit Module**

**App design** is the act or process by which designers develop a mobile app for mobile devices.

Consider an app that you find hard to use, perhaps due to its poor design.
- Who would download this app?
- What does the app help users accomplish?
- How might you improve this app?

Brainstorm potential solutions and sketch the sample app screens below.

| Login screen | First screen |
|---|---|
| | |
| **Second screen** | **Third screen** |
| | |

## H2. App Design Post-Visit Module

**App design** is the act or process by which designers develop a mobile app for mobile devices.

The following links allow *beginner* students to advance their graphic design skills:

- Marvel App - Creating your first prototype:
  https://www.youtube.com/watch?v=Vm1J2wUhNOk
  In this video, the instructor shows students how to sign up for marvel app and begin designing and app

The following links allow *experienced* students to advance their graphic design skills:

- Rapid Prototyping with Marvel App and Sketch App - Full app demo:
  https://www.youtube.com/watch?v=DfFcGdCWBKQ
  This video goes in-depth on creating an app in Marvel App, specifically, integrating other pieces of software such as Sketch App to create more complex designs

User Experience: These links describe rules and theories behind creating a user experience. The first article describes Google's user experience principles, and the second link describes additional key principles.w

- Google UX principles:
  https://medium.com/swlh/infographics-mobile-app-design-principles-13-rules-for-creating-apps-that-stick-f607959692be

- Mobile UX design:
  https://uxplanet.org/mobile-ux-design-key-principles-dee1a632f9e6

### H3. Graphic Design Pre-Vist Module

**Graphic design** is the art or skill of combining text and pictures in a way that portrays a message.

Find a poster in a magazine, on a billboard, or somewhere else, and consider the following questions:
- What is this poster advertising?
- How does it draw your attention?
- How does this design influence you (or the intended audience)?

Utilising the examples below: (Feel free to use another sheet of paper!)
- Re-imagine one of the posters into the style of one of the others.
- Create a new poster of the same style but discourage the audience from using the product.
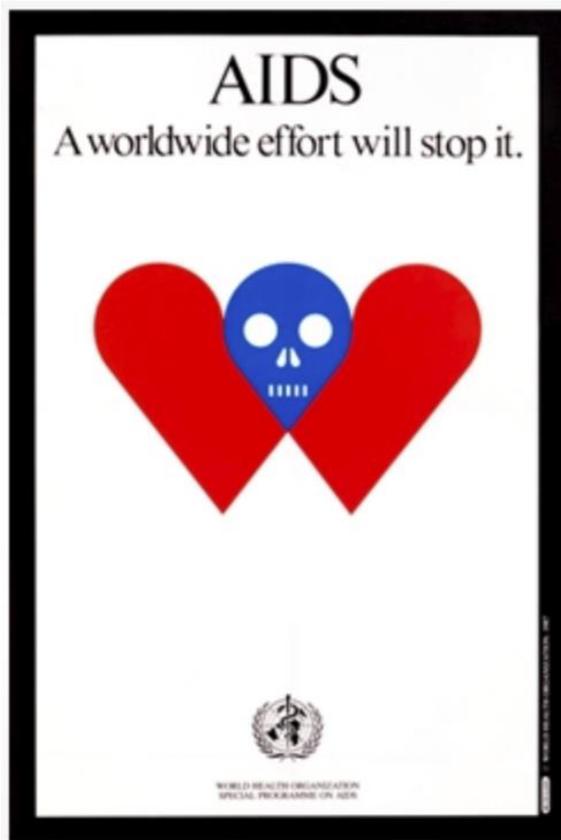
**H4. Graphic Design Post-Visit Module**

**Graphic design** is the art of combining text and pictures in a way that portrays a message.

The following links provide helpful information for how to use Sketchbook Pro and information about general graphic design principles.

- Instructions on all of the tools available in Sketchbook Pro and how to use them: https://design.tutsplus.com/tutorials/the-beginners-guide-to-sketchbook-pro--cms-30592

- 30-minute video tutorial and demonstration - see Sketchbook in action! https://www.youtube.com/watch?v=nhMIkZ4rdEQ

- Some useful things to think about when designing a poster and conveying information and/or ideas: https://ryanstutorials.net/graphic-design-tutorial/

**H5. 3D Printing Pre-Visit Module**

**3D printing** is the action or process of making a physical object from a three-dimensional digital model, typically by fusing many thin layers of a material in succession.

There are multiple types of 3D printing, all of which are utilised to complete various projects.

Find an object in your classroom, home, your bag, or somewhere else and consider how you might hack it using 3D printing.

Create a 2D drawing of your object modification from multiple angles. If possible, prototype it using cardboard while considering the following questions:
- What would you add to your object?
- What type of material would you use (see below table)?
- If you were to print it, would it require multiple parts?

| Type of Material | Fused Deposition Modeling (FDM) | Stereolithography (SLA) | Selective Laser Sintering (SLS) |
|---|---|---|---|
| Property | <ul><li>Melts and extrudes thermoplastic filament</li><li>Lowest price of entry and materials</li><li>Lowest solution and accuracy</li></ul> | <ul><li>Laser cures photopolymer resin</li><li>Highly versatile material selection</li><li>Highest resolution and accuracy, fine details</li></ul> | <ul><li>Laser fuses polymer powder</li><li>Low cost per part, high productivity, no support structures</li><li>Excellent mechanical properties resembling injection-molded parts</li></ul> |
| Best for: | <ul><li>Basic proof-of-concept models</li><li>Simple prototyping</li></ul> | <ul><li>Functional prototyping</li><li>Patterns</li><li>Molds</li><li>Tooling</li></ul> | <ul><li>Functional prototyping</li><li>Custom manufacturing</li></ul> |

**H6. 3D Printing Post-Visit Module**

**3D printing** is the action or process of making a physical object from a three-dimensional digital model, typically by fusing many thin layers of a material in succession.

The following links allow *beginner* students to advance their 3D modeling skills by utilising TinkerCAD:

- Learn how to create a die:
  https://www.tinkercad.com/learn/overview/OMPFUS5IYC6JRMP;collectionId=O2C1PXBIQ2KHCOD

- Learn how to create a chess pawn:
  https://www.tinkercad.com/learn/overview/O698ZZXIXGFTSXU;collectionId=O2C1PXBIQ2KHCOD

- Learn how to create a gear:
  https://www.youtube.com/watch?v=HuIqoVPCRZE

- Learn how to create a simple model of the Eiffel Tower:
  https://www.youtube.com/watch?v=LOKpUSnjHao

The following links allow *experienced* students to advance their 3D modeling skills by utilising TinkerCAD:

- Learn how to create an R2-D2:
  https://www.youtube.com/watch?v=6Rk2UbD2KsI&list=PLtmhShv-_MyLxorf-n9Ou1mYAWC8njGBq

- Learn how to create a lobster model:
  https://www.youtube.com/watch?v=HyYeR76vEzE