

SCIO: Material quizzing for primary education

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INTRODUCTION

Over last decade, Information and Communication Technology (ICT) has been increasingly adopted in education for teaching and learning [23]. Schools have made significant investments in these technologies [5]. Although difficult to measure, results in terms of student performance are not only positive [5,23]. Some argue that there is a null effect due to positive and negative effects cancelling each other out [7]. The place of digital devices in schools is still unsettled and actively evolving. For example, in the Netherlands, mobile phones have been recently banned from classrooms [20]. This makes it more difficult for teachers to host digital technology supported quizzes like Kahoot [20]. Although it is possible to use the devices provided by the school, they often boast their own set of issues. The use of individual devices has not reached primary school to the extent it has reached high schools. However, the desire for our society to become tech literate drives the change towards this reality and interest in design that guides this progress the right way.

In primary schools, the use of ICT technologies has taken form but is not fully established. Novel teaching product designs are still being introduced to the educational market¹². This unestablished nature offers a chance to guide and promote thoughtful adoption which might help find a healthier balance in the use of technology for primary schools. It might reduce the

negative effects of technology like distractions from (personal) devices. Opportunities of technology might be leveraged to promote factors that can improve education like learning through moving [18].

In Constructive alignment³ [3], education can be divided into learning objectives, learning activities, and assessment. This design process will focus on the learning activities, and not on objectives or assessment. In the Netherlands, learning objectives are set by the government [16] and assessment is something that happens according to formal and difficult to change procedures. Learning activities can be divided into the acquisition and consolidation phase [10]. In the acquisition phase, the learner 'acquires' knowledge in short-term memory, for example when the teacher explains a subject for the first time. During the consolidation phase, the learner 'consolidates' the acquired knowledge into long-term memory, for example by rehearsing it. The consolidation phase requires student motivation, a challenging aspect in primary education, as revealed in an interview with a primary school teacher. Furthermore, in a separate discussion, an educational designer emphasized that fostering motivation for consolidation is a valuable objective. Therefore, I will design for the consolidation phase.

¹ IMO-LEARN: <https://www.tast.studio/portfolio/imo-learn>

² Prowise Move: <https://my.prowise.com/nl-NL/collectie/prowise-move/>

³ Constructive alignment: <https://www.ru.nl/en/staff/lecturers/designing-education/designing-courses/integrating-learning-objectives>

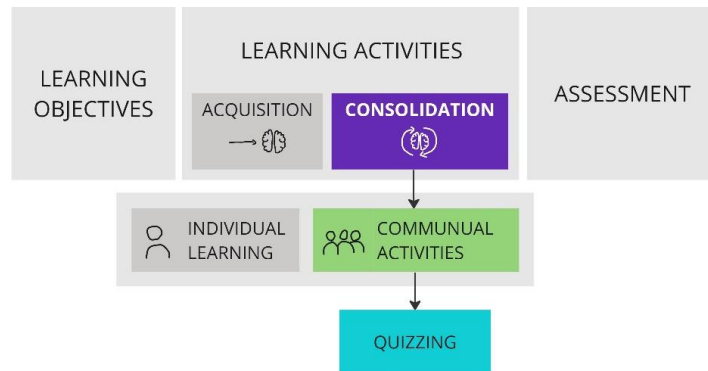


Figure 1: Framing of design

I will focus specifically on communal classroom activities. I am a designer that is interested in novel non-standard interfaces and innovative ways to interact with devices. I think that these interfaces can bring most value specifically to communal activities. For example, it is easiest to promote engagement and movement with these interfaces in group settings. Moreover, my goal is that this is a realistic project and the outcome is something feasible in the current market. Therefore, I want my design to work within the existing educational system. I will focus specifically on the Dutch education system. Educational systems can vary significantly per country and culture plays into how teachers teach and children are motivated and engaged. My target group is the last 3 years of primary school in the Netherlands, common ages being 10-12 years old. Finally, an important aspect of this project is understanding children, and how they learn and get motivated to learn in communal activities. This is a vastly complicated topic and it is impossible to consider all relevant factors. To reduce the complexity for this project, it was chosen not to focus on changing how children learn. Existing proven activities, like quizzes [12,24], are adopted instead of designing full new activities. Digital quizzing is a technology that is already adapted and liked by many teachers, making the proposed designs relevant and more likely to be adapted by teachers.

This is the design question: How can novel interfaces improve learning consolidation in communal quizzing activities in Dutch primary education?

To design for the current market requires a holistic design approach that considers many factors like literature, practice/reality, and technology. All these factors have a complex interplay which needs to be understood to propose a viable design.

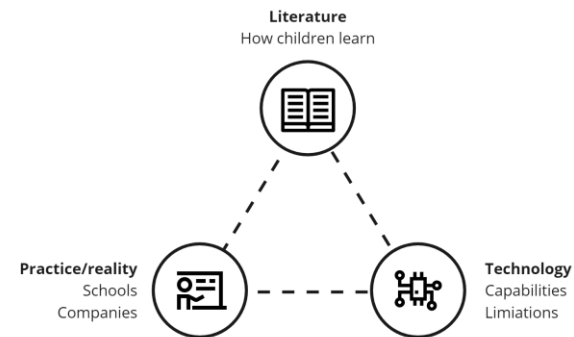


Figure 2: Design space triangulation

In this project, I will attempt to understand this complex design space. Using literature, real life insights and exploring technological opportunities/capabilities, I will break it down and summarize it into design principles. This will be achieved through a combination of literature research, prototyping/making, and talking to stakeholders. Throughout the process, I will make designs/prototypes which I will use to connect and make sense of the influential factors in the design space. For example, by leveraging prototypes throughout the design process one will quickly find the limitations of technology or make complex concepts understandable during interviews with potential users.

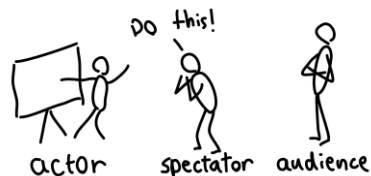
RELATED WORK

Understanding learning and play

To help children get motivated to consolidate learning in communal activities, it is important to understand motivation of children in the communal context. Specifically, it is interesting to look at intrinsic motivation, meaning that someone is self-motivated and gets satisfaction from the activity itself [9]. Extrinsic motivation, being driven by external consequences like rewards or punishment, is already inherently provided by the educational system for example by using grades.

Rob Tieben's PhD thesis describes how to elicit playful interaction from teenagers [22] within the context of interactive technology. Although this thesis focuses on teenagers rather than primary school children, it provides some structure to frame design, analyze existing designs, and map stakeholders' needs. Additionally, it might help support creativity by providing heuristics during ideation. However, designs produced using this knowledge should be evaluated for primary school children.

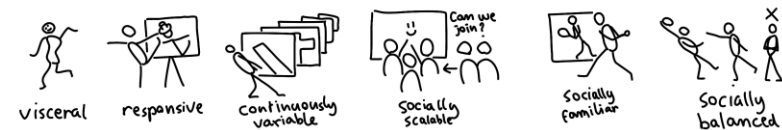
Who: In interactions with technology in public spaces, which are comparable to communal activities, there are three kinds of roles [8]. These roles are the actors (the people that directly interact with the design), the spectators (the people that indirectly interact with the design, for example by telling the interactors what to do) and the audience (bystanders, which only observe).



How: When interacting with technology in public spaces, there are various levels of which actions of interactors can be visible. Actions can be hidden, partially hidden, transformed, revealed, and amplified [22]. Motivating

children to play (or learn) can happen through curiosity. There are multiple ways to spark curiosity, namely through novelty, partial exposure, complexity, uncertainty, and conflict [22].

What: There are different interaction techniques which can be understood as ways in which a design should be used [21]. These are: energizing, calming, competing, performing, disinhibition and learning. Additionally, the authors provide design principles about ways that social immersive media can be described: They might be visceral, responsive, continuously variable, socially scalable, socially familiar, and socially balanced.



Finally, Tieben argues that design for public displays, and specifically exergames (exertion games, games where the main input mechanic is physical activity), should have a 'natural connection' between the action of the user and the digital representation on the screen [22].

Design principle: Design should have a **natural connection** between the action of the user and the digital representation.

Student Response Systems

As discussed earlier, this project focuses on quizzes. Quizzes should be activities where the students are either actors or spectators and not the audience [8,22] .

During a quiz, the teacher poses a question to the spectators and receives an answer. Currently, this kind of activity is technologically supported by Student Response Systems (SRS). SRSs provide interactions between student and teacher by giving students the tools to respond to the

teacher's questions giving immediate feedback to both parties. For example, a common SRS product is the clicker, which is a handheld device that sends answers to a central system. SRSs have been well researched and proven effective for university education [12]. A subcategory of SRS is the Game-Based Student Response System (GSRS), making existing SRS more engaging by adding gamification elements. The most well-known example of this is Kahoot⁴ which adds scores based on answer time. Kahoot originates from the academic world and is researched thoroughly, showing overwhelmingly positive results on learning and other factors like classroom dynamics and teacher and student attitudes [12,24]. Therefore, Kocak promotes the idea educational use of smartphones [12]. However, considering the double-edged sword of using personal devices in education, it is interesting to explore SRSs with alternatives to personal devices.

Unfortunately, SRSs and GSRSs have not been well researched in the context of secondary and especially primary schools [12]. Using (G)SRS elements could be way to achieve the goal for of this project while discovering if and how these systems could be used in primary education.

Learning Through Movement

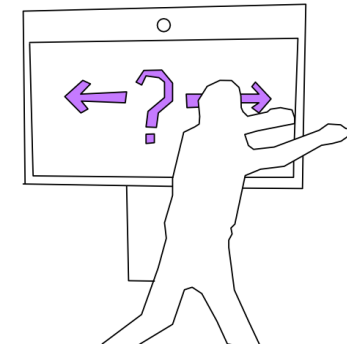
Movement for students during school has been an important consideration in the Netherlands. The Dutch Sports Council, Education Council and Council for Public Health and Society have together published a report outlining the lack of movement/exercise in education [17]. Dutch children move too little, and the councils see schools as the best place to address this, as all children go there. In addition to improving physical health, movement during schooltime has other positive effects like developing better cognitive abilities, learning teamwork, and learning norms of conduct and increasing academic results [15,17,18]. In addition to planning specific activities for movement, the council advises to

integrate movement into regular classes, possibly through creative digital solutions [17]. Some activities are already in use as also found in an interview with a teacher. This shows an opportunity to combine novel interfaces that will be discussed later and learning while moving. One attempt at this by Prowise will be discussed below.

STATE OF THE ART

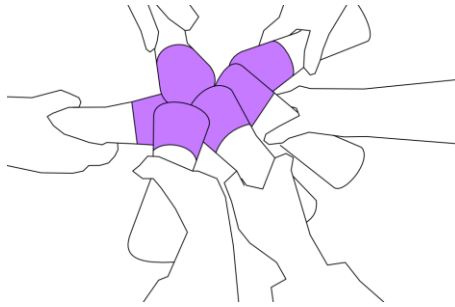
Attempts at design have been made with a similar value proposition as this project, namely using interactive technology to improve learning in communal activities for primary schools.

Prowise MOVE: Prowise introduced Prowise Move⁵ which is a combination of a hardware motion camera and software activities like (exer)games that can be played by moving in front of the camera like the Xbox Kinect. Prowise argues that learning while moving positively influence learning results and physical health through multiple factors, adding value to education [19]. This design has one actor and focuses on energizing, performing, and learning interaction, immerses the interactors viscerally (full body), is responsive/continuous and tries to elicit curiosity through new experiences. The limitation of this design is that it is not socially balanced and only one child (actor) can play while the other children remain in their chairs as audience or spectators. The value of this design might not be long lasting as most children are not actively participating and curiosity will disappear when different modes are exhausted.



⁴ Kahoot (GSRS): <https://kahoot.com/>

⁵ Prowise Move: <https://www.prowise.com/nl/prowise-touchscreen-ten/prowise-move-camera/>

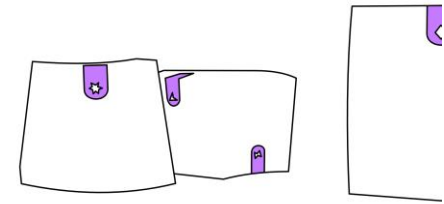


Picoo: Picoo⁶ made a gaming console for the outside that promotes movement and socializing attempting to improve games like tag. It contains a wide arsenal of games. Players have controllers that interconnect and

feature vibration, sound, and light. The value of the product is playing equality (not equity) through unbiased technology. The product promotes equality and not equity because it can only treat every child the same and not, like a teacher, tailor to each child's personality and needs. The product's drawbacks include the need for each child to have a chargeable device, increasing cost and effort. Framing this design based on the earlier established factors interactive playing (and learning), all children are interactors, it focuses on energizing and on competing and elicits curiosity through almost all modes throughout different games. It immerses players viscerally, responsively, continuously, and most importantly, it is socially familiar by mimicking existing play. It is socially scalable because all children are interactors. Although the product does an excellent job of facilitating play and motivating children, this product was meant for outside the classroom. Although children learn the associated skills, it does not help to teach course matter. Picoo demonstrates potential in crafting tech-based solutions that drive positive change and while remaining commercially viable, without the significant drawbacks associated with technology.

iMO-Learn: Finally, Studio Tast designed iMO-LEARN⁷ for i3-Technologies. This design also focuses on moving while learning. The product is a device with an array of sensors which can detect actions like drumming, shaking, turning, and throwing. The device is embedded in a square stool. The

product seems to be battery powered and therefore needs to be charged and becomes more expensive. Interactions with the stool can be used to drive learning activities. There is little information available on the content of the learning activities so it is difficult to frame it using the established factors. However, it can be determined that the product is visceral, responsive, continuously variable, socially scalable/balanced as all children are interactors and socially familiar.



Design principle: Design should be **socially balanced** so that multiple children can interact together at the same time. Moreover, design should be **socially scalable** so many children can participate at the same time. Not necessarily all individual children should be actors, but at least they should have a spectator role which provides motivation. If the value of the interaction is movement, most likely only the actors gain value from it.

Design principle: Design should be **replayable** and **retain curiosity and motivation** continually. To achieve this, design should spark curiosity through other means than only new experiences.

⁶ Picoo: <https://www.picoo.com/>

⁷ iMO-LEARN by Studio Tast for i3-Technologies: <https://www.tast.studio/portfolio/imo-learn>

PRACTICAL UNDERSTANDING

Relevant literature and state of the art have been reviewed in previous sections. In this chapter, we will focus on understanding the practical side of the design space. This practical side of the design space greatly constrains the range of possible designs but is essential to consider when wanting to make something that can reach the market. To understand this, the stakeholders in the product acquisition process (Figure 3) and the constraints that arise from this will be discussed.

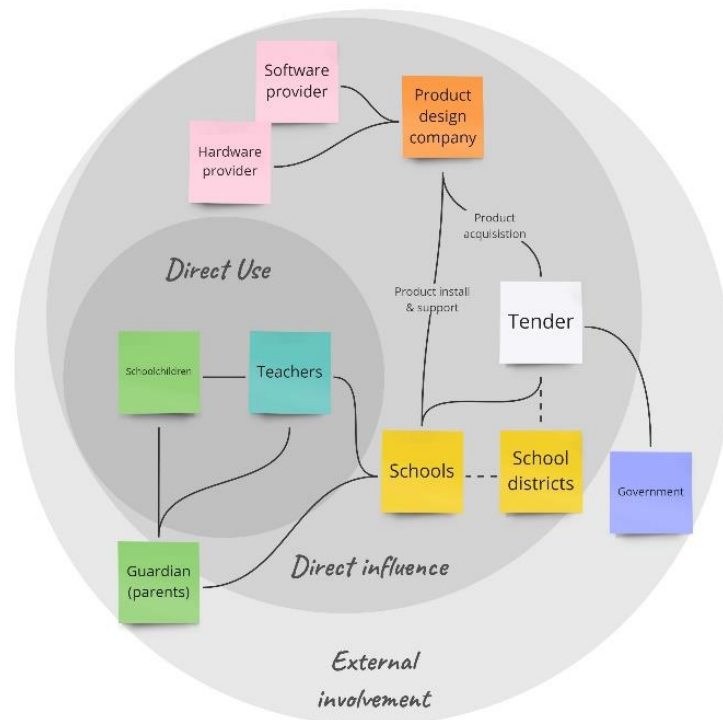


Figure 3: Stakeholder Map

Tender process

It is important to understand how ICT is acquired within an educational context. Firstly, schools either operate on their own and handle all acquisitions themselves or are part of a larger school district who, among other things, handles acquisitions on behalf of the school. If a school (district) in the Netherlands wants to spend more than €10.000, they are required by law to post a tender for the products or services they want to acquire. A tender is an invitation issued by the school for suppliers to bid on supplying specific technological goods or services for a specific budget. In this case, the suppliers are product design companies like CTOUCH, Prowise or i3-Technologies.

Innovation block

Due to the requirement/specification-based nature of tenders, it is difficult for companies to introduce new innovative features to schools and for schools to adopt them. Schools will not put innovative features on the tender and companies will therefore not be incentivized to innovate.

Why: A tender is a very specific description of the thing that is to be acquired. As the list of requirements is fixed, the price is often the deciding factor for who wins the tender. If a company introduces new innovative features, schools are not likely to put these in the tender description because they are not strictly necessary for teaching, their value might not have been proven and the schools are often already on a limited budget. If an innovative feature is not on a tender, it will increase price resulting in less chance to win the tender. Therefore, design companies have little incentive to innovate. From a buyer perspective, if neither the student, teacher, school, or school district strongly advocates for the implementation of such a feature, there will not be a reason to put it in the tender.

Solutions: The first strategy is to persuade the school to include specific features in their tenders by showing their benefits, either by direct appeal or through advocating by teachers and students. The company could offer

a low-cost minimum viable product (MVP) for free to demonstrate the feature's value, hoping it will be included in future tenders.

The second option considers that schools are only required to post a tender over €10.000. If this product could be sold separately, for a low price, there might be no need for a tender and schools (or even teachers and students) could acquire the product without a tender or the approval from a school district.

Design principle: The design should be *affordable*. This can be done by designing *cost-effective products* and leveraging *technology already present in classrooms*. Alternatively, a free trial version should be producible at low cost.

Ecosystem

One of the main problems that schools face is an ecosystem problem. Displays in schools are not always of the same brand or produced by the same company.

Why: Tenders exist so that buyers like schools cannot indicate which brand they want and can only indicate requirements and specifications. This is to prevent corruption and monopolies. It is mostly out of the school's hands to choose whether they want to stay within the same ecosystem. Schools can somewhat influence tender outcomes by aligning specifications with specific brands.

Results: Teachers sometimes must use different ecosystems. Within one school, different classroom might have different technology brands between which the teacher has to switch. Brands might also be changed over time. Teachers must learn multiple products. Course material that works on one board might not work on the other. Additionally, if the software is proprietary, schools are at the mercy (of the existence) of the company to update their products. Updates are especially important for privacy and the ever-changing educational material.

Design principle: Especially designing new interactions with unconventional technology might make it difficult to guarantee compatibility. It is important to work towards making elements of the design *replaceable, adaptable and compatible*. Following these principles might encourage tech savvy teachers, designers, or other third parties to create their own elaborations on top of the existing product.

Product design companies might have little incentive to follow this principle. However, supporting this level of openness might make them more competitive compared to other companies. Additionally, the principle can be described in a tender by the buyer.

Design philosophy

Different companies that design the same product have distinctive design philosophies. This becomes evident when comparing CTOUCH and Prowise. CTOUCH prioritizes a clean and intuitive design that is committed to keeping low threshold of use through simplicity, ensuring that their products are approachable and straightforward. Prowise appears to take a more feature-rich approach. They focus on packing their products with a wide range of functionalities and offer extensive course material. While Prowise attempts to create and design as much course material as possible, CTOUCH tries to avoid taking decisions about what course material should be. This will be relevant later when considering different levels of product (Appendix B, this will become clear later).

IT at schools

Schools are hesitant to connect their displays to the internet and in practice, most of these screens are kept offline. According to CTOUCH, 90% of the interactive touchscreens they sell are not connected to the internet.

Design principle: Relevant data cannot be saved in the cloud. Cloud storage should not be required or dealt with another way.

UNDERSTANDING TEACHERS

In the previous part, schools, design companies and tender were explored. How teachers teach and what teachers want is still unclear. This part of the project focuses on understanding teachers and how they (want to) teach. The first step is to understand their current teaching strategies and problems during communal activities. As no research has specifically been focused on teachers and novel interfaces in communal activities, it was chosen to hold a small study to directly receive input from the teacher. This study is a semi-structured interview. In the interview, among other things, concepts derived from literature will be discussed. These questions were mostly derived from Tiebens work [22] and somewhat from the TA Framework [1]. Additionally, these project's prototypes will be introduced and discussed.

Results

The first interesting finding is that quizzes like Kahoot are indeed common in the classroom, even going so far that the children use it in their own presentations.

Interestingly, the teacher said that occasional movement activities do not lead to chaos and loss of control. Rather students retain focus due to the increased fun and understanding that if they were chaotic, they would go back to classical teaching. Movement exercises were targeted towards energizing and consolidation.

On the topics of competing versus working together and individual versus teamwork, the teacher said that it was important to have both so children learn to operate in a wide array of scenarios.

Design principle: The design should be agnostic whether it is played with a team or as an individual. The design should allow teams to both collaborate and compete.

Finally, teachers have a desire for equity (over equality) and a personal approach. They want to target each child differently, accounting for their knowledge, skills, personality, issues etcetera. Currently, the school uses an online learning environment where students work within their own difficulty. When forming teams for communal activities like quizzes, the teacher still strategically pairs students with varying skill levels and expertise in the subject to ensure balanced and diverse teams. Interestingly, this is exactly the opposite of Picoo's philosophy of promoting equality through unbiased technology. However, Picoo is a technology provides some equality in the absence of a teacher, while this design considers the presence of a teacher.

Design principle: Actions like question creation, choosing teams and choosing rewards etcetera should be in the hands of teachers. The design should focus on student equity through teacher control. When the design should also work without a teacher, one might introduce technology enforced equality features.

DESIGNS

Two designs, BodySort and Material Quizzing, were formulated based on the understanding of the design space. Moreover, they were based on a technology review which can be found in Appendix A. These designs will be described here and discussed based on the principles.

BodySort

BodySort is a design where participants play learning games by physically moving in front of a depth camera. The core feature of this

game is that the participants stand in a certain order from left to right. Example games created with this mechanic are:

- Spelling (Figure 4 left): Each player is assigned a letter. Players must find and spell an existing word with these letters.
- History (Figure 4 middle): Each player is assigned a historical event. Players chronologically order the events.
- Math (Figure 4 right and Figure 5): Each player is assigned a number or mathematical operator and an outcome number is shown. Players must stand in the right order to create a math equation that results in the given outcome number.

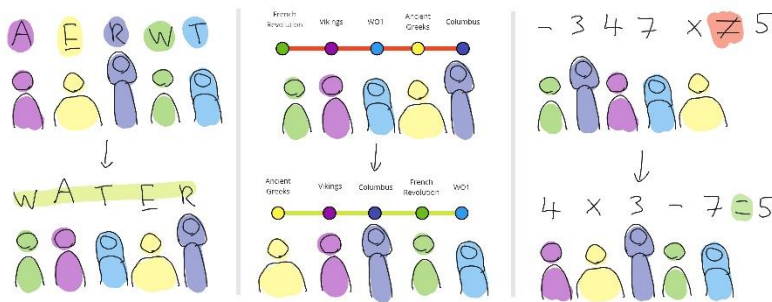


Figure 4: BodySort (Spelling, history and math)



Figure 5: Working prototype of BodySort Math

Design review

BodySort is an interesting design that boasts a strong connection between a user's action and representation on the screen. This design could be described as a learning through movement design.

The game is visceral and responsive, immediately responding to the full body. It is somewhat socially familiar as standing in a certain order is somewhat common. However, not enough children can be actors. It is difficult to involve spectators in a game where the core value is physical movement. The game is not socially scalable or socially balanced. Conceptually, this design is somewhat valuable for communal activities in education.

Unfortunately, technological limitations make this design unachievable. Motion tracking technology is still expensive, not readily available in classrooms and has few other purposes. Moreover, many of the possible games rely on persistent player ID tracking (remembering who is who). For the prototype of BodySort, it was already difficult to persistently track 4 people. Tracking even more children in a chaotic classroom with objects like tables seems impossible, especially with available computing power.

Additionally, the design is not easily replaceable, adaptable, and compatible as development tools are complex limited in the motion tracking platform. However, the design is replayable and retains motivation through the quizzing element which makes the game somewhat continuously variable. Finally, the design inherently requires one-player-teams, which makes it less socially scalable.

Given all this, it can be concluded that motion tracking and BodySort is currently not suitable for communal activities in education. However, the idea of sorting players physically is promising.

Material Quizzing

The Material Quizzing design elaborates on discussed technology findings of RFID and cameras, demonstrating their proposed opportunities while incorporating established design principles. The core part of this design is the quiz answering aspect called 'Material Quizzing' (MQ). On top of this, a gamification/visualization aspect called 'Rockets', which visualized the answering aspect of MQ and demonstrates the personalization capabilities of RFID.

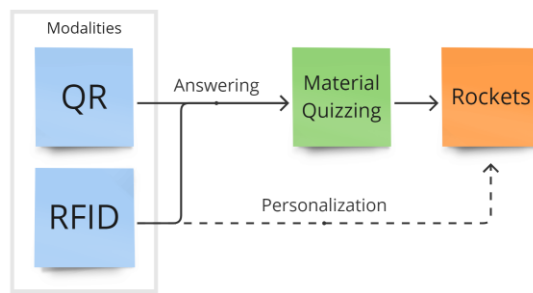


Figure 6: Material Quizzing toolkit explanation

Material Quizzing

Material Quizzing is a toolkit that allows participants to answer ABCD questions using either RFID cubes or QR cubes (Figure 8). Of the RFID cube, each side represents an answer (for example A, B, C or D) and has an RFID tag. By scanning the RFID tag, the participant answers the quiz question. Each RFID tag stores 'team' and 'answer' information. Of the QR cube, each side of the cube represents an answer and has a QR code. By showing the QR code to the camera, the participant answers the quiz question. There is freedom in the use of these answering modalities, as participants can have both QR and RFID cubes or just one of them.



Figure 7: RFID reader custom 3D printed design

Using this toolkit, product design companies, schools, teachers, or other third-parties could design their own game or other quiz frontend. The 'team' side of the RFID cube can contain custom data (max 144 bytes). This can be used by the designer to store custom personalization per team based on the content.

The current design is web-browser based to demonstrate that it is possible to develop it in an adaptable and compatible way. See a demonstration of the visuals here <http://niels.win/scio/>.

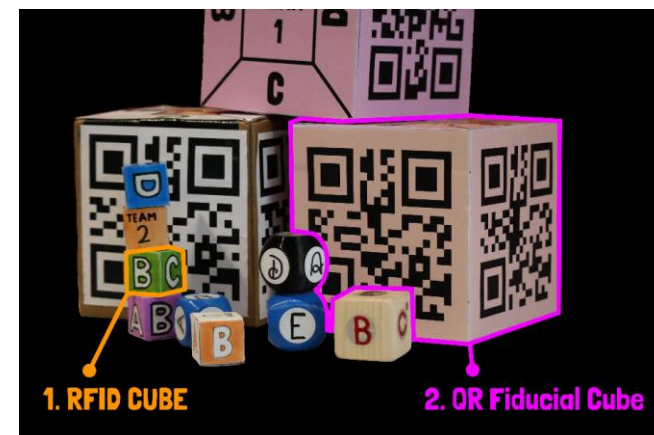


Figure 8: (1) RFID cubes and (2) QR cubes

Rockets

Rockets is an example of what such a design front-end elaboration might look like. Each participant has a rocket on screen. As the participants answer the questions right, their rocket will gain height, indicating score. When an answer is given, visual feedback is given on the screen in form of a ring (Figure 9), but it is not revealed whether the answer is correct. The host of the quiz can press a button to check all the given answers. In addition to changing height, each rocket shows an additional animation based on the correctness of the answer. In a separate window, a rocket can be configured and stored on the RFID cube. The different customization parameters of the rockets are color, rocket model and trail style (Figure 10).

Design review

The material quizzing design is versatile and allows choice between many different formats. The design is socially scalable due to its different scalable modalities. The design is agnostic about individual or team use which makes it socially balanced and even more socially scalable. This also makes it possible for the teacher to exert a significant amount of control over factors like team making. Although this specific design only features competition, adding other modes like 'sorting' using markers could give it teamwork modes as well. The nature of the RFID and marker cubes makes it only somewhat visceral and not socially familiar. Physical movement is only somewhat required but not to an extent where it can be compared to exercise. The design is replayable and retains motivation due to the quizzing element. This, in addition to the option for third party content and personalization makes this design continuously variable. Finally, the design has a strong connection between a user's action and representation on the screen.

All physical elements and devices are either affordable like the RFID scanner or RFID and marker cubes, or already present in the classroom like cameras. This allows for a low-cost trial version of the design to be offered to schools. Moreover, the RFID and marker cubes are child craftable. Moreover, the modularity of the design and its web-based

nature makes it compatible and adaptable over many different platforms and allows for third-party development. Additionally, the RFID technology allows offline storage of data. A downside to this design is the use of color cameras which can be a privacy problem.

Given all this, it can be concluded that Material Quizzing is very suitable for communal activities in education.

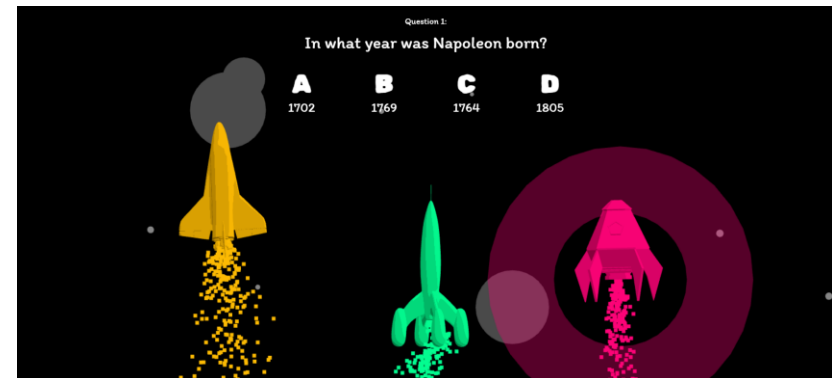


Figure 9: Rockets Quiz

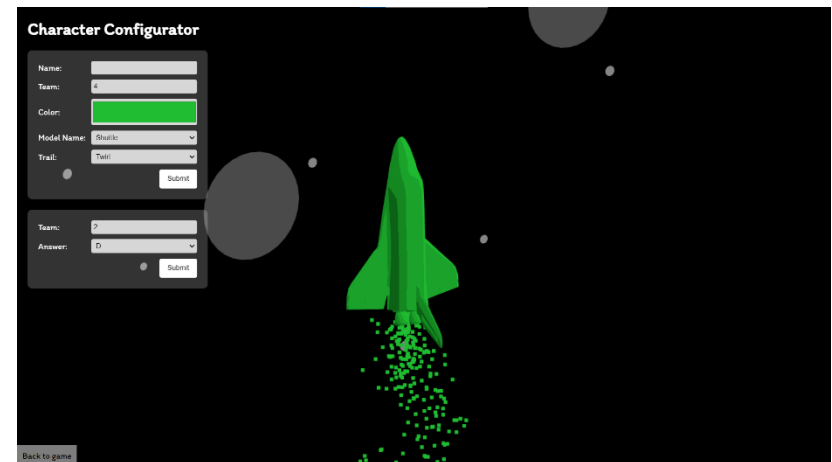


Figure 10: Rockets Configurator

FRAMEWORK

I propose a basic framework to explain designs within this context (Figure 11). This framework makes it easy to conceptually separate different elements of a product. This framework also makes it easy to frame a company's position. Finally, I will use this framework to explain my FMP proposal.

This framework is quite simple and consists of three layers: The modalities, formats, and presentation layer. The modalities layer considers the actual input 'modalities' for the design (how the user will interact). The formats layer considers the kind of activity that is being designed. For example, an ABCD quiz or sorting is a format. Finally, the presentation is how the format is being presented to the user. Presentations can be very simple like a bare-bone quizzing interface or elaborate and thematic like the Rockets visualization of Material Quizzing. A format can have multiple modalities and multiple presentation layers. An example of a detailed elaboration of the framework can be found in Appendix B and shows how companies can decide what kind of product to make.

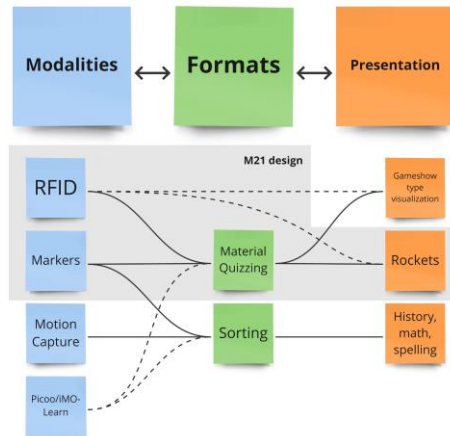


Figure 11: The framework (top) and examples (bottom). The context of this project is highlighted.

This framework can also be used to explain that this design can be implemented on many different levels by companies with different design philosophies. For example, Prowise, who have sold motion tracking cameras as well as developed their own educational content might opt to focus on all layers. On the other hand, a company like CTOUCH, who prefer focusing on their core product and toolkit and not making choices about educational content could only focus on modalities and formats and only building a minimal quizzing UI, while keeping the development of the presentation open to others.

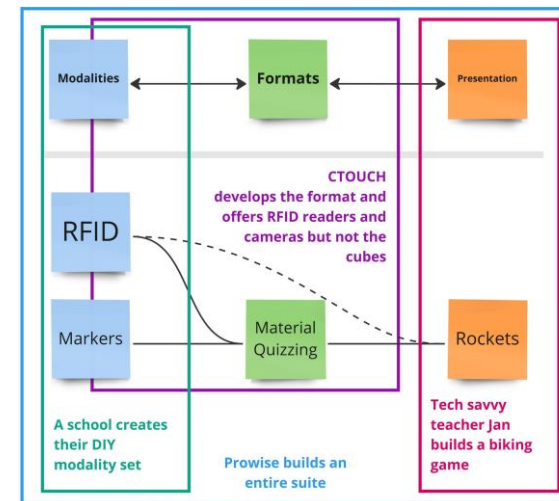


Figure 12: How different parties could arrange their product or be part of the ecosystem

DISCUSSION

This project has resulted in a promising design that, based on theory and some real-life insights, could provide value to the primary school classroom. However, the proof for this is still limited. The motivation through self-expression and personalization principle and other principles are based on Tieben's work [22] which focuses on teenagers around public displays and not schoolchildren. However, my target group are the oldest primary schoolchildren which are close Tieben's target group age. Moreover, during the teacher interview, the teacher confirmed that the proposed personalization in the Rocket design would motivate the children. Still, it is necessary to see more proof of this during future projects.

The design requires more validation. Conceptually, the design works well in every aspect of the design triangulation (Figure 2). However, it is not known whether it will work as expected in practice. Firstly, the design should be tested in a real-life setting. The design was not validated in a real life setting during this project because the modalities were not robust enough and the vast ethical difficulties of testing with children. When the design is tested, it should be first tested to see whether the modalities and format work and are motivating by themselves as a baseline without a presentation layer. After this is tested, designs with presentation layers can be tested to discover the added value of presentation layers. Secondly, more experts in the field of education should be consulted. Although this design is based on literature, the opinion of experts and their interpretation of literature might be valuable to the design process. They might especially help provide more understanding about how a presentation layer might be designed.

The current QR-code technology used in this project faces scalability issues due to its computational intensity and difficulty in detection from a distance. QR-code markers were chosen because there are many

JavaScript implementations available and because they can store raw data like answers. ArUco⁸ markers present a better alternative, offering less visual complexity and improved tracking performance. When testing, it seems easier to track 10 ArUco markers than 1 QR code. They can be detected at greater distances and facilitate enhanced AR interactivity, like having better positional awareness. For example, rockets could follow the markers on the screen. However, unlike QR codes, ArUco markers only contain numerical IDs, requiring additional mapping to associate them with specific data.

The interactions made possible by RFID are already promising. However, during the project they seemed to have the problem that only one can be used at a time. For example, during the demoday, someone suggested that children could build their own rocket out of different parts by stacking RFID cubes. After looking into this, Rong-Hao has been researching this topic [13,14]. His research has considered stacking NFC⁹. This is interesting in my design context as well. For example, a user could stack all their answers and answer at once. This research offers many new opportunities which are worth exploring in future projects.

CONCLUSION

In this design project I designed novel non-standard interfaces that help with the consolidation part of learning for communal activities in the Dutch primary school classroom. I designed BodySort, which did not solve my design goal, yet helped me formulate another design, Material Quizzing. Material Quizzing is a new way of interacting with a quiz without using personal devices, using RFID and fiducial marker technology. On top of this design, I made a presentation layer to support and explain this design. I while I found that my motion tracking design BodySort does not work for this context, my Material Quizzing design featuring fiducial marker and RFID technology is promising.

⁸ ArUco: https://docs.opencv.org/4.x/d5/dae/tutorial_aruco_detection.html

⁹ NFCStack: <https://www.youtube.com/watch?app=desktop&v=ta9pEGWFdo8>

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APPENDIX A: RELEVANT TECHNOLOGIES

With the established design principles, it can be discussed how possible technologies can play a role in communal quizzing activities. In this chapter, promising technologies for this design problem will be reviewed based on earlier established factors. These technologies are interactive touchscreens displays, cameras, and RFID.

Interactive touchscreen displays

Interactive touchscreen displays, also known as smartboards, are large touchscreens displays used by teachers in front of a class in a communal teaching setting. These have been a staple in the classroom for years, are now readily available in almost all classrooms in the Netherlands and have reached a good level of technological sophistication. A limitation of these displays is their limited computing power which will make it difficult to run more demanding computations on them like ML algorithms or advanced graphics. Their computing power is comparable to a modern smartphone¹⁰.

Design principles: The interactive touchscreen display serves as a great device to run possible designs. However, its limited computing power indicates that the design should be computationally performant.

Cameras

Cameras have not been common in primary educational settings as there has never been a real need for them. However, after Covid-19, standard color cameras, also known as visible imaging (RGB color) cameras, have become more discussed even in primary education [11]

to allow children to partake in class remotely. However, statistics on usage could not be found.

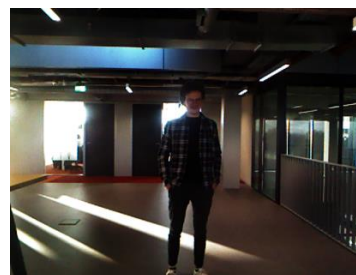


Figure A1.1: Color image



Figure A1.2: Depth image

Another promising type of camera is the depth camera. Depth cameras are often described as motion capture cameras, hinting at their common use case of tracking human body motion. For example, Kinect for Xbox¹¹ uses one for interacting with games, Apple has integrated these cameras into their iPhone and iPad Pro models¹², the academic world has also used them [4,6], Prowise has collaborated with Intel to launch Prowise Move⁵ and other applications too¹³.

Availability: CTOUCH, Prowise and i3 have no built-in cameras, only giving the option to add an external color camera.

In the classroom: Cameras can serve to interact with the central display over a distance. Not all children can directly interact with a central device through touch or other physical means due to the classroom layout. This means that either a solution like the Prowise iPro Liftsystem¹⁴ is required or another way must be found to bridge interaction over distance. By processing image data, inputs can be formulated based on fiducial markers, body movement, color or other things that can be seen by a camera. The advantage of cameras is that they can perceive multiple

¹⁰ CTOUCH Specifications, Prowise Specifications, i3 Specifications

¹¹ Kinect: <https://en.wikipedia.org/wiki/Kinect>

¹² Apple LiDar: <https://www.apple.com/ca/newsroom/2020/03/apple-unveils-new-ipad-pro-with-lidar-scanner-and-trackpad-support-in-ipados/>

¹³ ValoClimb: <https://www.valomotion.com/valoclimb>

SmartWall: <https://hetnieuwegymmen.nl/product/smart-wall/>

¹⁴ Prowise iPro Liftsystem: <https://www.prowise.com/product/ipro-liftsystemen/>

interactions at the same time, possibly allowing the entire classroom to interact at the same time.

Privacy: In primary education, having a camera facing children might be an important privacy issue. Color cameras produce identifiable output (Figure A1.1), leaving the privacy up to the developer. Depth cameras, however, are inherently more private (Figure A1.2).

Audio

Although audio might also be used to interact over distance. However, in the context of a classroom with many children, this will be too chaotic for teaching and difficult to detect individual interactions.

RFID

RFID (Radio-frequency identification) is a promising technology to replace personal devices in education. Picoo uses the RFID¹⁵ load and play games, it was proposed in a thesis [2] and SRS clickers often work based on radio frequency (RF). Finally, Rong-Hao Liang at the TU/e ID department has done significant work in exploring the opportunities of RFID (in an educational context) [13,14]

Types of RFID: The two main variations of RFID are passive and active. Passive RFID can transmit data over short ranges but requires no power from the tag and remains a small form factor. Passive tags are in essence an antenna and a chip. Active RFID has a larger range of 10-50 meters but requires a power source like a battery. Passive RFID tags are much cheaper and more sustainable than their active counterparts due to their lack of battery, additional electronics, and casing.

Type	Model	Range	Storage	Price (as business)
Passive	Mifare Classic	< 10 cm	1 kB	~ €0.05
	Mifare Ultralight	< 10 cm	144 bytes	~ €0.01
Active	-	10-50 m	> 1 kB	~ €1

Table A2: Comparison of relevant RFID technologies



Figure A3: MIFARE Classic droplet (left) and Ultralight sticker (right)

In the context of education: Especially passive RFID can deliver value primary educational because passive tags can be used in greater quantities, they are cheaper and more sustainable than active tags. They allow offline and physical storage of data. This is promising because it allows children to carry their own data. This works well with previously discussed ecosystem issues, as the RFID protocol is standardized. As discussed earlier, 90% of all screens that CTOUCH sells to schools are never connected to the internet. This means that RFID storage might be effective to gain that cross-classroom storage functionality in an offline way. This circumvents the need and associated effort, cost, and risk of setting up a server.

Personalization can be stored on the tags. This would allow students to have personal RFID tags that can store progress, scores, and

¹⁵ Youtube video about Picoo demonstrating the use of RFID cards:
<https://youtu.be/oQcskIXcpcU?feature=shared&t=48>

personalization that they can carry with them. For example, if a student has scored the highest in a game, they might receive a reward like a custom avatar or token that can be redeemed.

It is most straightforward to connect the RFID reader to the display. Some displays already have built-in RFID readers, making this product even more low-cost for them¹⁶. Users still need to move to the reader/screen to scan their RFID tag. Although this is not a problem for loading and updating personalization and score, it might become tedious when using RFID for answering quizzes with many users.

¹⁶ CTOUCH Neo: <https://ctouch.eu/nl/touchscreens/neo>

APPENDIX B: EXAMPLE OF SUB-LAYERS

A company can decide to which level they would like to develop the product. For example, company A might offer a camera and the image files for the markers, while company B might offer a full marker cube product.

