

Qwiz

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INTRODUCTION

In the past two decades, education technology (EdTech) has become a core part of the primary school classroom. It has majorly changed the way in teacher teach and students learn. Digital interactive whiteboards and personal devices like laptops for all students have become the standard. The first reason for this is the level of personalization/differentiation for individual learning that can be achieved through digital technologies [18], allowing teachers to address students in a personalized way at their individual level to an extent not possible before. The second reason is the increased interactivity, for example through game-based learning [18]. Quizzes, like Kahoot, have been found to stimulate motivation, learning performance and classroom dynamics [33, 34]. Both these benefits are made possible by orchestrating tasks through technology that were previously impossible or too time-consuming for teachers, such as increasing interactivity by collecting and analysing thirty student responses in a fraction of a second.

However, technology in primary school education currently has three main problems, which are caused by personal devices. Firstly, technology can negatively affect learning. Regardless the advantages of technology like saving teachers time and making students more motivated, learning outcomes have not significantly improved [2, 4, 6]. One possible cause could be students getting distracted by devices [20]. Increased screen time also has its concerns and, although difficult to prove, social interaction might suffer as well. Secondly, even though EdTech has matured, the landscape of tools, materials & resources, and ecosystems is still fragmented and inconsistent, requiring teachers to switch between and understand a vast range of products. Thirdly, many schools and students have accessibility problems with technology because of cost, electricity access or internet access [3, 19, 20, 30]. Especially, if technology enabled teaching and learning becomes the standard, less technology inclined schools might fall behind. All these problems find their reason in (the reliance on) personal devices like laptops and mobile phones. Personal devices create much distraction, are costly if bought for each student, and connecting all these devices through

to a central system can be difficult to manage for a teacher or even impossible due to lack of internet. Due to concerns about disruptions of the class and distractions, mobile phones in schools have recently become banned in many countries [5, 22, 35], including the Netherlands. Although the use of technology is justified in many cases and genuinely helps teachers and students alike, the overall problem is the overshoot in technological adaptation for the wrong activities where other solutions might be more valuable.

This creates the opportunity to introduce innovative design that retains benefits of technology like interactivity and differentiation but without the use of personal devices and their inherent problems. It is difficult to replace personal devices for individual learning because they are integral to differentiation. Because each student needs their own device when working individually, no clear design opportunity emerges for individual learning. However, there is a more promising opportunity to replace personal devices for communal learning. Especially interactive communal activities, like quizzing do not rely on personal devices to the same extent that individual

learning does. They are supported by the teacher controlled interactive whiteboard (IWB). The design challenge for this project can therefore be formulated as: Support interactive communal teaching activity through other means than personal devices.

My goal for this project was to solve this design challenge in a way so that the outcome is feasible in the current market. I achieved this with a triangulation approach between user, industry, and technology perspectives. I reviewed my M21 design (mostly industry and technology) and relevant literature (user), interviewed a teacher (user) and observed two primary school classrooms (user). With the insights of these activities, I formulated a list of design principles about designing interactive formative assessment learning activities for primary schools. Based on these principles, I designed a quizzing tool called Qwiz with four unique question formats. Then, by making a Qwiz prototype, I suggest how this design could be realized (technology). Thereafter, I discussed the market adaptation of this design with EdTech industry experts (industry). Finally, I did a field study in a real class which gives insight on how this design is used, its advantages and its limitations (user).

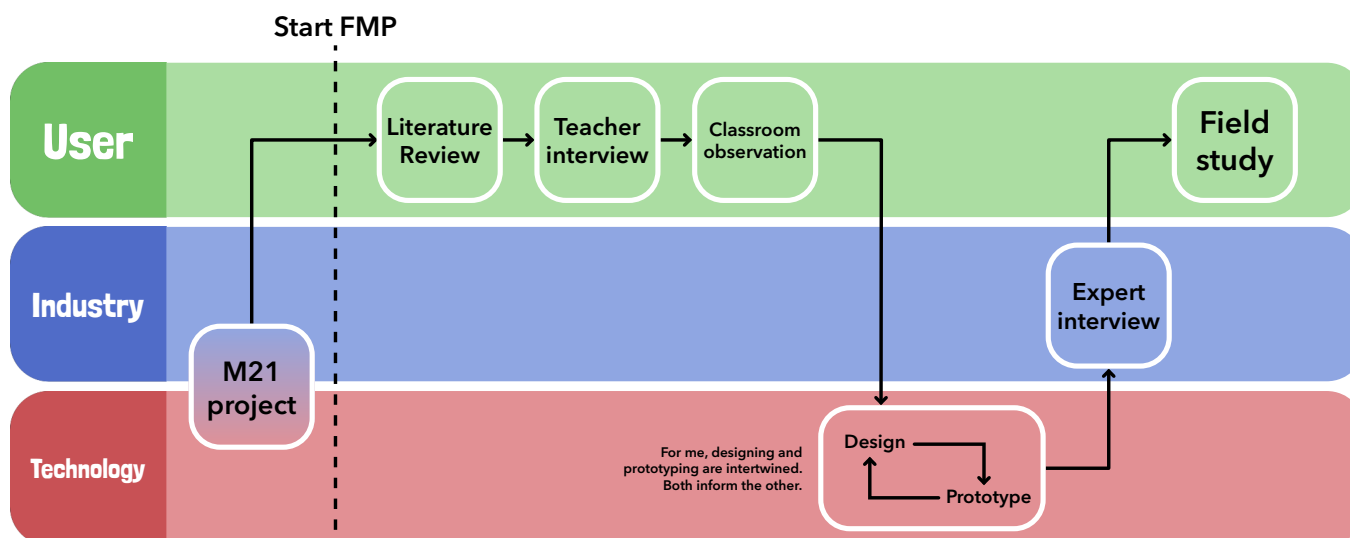


Figure 1: Triangulation of user, business and technology

BACKGROUND

Framing the design space

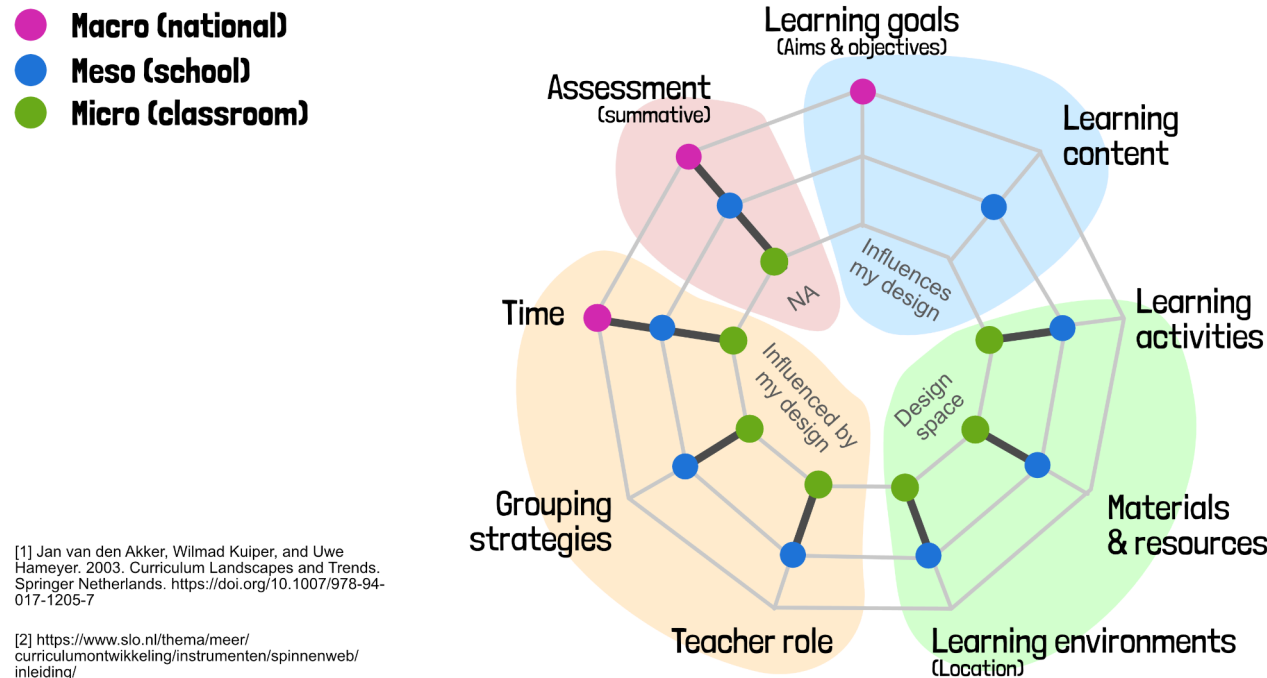
The primary education system is multifaceted and complex. It has many stakeholders and ways in which these influence the system. To make sense of this system, Akker et al. introduce the Curricular spider web which is meant to help schools plan their curriculum [1]. SLO¹ elaborates this model in the context of the current Dutch educational system by explaining how each factor is relevant to each stakeholder. I made my own interpretation of the spider web in Figure 2, where I show which stakeholders influence which factors from the perspective of my design.

As shown by Figure 2, the aim for my design consists of redesigning learning activities through materials & resources and learning environments. These are determined on a school (meso) and classroom (micro) level and are most open to change. These factors, and therefore the design, are influenced by learning goals and learning content. Learning goals are set on a national (macro) level by the government and cannot be changed. Learning content is determined by the schools based on the learning goals in combination with the school's vision, specifying ideas like themes and teaching methods. Because learning content is the core of a school's identity, and my goal is to design something that works for the current market and users, I will focus on catering to these contents rather than changing them. Then factors like time, teacher role and grouping are not the core elements of my design but might be influenced by or influence my design. Finally, (summative) assessment is separated from the other elements, especially since all assessment that happens as part of the learning process is called formative assessment.

¹ SLO Spinnenweb:

<https://www.slo.nl/thema/meer/curriculumontwikkeling/instrumenten/spinnenweb/inleiding/>

MY INTERPRETATION OF THE SLO SPIDERWEB



[1] Jan van den Akker, Wilma Kuiper, and Uwe Hämeier, 2003. Curriculum Landscapes and Trends. Springer Netherlands. <https://doi.org/10.1007/978-94-017-1205-7>

[2] <https://www.slo.nl/thema/meer/curriculumontwikkeling/instrumenten/spinnenweb/inleiding/>

Figure 2: My interpretation of the spiderweb proposed by Akker et al.

Reviewing my M21 project SCIO

The goal of my M21 project was to find out how novel interfaces can improve learning consolidation in communal quizzing activities in Dutch primary education. For this project I used a triangulation approach as well. I did a literature and market review, collaborated with the IWB company CTOUCH¹ to understand limitations of the market, explored technological opportunities through prototyping and did an interview with a teacher. Based on these insights, I formulated a list of design principles. This list can be found in Appendix A. Using these principles, I designed Material Quizzing, which is the final design of the project. Material Quizzing is a gamified student response system toolkit to answer multiple choice quiz questions using RFID or visual marker modalities, eliminating the need to use personal devices. The physical answering modalities are made of affordable cardboard and RFID chips. The design features 'juicy' [27] visuals of rockets on the whiteboard screen that represent the current score. Personalisation like the rocket visual, scores and names can be stored on the RFID chips without needing an internet connection. Because the design proved promising for quizzing activities, it was chosen to further continue design quizzing activities.

Although the project outcomes are promising, the main problem is that the project did not consider how the design can be integrated into the primary school teacher workflow. Rather, it followed a common quizzing workflow like for example the one of Kahoot!, which assumes all questions are asked consecutively on a standalone app. Although the project delivered relevant insights into the technology and industry sides of the triangulation, the user side was not considered well enough yet. Therefore, in my FMP proposal, I explained the goal to reevaluate the context from a user perspective during my FMP.

One of the contributions of my M21 project was the framework (Figure 5) to differentiate between different layers of these kind of designs. For example, this can make it easier to explain stakeholder involvement. The framework has three layers: The modality, format, and

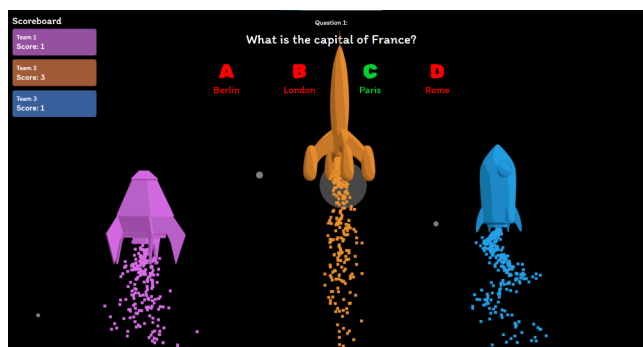


Figure 3: Screenshot of M21 app



Figure 4: Photo while using the M21 prototype

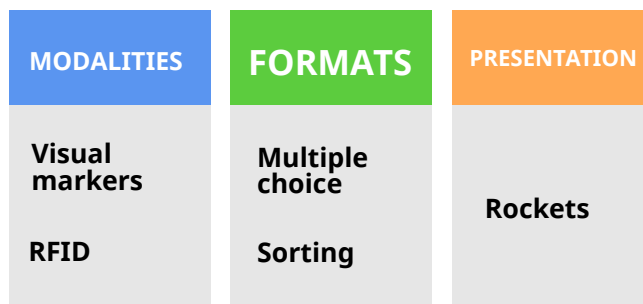


Figure 5: M21 design layers framework



Find my M21 project at
niels.win/projects/scio

presentation layer. The modality layer considers the actual input 'modalities' for the design. The format layer considers the kind of learning activity that is being designed. For example, the multiple choice (ABCD) question is a format. Finally, the presentation layer is how everything is being presented to the user.

Theoretical framework

Learning by testing one's knowledge during the learning process is called formative assessment (FA). Quizzing is one way to operationalize FA. While summative assessment is testing the knowledge after learning, formative assessment is testing knowledge during learning. It allows students to firstly consolidate [8] information they have acquired it and secondly to reflect on their learning. Formative assessment, regardless of the name, is part of learning activities rather than actual assessment in the spider web model [1] (Figure 2).

TEACHING & TECHNOLOGY

To design for communal interactive FA learning activities, it is important to consider how teachers use technology, and especially interactive whiteboards (IWBs). Although IWBs have been found to be able to support learning, they have not been found to directly improve it [14]. Quality teaching contributes most to learning. IWBs and technology can promote quality teaching through supporting teaching methods like dialogic interactivity which have been found to improve learning. Dialogic interactivity means learning through dialogue. Dialogue can be between the teacher and students or among the students, for example by exchanging ideas and perspectives.

Additionally, the idea of mediated teaching says that teachers should actively shape and guide the use of digital tools rather than only deploy them as they are [18]. For design, this means that in addition to supporting teachers dialogue, design should support technology mediation as well.

QUIZZING AND TESTING

Quizzing (or testing) is one of the main ways in which teachers operationalize formative assessment. Testing

¹ CTOUCH. <https://ctouch.eu/nl/educatie>

is traditionally used for summative assessment but can also be used to consolidate information through formative assessment. Testing is considered an effective learning strategy [34]. The testing effect is the effect that testing knowledge is often more effective than other learning strategies, after the knowledge has already been acquired [9, 23]. The testing effect also applies to primary education [34]. However, it was also found that the 'testing effect' was not present for primary school learning when questions had a high element interactivity, which means the complexity of how many elements must be understood in relation to each other [15].

STUDENTS RESPONSE SYSTEMS

A common way to technologically operationalize testing/quizzing for formative assessment is through Student Response Systems (SRS). SRSs support digitally support interactions between students and teachers by giving students the tools to 'respond' to the teacher's questions giving immediate feedback to both parties and automating response collection and processing. SRSs have been found to offer pedagogical advantages and boost learning performance, interaction, and feedback [12]. As discussed earlier, these advantages only exist when combined with the right teaching approach.

Game-Based Student Response System (GSRS) are a sub-category of SRS, making them more engaging by adding gamification elements [25]. Originating from the academic world, Kahoot! is a well-known example of a GSRS application featuring game design patterns and mechanics through time-based scores and leaderboards. This approach is considered to be effective. Kahoot! has been found to have positive effect on factors like learning performance and classroom dynamics [33].

An innovate example of an SRS tool without the need for personal devices is Plickers¹. Plickers allows teachers to collect multiple choice (ABCD) answers from students scanning the paper printed fiducial marker cards with their phone. Plickers was found to have a positive effect on learning performance and

¹ Plickers: A visual marker based students response system. <https://get.plickers.com/>

student attitudes when tested in rural primary schools [3]. The authors also argue for its cost-effectiveness and equitability, especially for rural schools.

The effectiveness of (G)SRSs specifically in primary schools has not been sufficiently researched [12]. Considering that the testing effect applies to primary schools, it can be concluded that (G)SRSs (quizzing) tools prove a promising opportunity to support FA.

COMMUNAL LEARNING

When designing for communal learning as opposed to individual learning, it is important to consider to how students interact and work together in a learning environment. Theories like the socio-affective method and [10] argue for the importance of social interactions and emotional factors in learning. Additionally, the previously established need for dialogic interactivity also supports this. This means that during communal learning, the students do not only listen to and interact with the teacher for the sake of information acquisition, but also interact among themselves by which they learn from each other and learn additional skills like teamwork and norms & values.

Student interaction, in the context of this design project, can be split up into collaboration and competition. Lopez-Faican & Jaen and Chen et al. have considered both in their designs [2, 16], while applications like Kahoot! [33] only rely on competition. There is not enough evidence to say which one is preferred, and Lopez-Faican and Jaen argue for a mixed approach [16].

Although the motivation created through competition (performance) might not be considered preferred, competitive learning tools like Kahoot! have proven effective [33]. Their wear out effect is minimal in the long-term due to their competitive nature [32]. However, we can still define some guidelines for designing primary school appropriate competition. The students should focus on succeeding by winning rather than trying not fail by losing (approach rather than avoidance state, see Appendix B) [2]. This can be done by limiting the level of competitive elements, like time-based score counts, as they might induce adverse effects like stress and fear of losing [33]. According to

Shindler, healthy competition happens when learning and fun are more important than winning, winning has only symbolic and no real value, the competition and its results limited to a short timespan, and everyone has an equal chance of winning [11]. On the other hand, collaboration does not focus on competitive motivation (performance) and focuses more on developing competence (mastery). Elements of good collaboration are: Having a common goal. Positive interdependence through teamwork. Only achieving goal through collaboration. Student interaction focusing on helping and learning from each other. Individual accountability and everyone receiving the same or a shared reward [10, 16].

Considering the findings about dialogic interactivity and mediated technology, the conclusion is that both collaboration and competition have a place in communal teaching and that design should focus on giving teachers the tools to easily deploy them both in a healthy way and form dialogue their advantages and disadvantages.

USER INSIGHTS

The goal for this chapter is to better understand current interactive formative assessment in primary education. This chapter consists of an interview with a teacher from a Montessori primary school and observations of two different classrooms.

Teacher interview

PREVIOUS WORK

In my M21 project, I interviewed a teacher of 'groep 5' (9-year-olds) in a regular school. This yielded some useful insights like that standalone quizzing apps like Kahoot! are often hosted by students but not by teachers, should offer both a wide variety competitive and collaborative learning scenarios affording different classroom dynamics, and provide teachers with control on how to implement them.

GOAL

My aim for this interview was to formulate a more

general understanding of interactive communal formative assessment activities in primary education. Having interviewed a teacher for my M21 project, I wanted to extend this knowledge and see whether it applies to a larger variety of schools (with different learning contents/vision). I interviewed a teacher of 'groep 7 & 8' (11/12-years-olds) at a Montessori school¹, getting a different perspective in terms of age of students and vision on education. The interview discussed topics like technology in the classroom, relevant pedagogical topics like competing/ collaborating and equity/equality, and a preliminary prototype based on my M21.

RESULTS

The teacher was optimistic about the use of technology in education. The class uses an IWB, tablets, and notebooks which are connected by a software suite. The teacher likes the differentiation, automatization, and immediate accessibility to media aspects of technology. Their main problem with technology is the distraction caused by personal devices. This requires them to regularly monitor the students' screens on their own device.

The class of this teacher uses quizzes and students often make their own quizzes. According to the teacher, quizzes can inspire much motivation in their students, especially for boys. When discussing teamwork versus collaboration using quizzes, the teacher had more faith in the direct results of competitive quizzing formats than in collaboration. However, the teacher indicated to like the idea of collaboration in the context of Montessori. When discussing teamwork, they indicated these formats are often problematic when one participant can singlehandedly ruin the outcome for the others. Conclusively, both competitive and collaborative scenarios have a place in their classroom.

The teacher was positive about the design itself. They

¹ The vision of Montessori schools is students developing independently. The teacher's role is to focus on bringing out the interest of the students and guiding them in learning with less focus on classical teaching. <https://www.onderwijsconsument.nl/montessori/>

said that students would understand it easily but worried that they might find a way to misuse it. The teacher also compared my design to Plickers and mentioned that the cubes would be lost not so easily as the Plickers cards.

Concluding, a lot of parallels between this and the previous interview with a 'regular' school can be found. Firstly, both teachers like the quizzing but see it as an activity to be hosted by students. Secondly, a mix of both competitive and collaborative quizzing scenarios is desired.

Classroom observations

GOAL

The main goal of the classroom observations was to gain a more in depth understanding of a contemporary primary school classroom. Firstly, I wanted to immerse myself and gain a 2nd person perspective [26]. Secondly, the aim was to get a more concrete picture of what a primary school class day looks like from start to finish, filling in and elaborating on Spider Web (Figure 2) elements like learning activities, sources & materials, learning environments, teacher roles, time, and grouping. Thirdly, I wanted to identify opportunities where interactive formative assessment might be improved through design by replacing personal devices.

METHOD

A rapid ethnography approach [31] was employed to quickly gain valuable insights. Specific observation topics consisted of the Spider Web elements, discussion points from previous interviews, relevant theory and the learning plans that were requested

beforehand. Beforehand, I told the teachers not to alter their teaching for this observation. During the observation, I interfered as little as possible with the class.

RESULTS

I observed two different classrooms each for a full day. The first one was a classroom of 9-year-olds (groep 5). The second one was a classroom of 12-year-olds (groep 8). The classes will be referred to as G5 and G8 respectively.

Time

The overarching finding of these observations is that time is an influential factor when it comes to teaching decisions. Both teachers struggled with finding enough time to both teach and do the other parts of their job in their working hours. Teaching almost takes up all their working hours, leaving little other time for other tasks, like lesson planning and preparation. The teachers were teaching with high efficiency and speed, wasting no precious time.

Method use

This time shortage results in teachers almost exclusively using existing lesson plans/methods and material created by external parties like publishers and not by themselves. Within the given time, they do not prioritize making their own content and lessons. They often closely followed lessons as provided by publishers like Malmberg or Gynzy or by other parties like museums/NGOs through software like LessonUp. This method seemed to work well for them, and they were still able to give an interesting lesson by teaching it in an engaging and personalized way.

Quick activity rotation

Related to time management, both teachers frequently and quickly rotated between various kinds of learning activities. For example, all within 20 minutes, the teacher might explain a math concept, demonstrate solving an exercise, demonstrate an exercise with student input, then ask students to do it on their own, observe difficulties and clarify them, and ask them to do another on their own. These switches were often between acquisition (explanation/demonstration) and

consolidation (exercises) activities. Both activities, especially consolidation activities, often featured interactive elements. The first method the teachers supported this was through physical interactivity like sitting versus standing or showing hands. The second method (observed at G5) was to let students write an answer on a small handheld whiteboard and check the answer. The third one is to use the interactive capabilities of the IWB by calling students forward to interact with the IWB, for example through a dragger question (sleepvraag)¹.

Interestingly however, for these exercises, laptops or phones were never used even though the option to join a quiz this way was given in the used software. When quickly rotating between activities, it takes too long to start a laptop. The average time it takes the entire class to start their laptop and join a quiz was observed to be around 3 minutes. This is reasonable when playing longer quizzes with multiple consecutive questions. However, this takes too much time when quickly rotating between shorter activities, where the activity

¹ Sleepvraag. An interactive question where the player is asked to drag items on a board to their correct containers. <https://www.lessonup.com/nl/channel/lessonup/plan/k6JCAcz25jh446Fkw>

might be even shorter than the time to start a laptop and join the quiz. On the other hand, leaving the laptop open during the class might be too distracting for the students. Concluding, personal devices do not suit interactive communal learning activities, and design should find a way to support these quick and frequent activity rotations.

Standalone longer quizzes and student hosting

Both due to the frequent activity rotation and time shortage, teachers do often not make their own longer quizzes in apps like Kahoot. This is due to the time it costs to make and host them and that this format does not fit into current 'frequent and quick activity rotating' teaching workflow. However, as found previously, teachers let their students make these longer quizzes, for example as part of a presentation, because the students like it, it costs the teacher no time and it is a learning opportunity. Therefore, design should also allow the students to host their own quiz.

During the Kahoot quizzes that were held by students, the presence and dialogic interactivity of the teachers during the quizzes was essential. The G5 teacher let some students from a school committee host a quiz. Throughout the quiz, the teacher started short

discussions through thought-provoking questions and elaboration on questions which improved the quality of the quiz. On the other hand, during the other class, the teacher was occupied elsewhere during the quiz and the comparative educational value was less and the class was more chaotic.

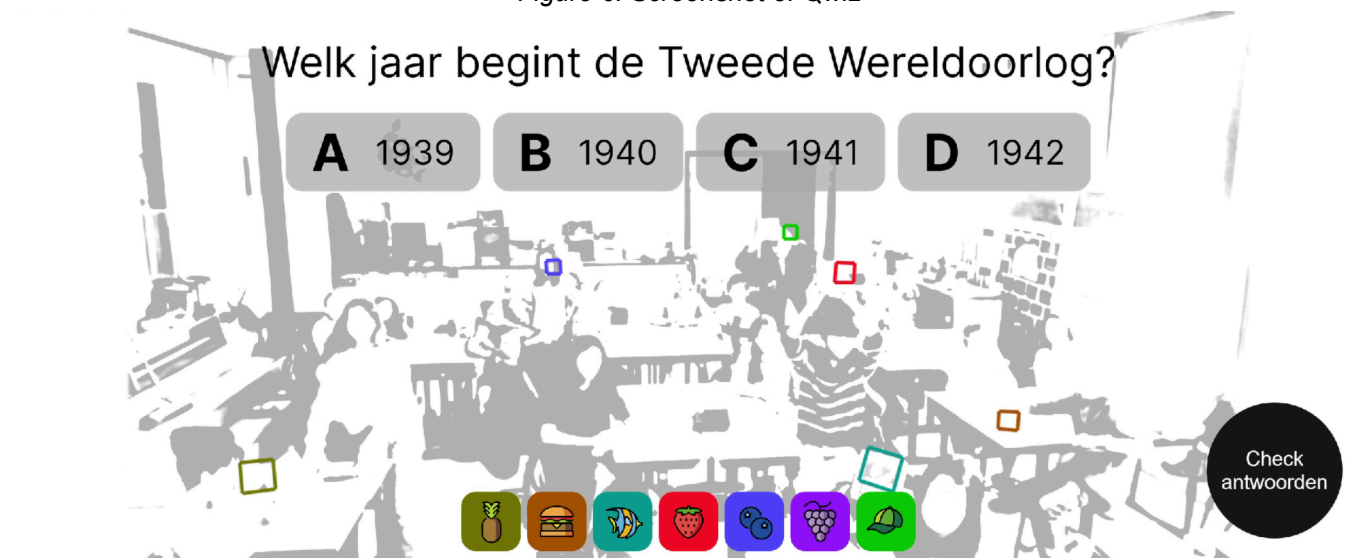
Quizzes as evaluation tool

Finally, during the G8 observation, it was found that teachers also use quizzes as an evaluation tool to quickly judge student progress and understanding of a topic. Evaluation insights can vary between insights about the entire classroom, individual students, or specific subject matter etcetera. The teacher uses these insights to plan their lesson and differentiate between students. During the G8 observation, the teacher used a five-question quiz (in Socrative¹) at the beginning of the lesson to test and refresh knowledge. Through this quiz, the teacher discovered that the students did not understand the topic as well as expected and that some subject matter had to be repeated.

Quizzing scenarios

After discussing with the teacher, there are four common scenarios for using quizzes as part of formative assessment (later during the expert interview, a designer from Gynzy also named these scenarios independently): (1) Evaluating prior knowledge, for example testing knowledge of the previous lesson. (2) Acquiring new knowledge by asking question about unfamiliar knowledge. (3) Consolidating information after acquiring it. (4) For fun. It becomes clear that in addition to using FA quizzes for consolidation, it can also be used for other scenarios like acquisition. What they all have in common is that they can all used to evaluate students understanding and are part of the learning process (FA).

Figure 6: Screenshot of Qwiz



¹ Socrative: A well-known SRS tool. <https://www.socrative.com/>

DESIGN PRINCIPLES

The goal of this chapter is to combine previous findings into clear design principles on how to achieve the design challenge to support interactive formative assessment activities for communal teaching through other means than personal devices. The previous findings consist of the previous M21 project (Appendix A), theoretical framework, teacher interview and the classroom observations. The principles can be divided up into three categories: Design for teachers, design for students and design for accessibility.

Design for teachers

Frequent and quick rotations

As found during the classroom observations, design should allow teachers to rotate frequently and quickly between many different teaching activities, alternating between acquisition activities like explaining, demonstrating and consolidation activities like exercises and quizzing. Therefore, design should require minimal startup time and effort to establish interactivity and afford quick student responses. There is no existing EdTech solution that supports this well enough yet. Therefore, this will be the main aim of the design from now on to create new and unexplored value over personal devices.

Teacher control and flexibility

The findings of my M21 project, theoretical framework, teacher interviews, classroom observations and EdTech expert interviews all corroborate that it is important to give teachers control and flexibility on how to teach. Firstly, teachers want to teach their students to operate in a variety of different scenarios, including ones that might be difficult and create friction. Therefore, even when certain options, like competition, are educationally or pedagogically not appropriate or ideal, these options should still be offered to teachers. Secondly, teachers want to pursue student equity, rather than equality. For example, rather than automatically assigning teams, teachers want to purposefully combine students to create a certain social dynamic.

Evaluation

Design should allow teachers to evaluate student progress and understanding. Teachers use the evaluation results to plan their lesson and differentiate between students.

Design for students

Socially scalable and balanced

As found during my M21 project, design for communal classroom activities should be socially scalable and socially balanced [28]. This means that activities should work for both few and many players and that there should be a balance between the players focus on the media, themselves, and others. All students should have an active role which is either directly interacting (actors) or being indirectly engaged for example through teamwork (spectators) [29]. Students should not sit on the sideline and only watch (audience). A way to design for scalability is to make the answering mechanism player agnostic. This allows students to team up and use one answering modality as a team. For example, in the M21 project, I found that motion tracking is not player agnostic.

Collaboration and competition

Design should both provide collaborative as well as competitive formats. While the interview with the teacher argues for competition and the expert interviews for collaboration, the theoretical framework, interviews with teachers and classroom observations argue for both. In combination with the principle to give teachers flexibility and control, it can be concluded that formats with both modes should be offered.

Design for accessibility

As accessibility has been found to be a major barrier to adoption, design should be accessible to all classrooms. There are a couple of ways this can be achieved.

Firstly, design should focus on affordability. This applies to cost of the designed product directly. Additionally, the use and requirement of other resources like laptops and internet also influences this. Are expensive

resources like laptops required and can already present technologies in the classroom like IWBs and webcams be leveraged?

Secondly, the design should not require internet access or a local network connection. Not all schools can or want to connect their devices to the internet or establish a local network.

Thirdly, design should be replaceable, adaptable, and compatible. This issue is part of the ecosystem fragmentation issue described in the introduction. Due to tender processes, schools can often not choose their hardware/software provider which might force them to switch between devices and software suites from time to time. Therefore, the design should follow these principles, for example by using off-the-shelf parts and be hardware/software agnostic.

Finally, the design should be able to integrate into existing software/methods/lessons. Since teachers have limited time, they will not create their own lessons and mostly use existing methods and lessons.

DESIGN

To create an interactive formative assessment tool that does not use personal devices, I designed Qwiz. Qwiz is an interactive quizzing tool that supports current teaching practice while being viable for the current market. The design can be split up into two parts: (1) A conceptual design which will be discussed in this chapter. (2) A prototype that concretely demonstrates how such a design might be realised in practice which will be discussed in the next chapter.

Qwiz is a visual marker based interactive quizzing tool offering both collaborative and competitive modes. Players answer questions by scanning their marker cube (Figure 7) on a camera that is connected to the central interactive whiteboard by showing a specific side or positioning the cube relative to the camera spatially. To keep the functionality description concise, a demonstrating video can be found on the demoday website and on my portfolio. Additionally, the full prototype can be experienced on my website.

Visual markers

The idea to use visual markers was inspired by my M21 project design called Material Quizzing. This design consists of both marker and RFID answering modalities. The visual marker answering modality was found to be a good fit for the design challenge in combination with the principles. On the other hand, the RFID modality did not match well due to the need to move towards a physical scanner.

The visual markers in this design can support current teaching practice of frequent and quick rotation between learning activities, requiring no startup and allowing quick answering. Additionally, they still afford the answers to be processed like a common digital multiple choice quiz retaining features like score and metrics allowing student motivation through gamification and allowing teachers to quickly evaluate student understanding. The design is socially scalable

by allowing the use of varying amounts of marker cubes and its agnosticism towards how many players use one marker cube together. As will be discussed in the next section, the use of marker cubes allows many interesting formats for both competitive as well as collaborative modes. Both the cubes and software can be made in a way that they are accessible by being affordable and open source.

Different formats

Qwiz offers four question formats. The first format is multiple-choice (ABCD) which is answered by scanning a certain side of the cube. The other three formats are category, sorter and pairs which are answered by moving the cubes spatially in respect to the camera. Figure 8 demonstrates the full mapping of all formats.

CUBE SIDE ANSWERING

The first way is to answer by scanning a certain side of

the marker cube to answer A, B, C or D. As discussed before, this was inspired by my M21 design. Additionally, this was inspired by Plickers, which lets players answer by rotating one marker. To provide the teachers with more control and flexibility as discussed in the design principles, the teacher should get an option whether to make the question count towards score and whether to show the given answers. By adding these two options, the teacher is given flexibility and can both create a competitive quiz as well as an opinion poll.

This 4-answer multiple choice question format is the most common one found throughout EdTech applications. Therefore, adding support for this is essential, as it allows companies that adopt this design to retroactively support existing questions in their content.

SPATIAL ANSWERING

The second way to answer is through positioning the cube relative to the camera in space. The different formats were found by comparing different input parameters afforded by cube with various modes in which primary school students are taught to structure information (Figure 8).

Input parameters

Input parameters for the marker cubes were found to be the following.

- ABCD sides of the cube
- Cube is visible versus hidden
- Cube x and y position
- Size of the cube on screen / z-position
- Rotation (on z-axis)
- Speed of the cube

Educational information structuring

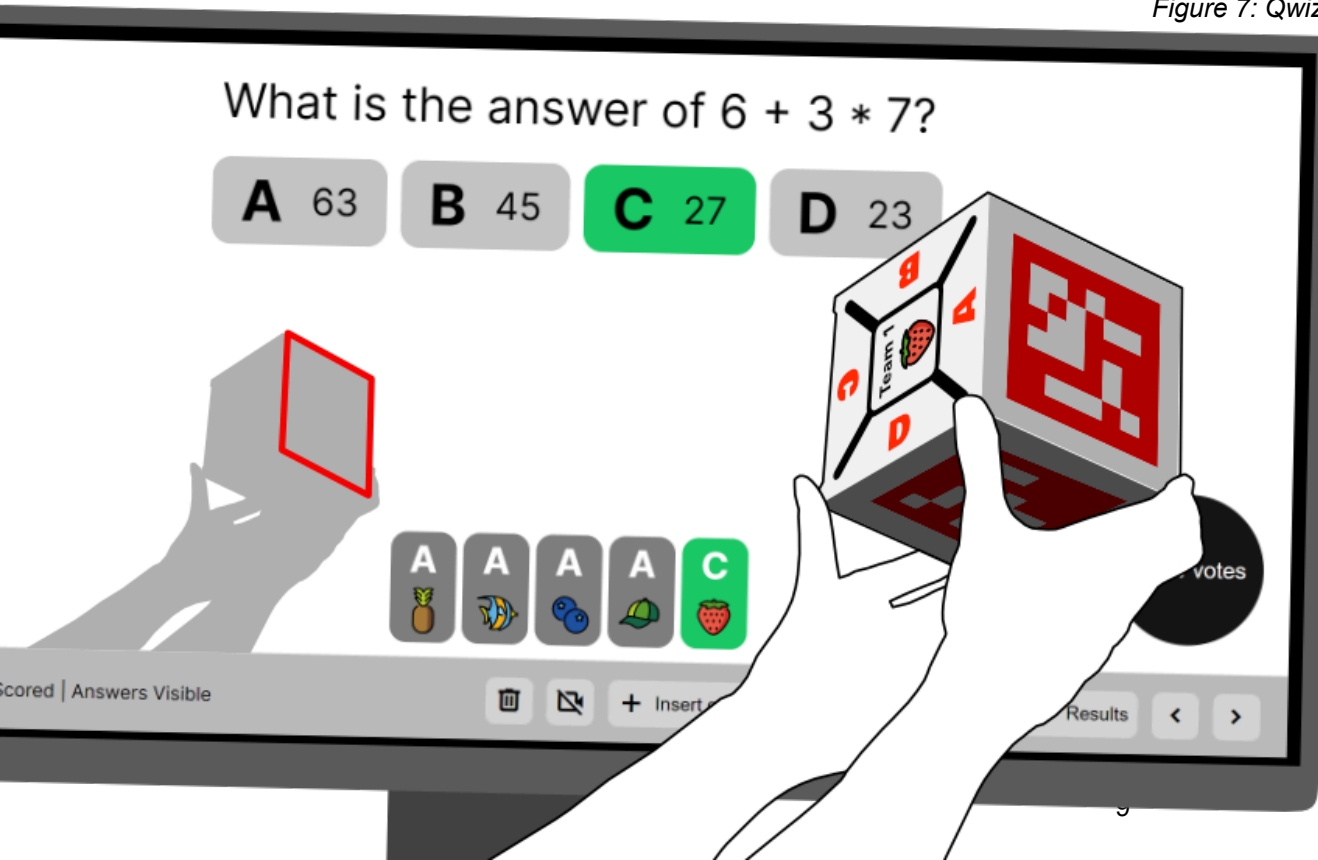
Learning contents were found by analysing TULE¹ (Intermediate Learning Objectives) learning goals and contents, published by SLO. I generalized the different information structures in which information is taught at

¹ TULE: Tussendoelen Leerlijnen (Intermediate Learning Objectives). <https://www.slo.nl/thema/meer/tule/>

TU/e ID page: projects.id.tue.nl/demoday/9712Pw
My portfolio: niels.win/projects/qwiz

Try the demo: qwiz.niels.win

Figure 7: Qwiz



primary schools. Although there are many more, I only considered the ones that fit the information bandwidth afforded by the cubes. For example, open ended answers are not within this scope. This resulted in the following modes.

- Choosing between different options
- Ordering small to big, old to new etcetera
- Pairing items in the same category or pairing items to a category
- Finding a numeric value

Combined

Finally, I combined the cube input parameters and information structuring modes into question formats. Figure 8 shows which formats resulted and why certain formats were chosen.

- Multiple choice ABCD: Choosing the right option(s) using the side of the cube (competitive)
- Sorter: Ordering items from left to right (collaborative)
- Pairing: Spatially pairing items by moving them close to each other. (collaborative)
- Category: Placing the item that is assigned to your cube by horizontally positioning the cube in the right category displayed on screen (competitive)

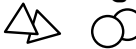
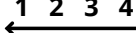
Combining cube side and spatial answering

Both cube side and spatial answering modes should be combined into one format. For example, combining them could result in choosing an item by choosing a cube side and then positioning it accordingly. Combining questions would create high element interactivity (complex actions, needing to do many actions at the same time) [15]. As discussed earlier, quizzing was less effective for learning when element interactivity was high, shifting focus from the question content to how to answer the question.

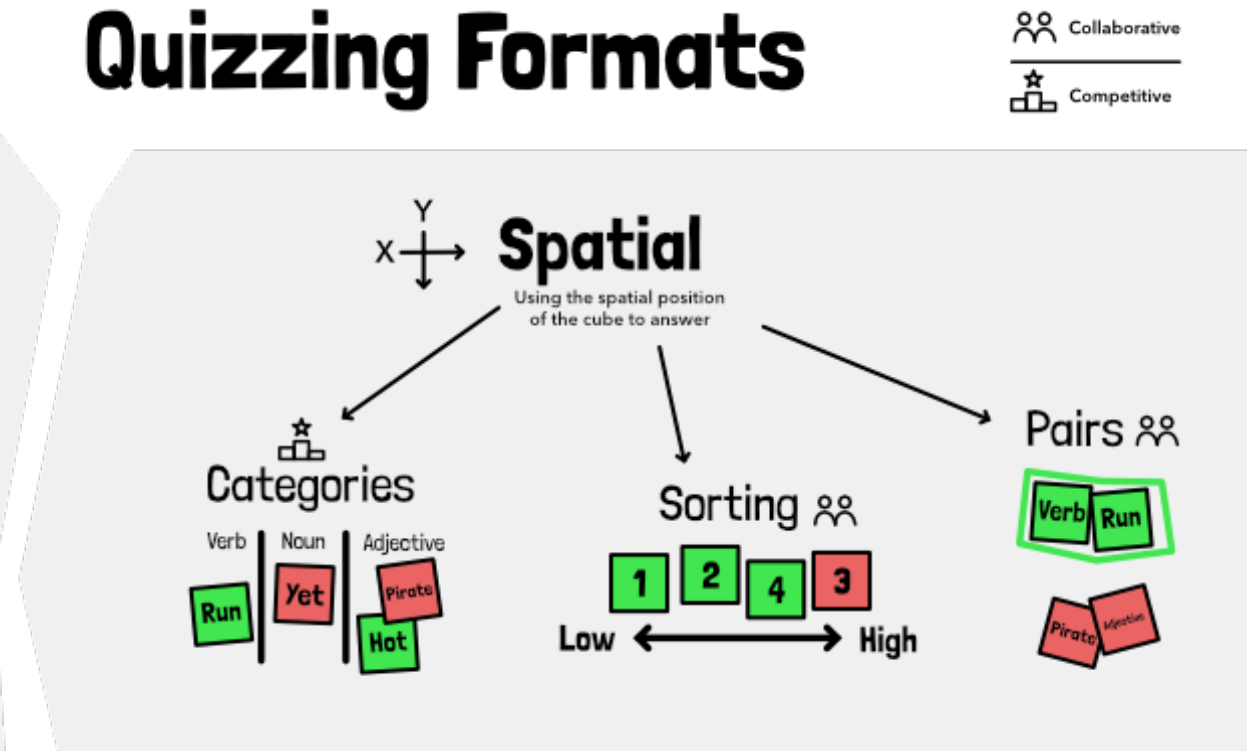
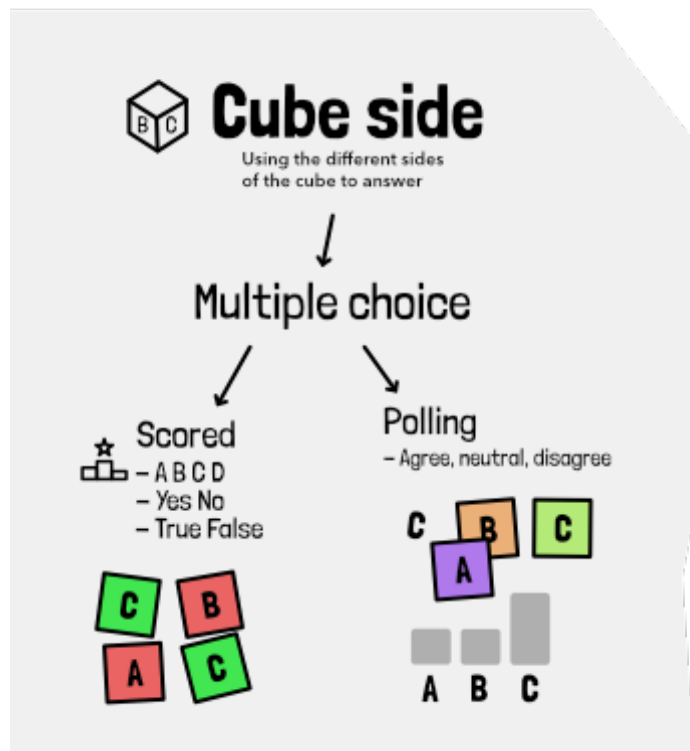
Figure 8: Combining cube inputs and information structures

This chart shows how to formats were found by combining cube input parameters with educational information structuring.

Green items indicate that the combination affords a versatile format that can be widely used throughout different subjects. Yellow items can also a good format but only with a niche application area. Orange items conceptually couple but no good formats were found. White items do not have a good coupling.

		Info structure			
		Choosing 1 ② 3 4	Linking 	Ordering 1 2 3 4 	Value 17 
Input parameter	Cube side 	Multiple choice			
	Visible/Hidden 				
	X Y 	Dragger	Pairs	Sorter	Guesser 
	Size /z-pos 			X-axis sorting is better	
	Rotation 	ABCD choosing is better			Turner 
	Speed 				

Legend
Versatile
Niche
Possible but no application
Not feasible



Quizzing Formats

Collaborative
Competitive

Figure 9: resulting quizzing formats

PROTOTYPE

The realised prototype consists out of two different major elements: The physical marker cubes and the quizzing web app.

Physical marker cube

The goal for the physical marker cube was to be accessible to acquire. This can be achieved through being affordable, compatible, replaceable, adaptable.

The open source ArUco markers¹ [24] were chosen as the visual marker technology for this prototype. Being open source allows anyone to integrate the marker cubes into their own system (adaptable) and anyone to produce the cubes themselves (replaceable). Additionally, ArUco is fast and does not require much computational power (compatible), making it able to run on most modern computers. There is a pure JavaScript version available which means that it can run on the web (compatible).

Tieben argues that design should have a strong and natural connection between the physical world and the digital representation [29]. The design establishes this

¹ArUco Markers. https://docs.opencv.org/4.x/d5/dae/tutorial_aruco_detection.html

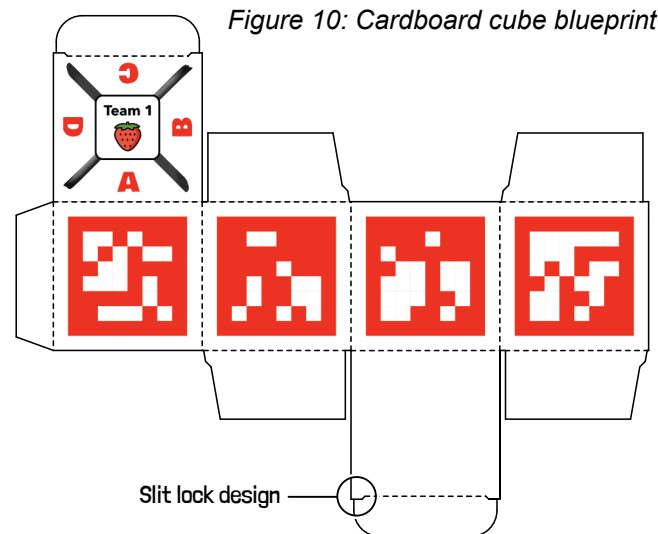


Figure 10: Cardboard cube blueprint

connection in multiple ways. Firstly, each cube has a team number. While making the prototype, it was found that team numbers could be confused with score when displayed next to each other. Therefore, in addition to team numbers, emojis were added to give each team a clear distinction in a playful way. Finally, each cube has a distinct colour. Colours were calculated in HSL by dividing the hue spectrum into equal spaces (in this case for 12 cubes $360 / 12 = 30$, resulting in hue values of 0, 30, 60, ...). In many computer vision systems, like Open CV, colours with the same lightness value do not necessarily have the same detectability. Equal detectability was calculated using the RGB to Gray conversion formula of Open CV¹.

¹RGB[A] to gray formula.
https://docs.opencv.org/3.4/de/d25/imgproc_color_conversions.html

Cardboard was selected as the preferred material for making the marker cubes. Cardboard is affordable, easily printable, sustainable, easily foldable, and safe (for example when thrown). Additionally, the cubes are accessible to different schools as they can be made by EdTech companies in mass for cheap, by third parties, or by the teacher/students themselves as a DIY project. The cardboard box model is Reverse Tuck End with two slit locks¹. Slit locks were chosen because compared to a friction lock, they are more difficult to open and do not come apart when the box is handled roughly for example when being thrown.

¹Box Styles for Folding Cartons. <https://www.howtobuy packaging.com/box-styles/>

Figure 11: Professionally lasercut and printed cardboard cube



Web app

The main goal of the software part of the prototype was to be lightweight as it should be able to run on the average computer. Additionally, it should be modular because of the need for different formats and easily switching between them. I made a web app, because websites have high compatibility as they can run on both windows and android systems¹. The web framework Vue.js² was chosen because its single-page nature makes it easy to switch between questions with different formats without having to fully load new pages.

The most important user interface decisions will be discussed here. Firstly, all important buttons are placed on the bottom of the screen because during the observations, students were struggling to reach the top buttons of the Kahoot! app. Secondly, a blur and threshold filter were added on the camera feed to reduce its complexity and distractibility. Thirdly, as discussed earlier, emojis were used as the main identifier for teams as they are easier to distinguish (from score). Specific interface design choices for individual formats will not be discussed.

Some essential features were added to the app (Figure 12). Firstly, a scoreboard was added, displaying all teams and their scores to allow teachers to leverage the discussed benefits of gamification (GSRs). Additionally, to address the teacher evaluation need to differentiate and plan future lessons, I implemented a results page of the quiz. The results page shows a table that displays what each cube team answered in addition to which percent of teams were correct. Finally, a question creator was added to allow teachers to quickly add multiple choice questions during the lesson.

¹CTOUCH uses Windows and Prowise uses Android.
<https://ctouch.eu/touchscreens/ctouch-riva-2#specifications>
https://www.prowise.com/content/uploads/2024/03/20240328-NL_Specsheet_TSUltra.pdf

²Vue.js. <https://vuejs.org/>

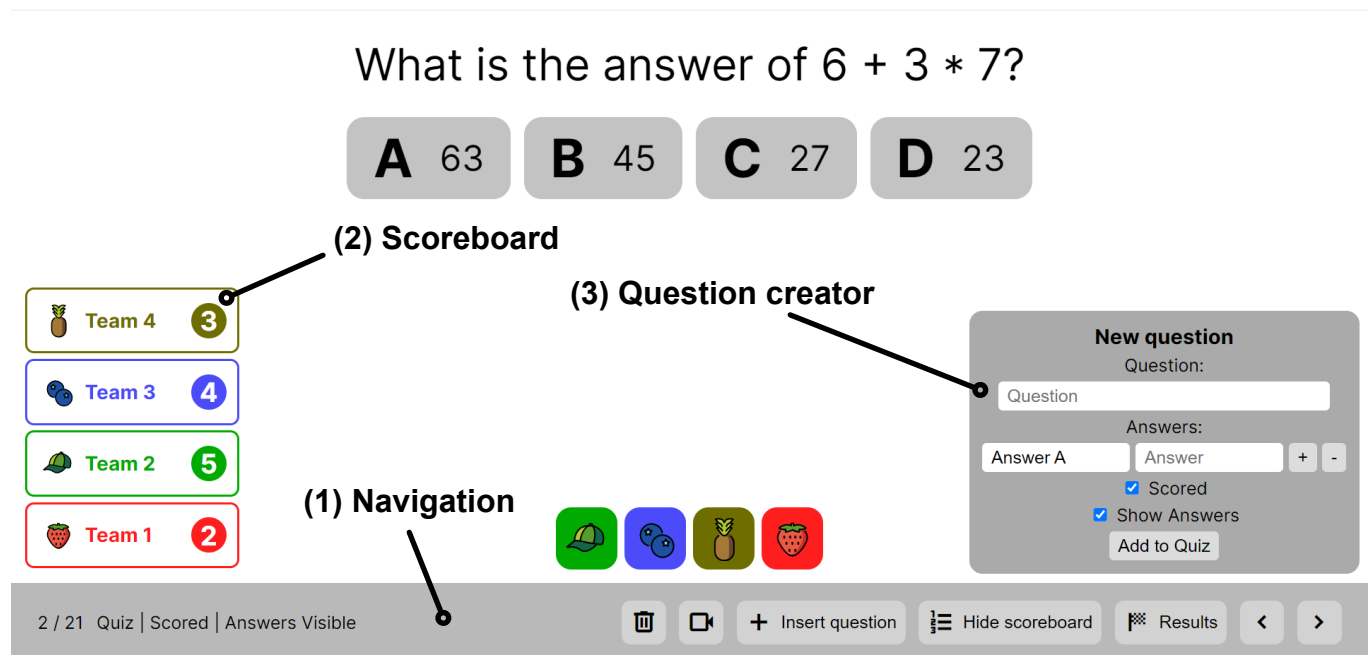


Figure 12: Qwiz user interface. (1) Persistent global navigation bar to manage quiz flow. (2) A scoreboard showing teams and their score. (3) Questions creator which allows teachers to add new multiple-choice questions on the spot.

	1	2	3	4	Correct %
Q1 : When was the European Union formed?	C	B	B	A	50%
Q2 : What is the answer of $6 + 3 * 7$?	A	C	C	C	75%
Q3 : Allies, Neutral of Axis Powers in World War 2?					75%
Q4 : Are they made of plastic?					50%
Q5 : Which is the largest planet in our solar system?	B	B	A	D	50%
Q6 : What is the capital of Canada?	A	C	B	B	50%

Figure 13: Results overview

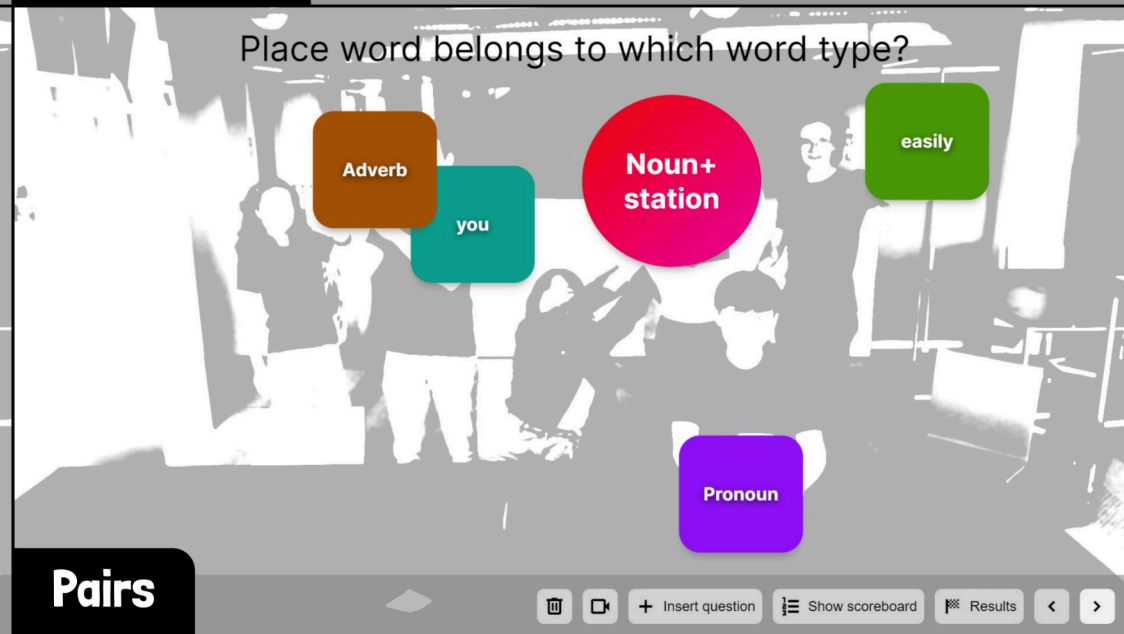
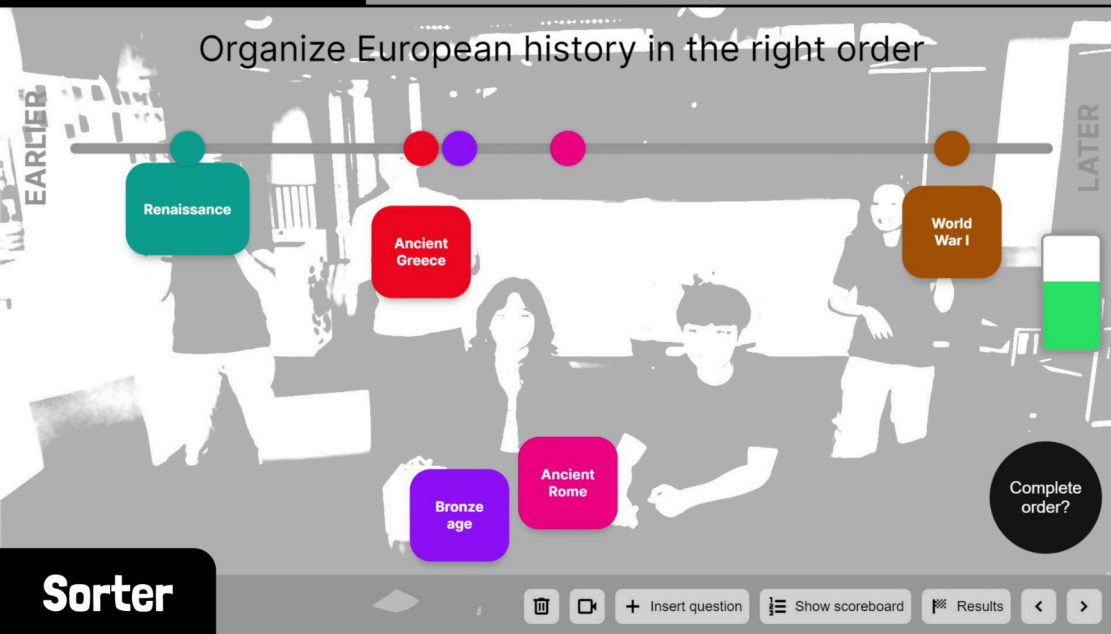
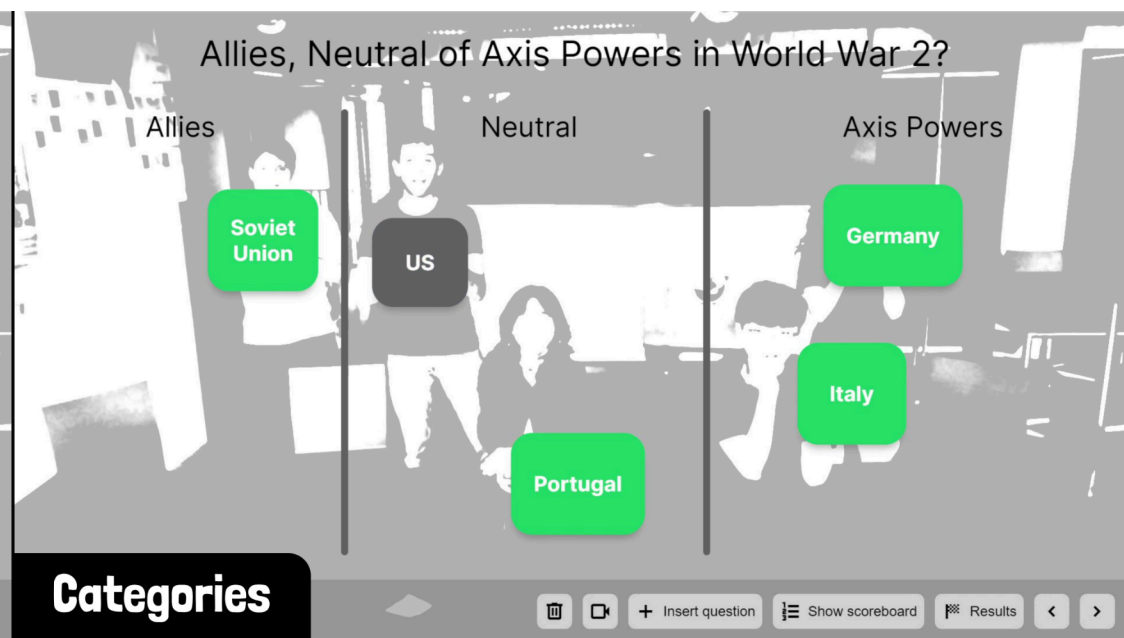
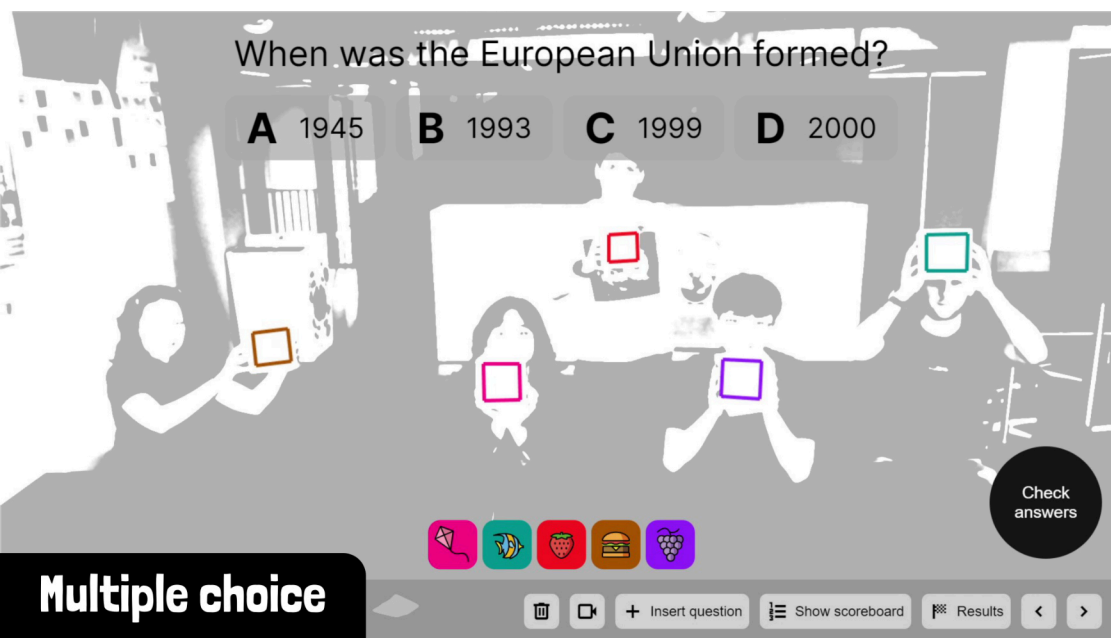


Figure 14: Question formats

EXPERT INSIGHTS

The main goal of the expert interviews was to find out how Qwiz could be brought to the market. As mentioned in the design principles, the design works best when integrated into existing market solutions. Therefore, it is important to understand whether and why existing EdTech companies like Qwiz and what it would take to integrate a design like Qwiz into their product.

Designers from the companies LessonUp¹ and Gynzy² were interviewed. Both companies were chosen because they were the main solutions used during the classroom observations. LessonUp focuses on making tools where teachers, publishers and other parties like museums and NGOs can make interactive lessons. During the classroom observation, a lesson about plastic soup in the ocean was given using LessonUp³. The interviewed designer described LessonUp's vision as making good education for everyone, regardless of who you are, how you are and where you are. Gynzy is one of the larger parties in this sector. They make their own software and lesson content, offering additional functions like support for student differentiation.

Qwiz

Both designers see value of Qwiz. However, they both think that it could only work when integrated into an existing product because the teacher should not have to switch between different applications. The LessonUp designer thinks Qwiz fits into their company vision because it offers accessibility to schools with less access to technology. Additionally, they like that the everything happens on one central screen (the IWB) and that there is no startup time for answering the quiz. According to their internal research, not all schools have many cameras like webcams. Gynzy likes that Qwiz allows testing the same knowledge using different

¹ LessonUp. <https://www.lessonup.com/site/en>

² Gynzy. <https://www.gynzy.com/en>

³ LessonUp lesson about plastic soup.
<https://www.lessonup.com/nl/channel/plasticsoupfoundation/lesson/r9mxR2qaR6pnz44CE/NuGwicCSfmJJ36Wyl>

formats. Additionally, they found that teachers wanted to do their quizzes without personal devices, and that Qwiz might be a good middle ground for this.

Integration

The main conundrum for integration is that software companies like LessonUp and Gynzy are interested in solutions like Qwiz, but do not want to sell physical products (like the marker cubes). On the other hand, hardware companies like CTOUCH, who are better equipped to sell physical products, do not make the software which would benefit from integrating solutions like Qwiz. Furthermore, software companies like LessonUp and Gynzy, prefer to integrate such a solution themselves, without relying on another company's product. Gynzy says that this could be solved through an official collaboration with a hardware company. LessonUp suggests that the marker codes could be standardized, and possible produced separately.

Business approach

Although there is no single solution to this problem, I will formulate a general business approach. Firstly, the use of ArUco codes for marker cubes should be standardized. A certain team in combination with a certain side of the cube should always have the same marker ID. Following this standardization, different companies can produce their own quizzing software and cubes independently while still being compatible with each other. Secondly, I (for example as a startup) could offer an API with higher level functions like support for teams/score management and different formats. This would allow companies to integrate it into their product for a small price without needing to develop it from the ground up. An EdTech designer on demoday advised me to implement this by serving it as a web iframe¹. Thirdly, I (for example as a startup) could make a free standalone quizzing application and sell basic marker cubes myself. The application would allow anyone who has the cubes to make and host their own quiz. This would be targeted towards being used

¹ <iframe>: a HTML element that represents a nested browsing context. It allows the user to embed a HTML into another.

FIELD STUDY

After the prototype was built, a field study with the Qwiz design was conducted in a classroom. The main goal of the study was to understand how the teacher and students use the system in a real setting. Firstly, this includes how teacher use it to teach. Secondly, this includes how students use it to answer the questions but also the social dynamics of how they interact among themselves. Social dynamics can be divided up into the following subtopics [17]: Communication; How students communicate with each other. Measured by counting verbal and gestural communication. (2) Participation; How involved each student is. Measured by identifying number of actors, spectators, and audience [29]. (3) Coordination flow; How groups organize teamwork.

Another goal was to find out how well the system works in its current state and how to improve it. Especially because the design is novel, this entails mostly to find whether the teacher and students understand it, it is usable, and the users enjoy using it. Drawing conclusions about higher level outcomes like learning outcomes is not appropriate at this stage.

Method

The goal is to mimic a natural setting as much as possible. Therefore, the user test was conducted as part of a real primary school class. Additionally, Qwiz was integrated into an existing lesson of a subject that was currently being taught in that class.

The results were acquired through observation, a survey for the students (Appendix C), a discussion with the teacher and the usage data from the system. To completely focus on observing, the researcher employed another TU/e ID master student to help setting up and troubleshooting the user test. Additionally, a video was recorded from the back of the classroom and a screen recording was made of the web app which was later used for more detailed and accurate observations.

Results

The user test took place in a 'groep 8' (age 11-12) class

of about 28 students. The researcher provided 12 marker cubes. The current subject was history of World War 2. To create the questions, the teacher provided me with a workbook about the lesson.

INTEGRATING THE QUESTIONS

Most questions were copied from the workbook and fitted to the formats. Some new questions were formulated with teacher help. From a total of 14 question in Qwiz, 10 were multiple choice, 2 were category, 1 was a pairs and 1 was a sorter. Additionally, one easy question of each format was added at the beginning for the class to practice. See Appendix D for the list the questions . I found that some formats being used less frequent does not necessarily mean that they offer less educational value. For example, the sorter question in this lesson was a valuable concluding activity where all subtopics are holistically put in a final order together. On the other hand, some questions would fit other subjects better. For example, the pairs question could be used more than once when linking words to types of words (noun, verb, etcetera) during spelling. Finally, I found that history as a subject does not lend itself well to questions with absolute answers due to its subjectivity and interpretability.

FINDINGS FROM USE

During the main part of the quiz, the teacher gave every table group (of 4/5 students) a cube, which resulted in the use of 7 cubes.

Understanding

Both the students and the teachers quickly understand how to use the system and formats well. Before the user test, the teacher was given a brief explanation by the researcher and some time to play with it. During the

test, the teacher was able to clearly explain the functionality of the system to the students with no assistance of the researcher or technical assistant. After doing the four practice questions, the students all easily understood how to answer all formats. Additionally, the emojis proved to be an effective way to identify teams. The teacher three times successfully referred and established contact with a team by their emoji. Team numbers were not referred to once.

On the other hand, the feedback provided by the system was not always clear to the students. During use, several verbal utterances of confusion were observed. Especially the scoring system was not clear. For example, after the students had answered and their answers lit up as correct/incorrect, they could still change their answer without affecting their score, which caused students to think they were treated unfairly. Additionally, when a multiple-choice question was not scored, the students were confused when the correct answer did not show and they did not get any points, even though it was indicated after the question with a 'no score' text. It is important for the design to have a clear and simple system feedback system.

Quizzing procedure

A strategy was discovered on how teachers want to structure quiz questions and how this can be implemented into the design. Three observations contribute to this conclusion. Firstly, the teacher decided to read all question aloud together with the entire class before answering them. Secondly, the students get distracted by the camera feed and the digital representation of their marker before and after answering. While reading the questions aloud communally, some students already started to use the cubes. Thirdly, while answering, the students did not

discuss the answer but rather scream the right letter at each other. Even though the teacher instructed the teams to wait and discuss the answer without screaming the letter, many teams did not follow this instruction. With the current design, many students are not able to properly discuss the question and wait to answer while the camera feed is on, giving the option to answer. Even though the teacher had a button to disable the camera, he did not use it. They might have forgotten it because it is a repetitive and non-obvious task. Since this is a repetitive and tedious task, disabling and enabling should be automated to show the camera only when used for answering.

In a discussion after using it, the teacher said that normally a multiple-choice question flow consists out of three steps. (1) Showing the question without the answer so students can deliberate open-ended. (2) Showing the possible answers to which students can compare their initial answers. (3) Answering the question. Combining this process with the design, the design's new desired answering steps (Figure 15) can be formulated as: (1) Showing the question without the answers while the camera is turned off. (2) Showing the possible answers while the camera is turned off. (3) Allowing the students to answer by enabling the camera. (4) Checking the answers and disabling the camera. (5) Viewing and discussing the results. After quickly implementing this into the design, the teacher agrees that this is the correct operationalisation of these steps.

Teacher strategies

In addition to reading the questions aloud together with the students, more teacher strategies were identified. The first strategy was to gain control over the students by leveraging their moment of highest anticipation just

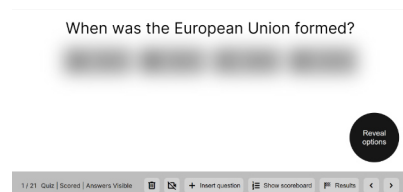


Figure 15.1: Questions shown, answers and camera hidden

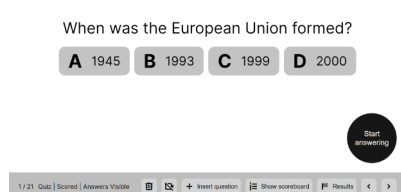


Figure 15.2: Answers now shown



Figure 15.3: Camera now shown and option to answer

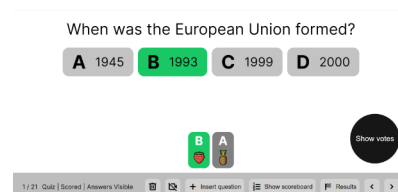


Figure 15.4: Right answer shown and camera disabled

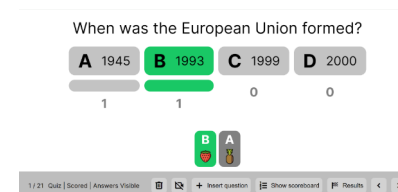


Figure 15.5: Results shown

before checking the answers. This way, the teacher could more easily achieve his goals like quieting the class. Before pressing the button to check the answers, the teacher counted down from five. However, towards the end he slowed down and for example often waited until the class quieted down before checking the answer. Because the teacher needs control over this strategy, a timer to support the counting is not advisable. The second strategy was using problems or inconsistencies of the design to enhance teaching. During the pairs question, one cube user had no pairing due to the uneven numbers of cubes. Rather than disregarding this problem, the teacher asked the class what would have been the correct pairing for this cube. As there is no perfect solution to this problem, the designer would have to make major compromises in usability by requiring the teacher to fill in the number of players beforehand. Rather than designing cumbersome solutions to these kinds of quirks in the system, designers should wonder whether they are truly a problem for the teacher and should be solved at all.

Student social dynamics

Social dynamics can be divided up into communication, participation, coordination flow and reasoning levels [17]. Overall social dynamics varied significantly per team, some teams displaying more social behaviours than others. Observations of social dynamics are limited because the camera was placed facing the backs of students due to privacy reasons and a student accidentally moved it, allowing me to observe three teams only effectively.

From observation, it was found that communication differs much between teams. In some teams, every student was involved and almost all students communicated during all questions. Moreover, there is a significant difference in the participation between teams. The teacher instructed the teams to hand over the cube every round and between all team members. Some teams followed this instruction while other teams almost never handed over the cube or only between a subset of the members. According to the survey, the students generally answered that communication and participation went well. Comparing both results, communication and participation do not always

correlate. For example, in a team (team 4) where only one student controlled the cube due to the team's awkward position relative to the camera, both the observations and the survey reveal that every student felt and were involved and communicated.

Student outcomes

All teams ended with similar quizzing scores. According to both the survey and observation, the students had much fun using Qwiz. Interestingly, the students still had a small preference for Kahoot! over Qwiz. It is probable that the previously discussed inconsistency frustrations were the cause for this.

Formats

The best liked format according to the survey was the multiple-choice format. 23 out of 26 students indicated to want to play it again. This might be caused by the familiarity with the format, possibly explaining their preference for Kahoot!. Of the category and pairs formats only 20 out of 26 students wanting to play it again. Finally, of the sorter format only 13 out of 26 wanting to play it again and 3 students not wanting to play it again. However, the cause for this might be that I decided that during the only sorter question at the end of the quiz, the remaining 5 cubes should be distributed over random students to test the system with all cubes. The students with the cubes standing in a row created a wall of people. Especially the students behind this wall stopped being involved with the quiz. One could speculate that for most participation, either all or only a small amount (1 per 4/5) students should have a cube and that anything in between leads to less participation. It would be interesting to test this in the future.

DISCUSSION

At the beginning of this project, I established the design challenge to find a solution for interactive formative assessment activity alternative without the use of personal devices. During this project, I found that to achieve this, it is essential to support the workflow of teachers which means supporting frequently and quickly switching between different teaching modes.

My design Qwiz addresses this design challenge. Qwiz supports teacher workflow by allowing students to

answer questions by scanning visual markers. In contrast to personal devices like laptops, the solution has no startup time and therefore fits better into the teacher workflow. Additionally, it retains most advantages of common quizzing tools supported by personal devices, like teacher outcome evaluation and benefits of gamified student response systems (GSRS) like Kahoot!. However, compared to personal devices, the visual markers of Qwiz do not allow for rich answer formats with a high information bandwidth like open ended text answers.

Qwiz offers an accessibility advantage over personal devices. The cardboard cubes are affordable, allowing teachers and schools to acquire them without a tender process. However, Qwiz still requires a modern interactive whiteboard and a sufficient camera. Even if a camera still needs to be acquired, the price of a complete set is still affordable, being in the price range of around one student laptop¹.

Using Qwiz, student social balance and roles are not always equal. Firstly, there are cases where not all students have marker cubes, and the cube needs to be shared within a team. During the field study only seven cubes were used for 28 students. It was observed that not all teams shared the cubes equally, and some students, who did not use the cube, regressed from being a spectator (not actively using, but still engaged) to becoming audience (just observing and not engaged) [29]. Additionally, the spatial quizzing and/or collaboration formats currently work best when used with ten cubes or less. If more are used, the screen becomes cluttered and collaboration formats become too difficult to solve. However, the multiple-choice format has been tested to work with up to 30 cubes², which allows all students to participate assuming they

¹ Rough price estimation: Set of Qwiz cubes (€30) + Logitech Streamcam (€130) = €160.

² The program performance stays the same if more cubes are in view. The marker detection runs of a separate CPU thread. The detections per second remain the same (6 detections per second on my computer) regardless of whether there are zero or thirty cubes in view. Furthermore, the thread managing the frontend of the website was far from reaching its computational limit, even with 30 cubes.

have a cube and are in the camera view.

A goal for this project was to make a design that could work in the current market. The conundrum that relevant software companies are not ready to make physical products was already discussed. From a perspective of the user who acquires this solution, Qwiz might be perceived as a middle ground between non digital solutions and fully digital solutions like quizzing with personal devices. Schools that already have bought personal devices might not want to acquire yet another solution that has similar functionality. However, schools that do not have access to technology like laptops, internet, or even a local network, might find this solution more appealing due to availability and price. Additionally, schools whose vision is to limit technological adaptation might find this solution an acceptable middle ground.

FUTURE WORK

Qwiz demonstrates the versatile and most obvious quizzing formats. However, I believe that many more niche formats can be made in this system. During the Montessori teacher interview, the teacher showed me the Montessori 'taalsymbolen'¹. These are combination between primitive shapes and colours that visually represent a type of word. In a similar fashion to the Sorter ordering format, these could be implemented in Qwiz to create sentence. Additionally, two additional niche formats are described in Figure 8. Using the Turner format, the student selects a value by rotating the cube and might be used to understand analogue clocks.

Qwiz might also be used in high schools in the same fashion as in primary schools. However, in high schools, the switches between teaching modes become less frequent. It remains to be seen whether Qwiz can provide any value to high school classrooms. Qwiz might also be valuable in other scenarios than interactive formative assessment quizzing activities. During the G8 classroom observation, the students had to give a presentation to their parents. Some groups hosted a quiz for the parents. These quizzes were held

¹ Taalsymbolen. <http://kelpin.nl/fred/download/montessori/Taalverwerving/taalsymbolen.pdf>

without devices, possibly due to the difficulty of establishing interactivity. Qwiz might be valuable in these kinds of scenarios. Additionally, during demoday I was approached by someone who does employee training workshops for companies. They were interested in trying Qwiz for this purpose and further proved this by sending me a text message afterwards. Interestingly, they even said to prefer the playful aesthetic for this purpose over conceptually toned-down versions.

CONCLUSION

This project tackled the challenge of designing an interactive formative assessment tool for primary education without relying on personal devices. Qwiz, the resulting design, uses visual marker cubes to enable students to quickly answer quiz questions and requires no startup time, aligning seamlessly with the teacher's workflow by supporting quick and frequent activity transitions. This design retains the benefits of gamified student response systems, such as evaluation data for teachers and student engagement, while offering greater accessibility and affordability. Both teachers and students quickly understood, effectively used and liked Qwiz. Qwiz's is an appealing solution for schools with limited technology access or those seeking to reduce personal device usage. Future exploration could include discovering more question formats and applications in other scenarios.

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APPENDIX A: DESIGN PRINCIPLES

This part summarizes and explains the design principles of my previous project into a list.

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

This design principle comes directly from Tieben's work about playful interaction of teenager in public spaces [29], which is relevant for the design of communal teaching with IWBs. When designing exergames, where physical exertion is a goal, a natural connection between physical action and game representation makes the movement itself more intrinsically motivation rather than only the reward. Although this project does not necessarily focus on physical activity, the notion that the natural connection makes the actions of playing the game more intrinsically motivating can still be leveraged.

Design should be socially scalable participation is designed to be a shared exercise where the number of participants is dynamic. Design should be socially balanced so that the users interact with the device as well as among themselves.

Snibbe and Raffle proposed a set of design principles when designing for social immersive media [28]. I imply from these principles that all participants should have a similar role. Preferably, most of them should be actors or spectators and as few as possible audience [29]. After reviewing the Prowise Move and Picoo products, social balance and scalability were found to be most relevant. With Prowise Move only one child plays at a time and the rest watches, making the design score low on these principles. On the other hand, Picoo derived great value by implementing these principles well. Kahoot! also scores well on these principles by having a theoretical infinite scaling of participants.

Design should be replayable and retain curiosity and motivation continually. To achieve this, design should spark curiosity through other means than only novelty.

Prowise Move was found to mainly spark curiosity through the novelty of the interaction without other strong motivators. Other, longer lasting means like partial exposure through hiding or exposing information, as used as a mechanic by quizzes, are desired.

The design should be affordable. This can either be done by designing cost-effective products as well as leveraging technology already present in classrooms.

By working with the interactive whiteboard company CTOUCH, I found that tender processes are restricting the innovation in EdTech. When schools, or the school districts they are sometimes part of, want to acquire products or services over 10.000 euro, they must do so through a tender process. A tender is an invitation issued by the school for suppliers to bid on supplying the often most affordable version of the thing that the school wants to buy defined by a list of specifications. The supplier that satisfies the tender best, wins the bid. This means that the school (district), for better or for worse, theoretically has no influence on the supplier that is chosen.

Concluding, the education acquisition process has a requirement-based 'school pull' rather than 'supplier push' nature (although there are exceptions). Therefore, expensive, tender-subjected products have a lower chance of adoption as schools are not likely to describe them in their tender. This issue is part of the accessibility problem discussed in the introduction.

To bring innovative designs to schools, the designs should be either affordable enough to be bought directly (without a tender) or the schools should be convinced to invest the money. Trying a freemium minimum viable product might help schools consider the latter. Either way, designing an affordable product has merit. This can be either done through designing something affordable or leveraging already present expensive technology in the classroom.

Design should work towards making elements of the design replaceable, adaptable, and compatible. The design's functionality should transcend a single purpose use bound to one (eco)system.

This is another principle that follows from the tender discussion. As schools cannot decide which supplier they choose, there are often forced to switch between different ecosystems. Therefore, the design should principles of replaceability, adaptability, and compatibility for example by using off-the-shelf parts and creating ecosystem agnostic devices that be easily adapted by anyone. This issue is part of the ecosystem fragmentation issue described in the introduction.

The functionality of the design should not rely on an internet connection.

Many schools are hesitant to connect their displays to the internet. According to CTOUCH, 90% of displays they supply remain disconnected to the internet. Moreover, not all schools can be expected to have stable internet access or network infrastructure [13, 19, 20, 33]. This issue is part of the accessibility problem discussed in the introduction.

Design should be agnostic to whether it is played with a team or as an individual. Additionally, the design should allow players to both collaborate and compete.

In an interview with a primary school teacher, when discussing competing versus collaborating and individual versus teamwork, it was found that it was important for children to learn to operate in wide range of scenarios.

The design should support teachers promote equity through teacher control (rather than equality through automatization). Choosing teams, rewards mechanics and competition level should be controlled by teachers.

Additionally, in the interview it was found that teachers want promote equity by controlling classroom dynamics. They want to differentiate between students, accounting for their knowledge, skills, personality, issues etcetera for example by strategically pairing students with diverse skill and expertise when forming teams.

APPENDIX B: ANALYSIS OF PINTRICH'S FOUR- DIMENSIONAL MODEL

This appendix further explains my vision on how Pintrich's Four-dimensional model is relevant to the discussion of collaboration versus competition.

Looking through the lens of the four-dimensional goal orientation model by Pintrich [21], we can further understand their differences. According to the model, the student can be in an approach state, which means pursuing a positive outcome, or an avoidance state, which means avoiding a negative outcome. An approach state is preferred for learning [2]. The second dimension of the model is differentiating between performance, the goal of developing competence relative to others, versus mastery, the goal of developing competence for its own sake, defining success internally. Mastery aligns more with the vision of primary education, as the goal of learning is to make the students smarter and not better than other. I think, the model can also be linked to the self-determination theory that discusses intrinsic (mastery-approach) and extrinsic (performance-avoidance) motivation [7]. Intrinsic motivation might have a longer lasting effect. Additionally, intrinsic motivation often is missed in the classroom while extrinsic motivation is always present through elements like the teacher pressure and grades.

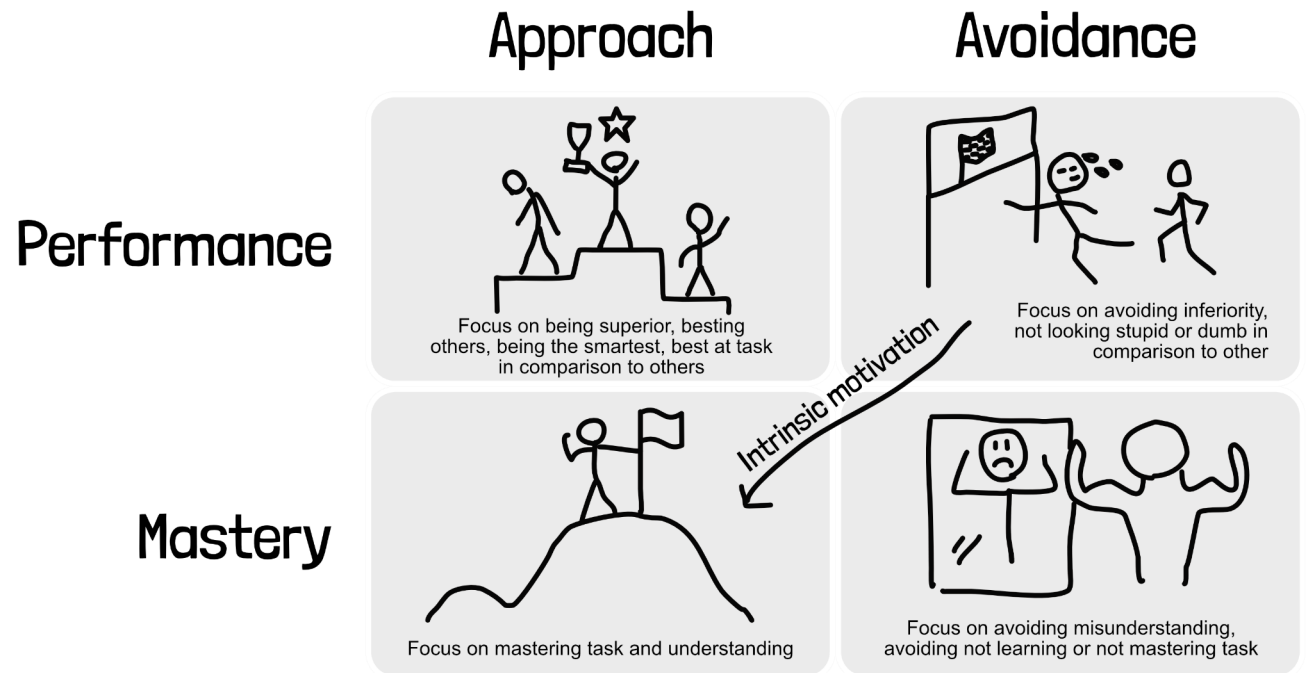


Figure 16: Graphic I made to explain Pintrich's Four-dimensional model

APPENDIX C: STUDENT SURVEY & RESULTS

Figure 17: Qwiz questionnaire. Red nummers were added only for this appendix to explain the results image.

Vragenlijst Kubus

Hoe leuk vond je de kubus?

☐ 1 
☐ 2 
☐ 3 
☐ 4 
☐ 5 

Helemaal niet leuk
 Niet leuk
 Een beetje leuk
 Leuk
 Heel leuk

Welke vind je leuker, Kahoot of de kubus?

☐ 1 Ik vind Kahoot leuker
☐ 2 Ik vind beide even leuk
☐ 3 Ik vind de kubus leuker

Ik had plezier tijdens de quiz

☐ 1 Nee
☐ 2 Een beetje
☐ 3 Ja

Het voelde alsof ik actief meedeed aan de quiz

☐ 1 Nee
☐ 2 Een beetje
☐ 3 Ja

Het samenwerken en communiceren met anderen ging goed tijdens de quiz

☐ 1 Nee
☐ 2 Een beetje
☐ 3 Ja

Zou je het nog een keer willen doen?

	Ja 1	Misschien 2	Nee 3
Welke kleur heeft een vos? A. Oranje B. Geel C. Paars D. Blauw			
Waar hoort de bij? A. De bij B. De bij C. De bij D. De bij			
Wat is de kleur van de vlag van Nederland?			
Combinez de dieren die op dezelfde plek leven			

Figure 18: Qwiz survey results.

Survey index	Cube team	Like (1-5)	Kahoot vs cube (1-3)	Fun (1-3)	Participate (1-3)	Teamwork (1-3)	Quiz (1-3)	Category (1-3)	Sorter (1-3)	Pairs (1-3)	Score	Fun per team (1-3)	Participate per team (1-3)	Teamwork per team (1-3)
1	1	4	1	3	2	3	1	1	2	1				
2	1	4	2	3	3	2	1	1	1	1				
3	1	5	2	3	3	3	1	2	1	1				
4	1	5	2	3	3	2	1	2	2	1				
5	3	4	2	2	2	1	2	1	1	2				
6	3	5	2	3	3	2	1	1	1	1				
7	3	3	1	2	2	1	1	1	2	2				
8	4	5	1	3	3	3	1	1	1	1				
9	4	3	1	3	3	3	1	1	1	1				
10	4	5	3	3	2	2	1	1	2	1				
11	4	4	2	3	3	3	1	1	2	1				
12	5	4	2	3	3	3	1	1	2	2				
13	5	4	2	3	3	3	1	1	1	1				
14	5	3	1	2	1	2	2	2	3	1				
15	5	4	1	3	2	3	1	1	1	1				
16	5	4	1	3	3	3	1	1	1	1				
17	9	5	3	3	3	3	1	1	3	1				
18	9	5	3	3	3	3	1	1	1	1				
19	9	5	2	3	3	3	1	1	3	1				
20	9	4	2	3	2	3	1	2	2	1				
21	2	5	2	3	2	3	1	2	2	1				
22	2	4	1	3	3	3	2	1	2	2				
23	7	5	3	3	3	3	1	1	1	2				
24	7	3	1	2	1	1	1	2	2	3				
25	7	5	3	3	3	3	1	1	1	1				
26	7	4	3	3	3	2	1	1	1	1				
Average		4,27	1,88	2,85	2,58	2,54	1,12	1,23	1,62	1,27				
Median		4	2	3	3	3	1	1	1,5	1				

APPENDIX D: FIELD STUDY QUIZ

1. Welk jaar begon de Tweede Wereldoorlog?

- a) 1939
- b) 1940
- c) 1941
- d) 1942
- Correct Answer: a

2. In 1933 wordt Adolf Hitler rijkskanselier van Duitsland. Hoe komt hij aan de macht?

- a) Meerderheid van stemmen
- b) Hij neemt zelf de macht als dictator
- c) Hij wordt benoemd door de vorige rijkskanselier
- Correct Answer: c

3. Waarom sloot de Verenigde Staten zich aan bij de geallieerden?

- a) Omdat Duitsland Polen binnenviel
- b) Omdat Duitsland de Verenigde Staten aanviel
- c) Omdat Japan China binnenviel
- d) Omdat Japan de Verenigde Staten aanviel
- Correct Answer: d

4. Geallieerden, neutraal of asmogendheden?

Geallieerden:

- China
- Verenigd Koninkrijk
- Sovjet Unie
- Verenigde Staten
- Sovjet-Unie

Neutraal:

- Spanje

Asmogendheden:

- Duitsland
- Italië
- Japan

5. Met welke gebeurtenis begint de Tweede Wereldoorlog?

- a) Met de inval van Nederland in 1940
- b) Met de inval van Polen in 1939
- c) Direct na Eerste Wereldoorlog
- d) Na Duitsland het verdrag van Versailles niet volgt
- Correct Answer: b

6. De Eerste en Tweede Wereldoorlog hadden niets met elkaar te maken.

- a) Waar
- b) Niet waar
- Correct Answer: a

7. Welke stad wordt platgebombardeerd om Nederland tot overgave te dwingen?

- a) Amsterdam
- b) Utrecht
- c) Rotterdam
- d) Arnhem
- Correct Answer: c

8. Combiner om de zinnen af te maken.

- De NSB → steunde de Duitsers
- Het verzet → maakte het de Duitsers moeilijk
- De grote meerderheid → probeerde normaal te leven
- De Joodse bevolking → werd zwaar vervolgd

9. Op 5 mei 1945 wordt Nederland bevrijd. Maar de Tweede Wereldoorlog is dan nog niet voorbij. Met welke gebeurtenis komt de oorlog ten einde?

- a) Met de val van twee atoombommen op Japan
- b) Met de zelfmoord van Adolf Hitler
- c) Met de bevrijding van Berlijn door het Rode Leger
- Correct Answer: a

10. Wie kreeg welke straf?

- Leider van NSB → De doodstraf
- Meisjes met verkering met een Duitse soldaat → Kaalgeschoren worden

- Een Nederlander in het Duitse leger → Een gevangenisstraf

11. De Sovjet-Unie speelde de grootste rol bij het verslaan van Duitsland in de Tweede Wereldoorlog

- a) Waar
- b) Niet waar
- Correct Answer: b

12. Oorlogshelden herdenken verheerlijkt oorlog

- a) Oneens
- b) Geen mening
- c) Eens

13. Zet in de juiste volgorde

1. Verdrag van Versailles
2. Begin Tweede Wereldoorlog
3. Nederland binnengevallen
4. VS doen mee aan oorlog
5. Achtervolging Joden
6. Verlies Stalingrad
7. D-Day
8. Market Garden
9. Hongerwinter
10. Atoombommen