Developing guidelines for integrating instruction in multimedia drills for Dutch primary schools

An educational design research

MASTER'S THESIS

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Lianne Groen
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Abstract

In the recent years, digital learning environments have been increasingly developed to support primary school teachers in offering differentiated education. Gynzy offers such an environment, including multimedia drills. When education is differentiated, instruction should be as well. However, teachers experience difficulties in giving differentiated instruction and instruction for multimedia drills has been little investigated. Therefore, this master's thesis focused on the development of guidelines for the integration of instruction in multimedia drills for learning to spell, in a design-based research.

An initial design was created based on problem analysis and outcomes of previous research. This design was tested in an iterative process with teachers and students, who use Gynzy iPads in their classroom. Two rounds of teacher testing were conducted through interviews with a total of 7 teachers. After these interviews, the design was evaluated with educational experts and revisions were made.

Finally, two rounds of testing with students were conducted, in which a total of 16 students were observed and interviewed. Based on the outcomes of the testing with teachers and students and consultation of experts, different guidelines were developed. These guidelines could be divided into the categories: content', 'learner control', 'representation' and 'providing help'.

In addition to the initially developed criteria, the most important guidelines that were derived from this research were: use multiple examples or vary with examples, choose most relevant terminology, use stepwise instructions, adapt hints or instructions based on different spelling phases and offer choices in showing or hiding buttons. These guidelines provide a baseline for further research into the integration of instruction in adaptive multimedia drills.

Keywords: multimedia drills, instructional design, spelling rules, spelling instruction

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1. Introduction

1.1. Background

Over the past years, primary schools in the Netherlands have been increasingly stimulated to provide inclusive education (Rijksoverheid, 2014). In inclusive education, students follow regular education as much as possible, including students that need extra support and those who previously would have gone to special needs schools (Rijksoverheid, 2014). This development requires a different approach towards education. The ministry of education in the Netherlands (2014), therefore states the importance of differentiation in the classroom. By differentiating, learners can grow and learn more efficiently, results can improve and motivation to learn can grow (Nieboer, 2015). However, a lot of teachers of primary schools in the Netherlands, experience difficulties in differentiating their instructions between the different needs of their students. It seems that this is often caused by high work pressure or insufficient preparation of the differentiation in their education (Inspectie van het onderwijs, 2014).

1.2. Organizational context

To support teachers who offer differentiated education, digital adaptive learning environments are being developed. In these learning environments, students can work on lessons or assignments individually. An organization developing such a learning environment is Gynzy. Gynzy offers a digital training environment, called 'Gynzy iPads', that includes adaptive techniques for practicing items of different subjects, like spelling and arithmetics (see chapter 3), at primary schools. In schools that use the software of Gynzy, every student owns an iPad that runs Gynzy iPads.

Gynzy iPads is being developed since 2015, by a cooperation of the organizations Topicus and Gynzy. It has been adopted in an increasing amount of classrooms of primary schools in the Netherlands. Most of the schools that use Gynzy iPads, started in September 2016. Gynzy iPads is currently available for grade 2 and 3 (Dutch grades 4 and 5) in the Netherlands. The software is still in development and will be updated regularly, to implement the latest educational developments and new challenges.

The content of Gynzy iPads includes sessions of items, that are provided in the form of a multimedia drill (Alessi & Trollip, 2001). In figure 1, the general structure and flow of a multimedia drill is shown. Drills can be developed for helping learners to practice material by repetition of the material until a certain skill or rule is mastered (Alessi & Trollip, 2001).

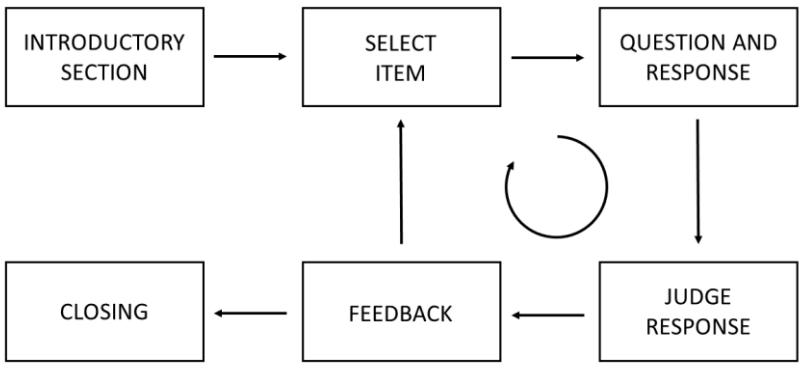

Figure 1. General structure & flow of a drill (Alessi & Trollip, 2001)

The current instructions in Gynzy iPads exist of short descriptions for each item about what is expected from the student. Furthermore, Gynzy is developing 'hints', short instructions meant to guide students towards the correct solution. However, more extensive additional

instruction, like explanations about learning rules that need to be learned (e.g. in spelling: differences between 'short' and 'long' sounds), is lacking.

In several studies, it was found that using a computer for offering spelling instruction was a feasible possibility (Fulk & Stormont-Spurgin, 1995; Gordon et al., 1993), because of the possibilities from computers to offer direct and personalized instruction for students with learning disabilities. Computer based instruction seemed to motivate students to learn. However, until now, there also have been no other digital training environments available for primary schools, that has integrated these instructions for students.

1.3. Learning to spell

One subject that Gynzy iPads offers, is spelling. Lots of students with learning disabilities experience difficulties with this subject (Bos & Vaughn, 2006). Learning spelling rules relates to procedural knowledge, which is defined as 'the ability to execute action sequences to solve problems, including the ability to adapt known procedures to novel problems (Rittle-Johnson, Siegler, & Alibali, 2001). Gagné (1970) defined learning spelling rules as an intellectual skill. He stated that in rule learning, it is not important if students can verbalize or state the rule. What is more important, is that students can demonstrate the rule by applying it appropriately to a class of problems, even problems that not have been encountered. This is also referred to as transfer (Simons & Verschaffel, 1992). When talking about transfer, near transfer regards to situations that are very similar. This occurs more often than far transfer: in which there is less similarity. Far transfer only spontaneously exists for a small part of very motivated and intelligent students. With hints or clues, this transfer exists for 10% of these students. With more extensive help or instruction, this is maximal 30%. To conclude, far transfer is most coherent with the aim of rule learning: being able to apply known rules to new situations.

1.4. The current research

Based on experiences from teachers and educationalists of Gynzy, it has become clear that students often struggle with different subjects at school. However, teachers are not always available to help, due to large numbers of students requiring their attention and administrative tasks. Also, in the current form of differentiated education, students might need different instructions at different times. It was found that learning rules could be stimulated, with hints or more extensive instructions (Simons & Verschaffel, 1992) and that using a computer-based instruction is a promising possibility, due to the possibilities for direct and personalized instruction and outcomes about enhancing the motivation of students to learn (Fulk & Stormont-Spurgin, 1995; Gordon et al., 1993).

However, until now, integrated instructions for 'drill & practices' like Gynzy iPads have not been investigated. Therefore, Gynzy requested an exploration of the possibilities for integrating more extensive instruction in the learning environment, in which students can consult the instruction at any time. For feasibility reasons, this research focused on the possibilities of integrated instruction for learning spelling rules and not for different subjects.

1.5. Research question and research model

Thorough problem analysis (chapter 3), including needs assessment (paragraph 3.1.1.) and specific questions stated by Gynzy, illustrated the need for the development of integrated instruction for spelling rules in Gynzy iPads. For this master's thesis, it was decided to focus on developing a text-based instruction. Therefore, the following research question was addressed: *"Which guidelines are important in developing textual spelling explanations in multimedia drills for students in grade 2 and 3 of primary school?"*

This research question is investigated in an educational design research (chapter 2). The results lead towards design guidelines for the integration of instruction in multimedia drills. Furthermore, a prototype for learning spelling rules in Gynzy iPads, is developed. Based on the final design, recommendations for the future design of integrated instructions can be made.

1.6. Scientific & practical relevance

This research could lead towards a standard for developing instructions for Gynzy iPads in the future, by developing a prototype of instructions for spelling rules. The integration of instruction in Gynzy iPads is expected to contribute positively towards the use of the current learning environment, because students will have access to instructions at any time.

Furthermore, the research contributes to the current research into integrated instruction in multimedia drills, which has been little conducted until now. The outcomes of this research are expected to lead towards more knowledge about the possibilities of designing adaptive instructions in multimedia drills for learning to spell in primary schools. The first development of guidelines for instruction in adaptive learning environments containing drills, leads towards a basis for future research and development.

2. Method

2.1. Research design

The type of research that was conducted in this research, is an educational design research. According to Reeves (2006), educational design research is structured in the order of analysis, development, testing cycles and reflection (figure 2). After each iteration, the prototype of the design is revised and evaluated until the desired stage has been reached. The line below defines the continuous evaluation and refinement of the problems, solutions, methods and design principles (Reeves, 2006).

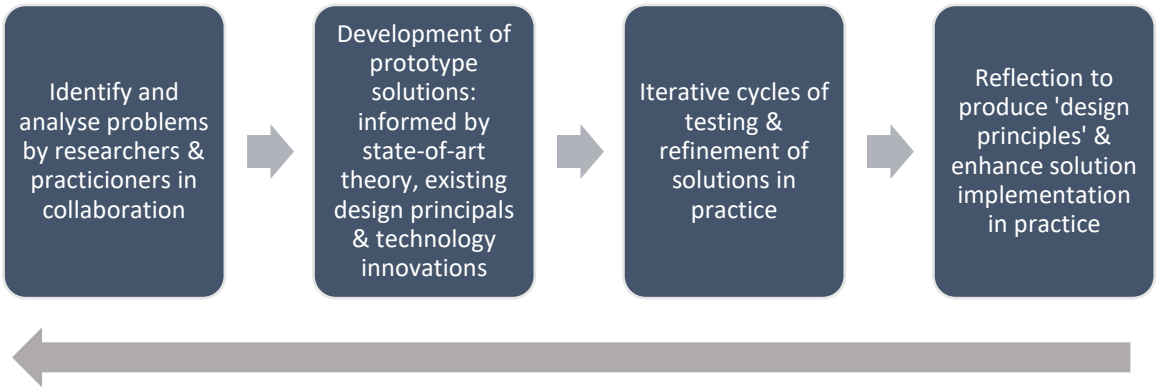

Figure 2. The process of educational design research (Reeves, 2006)

2.2. Respondents

The sample group in this study existed of educational experts, teachers and students of schools that use Gynzy iPads in the classroom. An inclusion criterium for teachers and students was that they experienced working with Gynzy iPads for at least three months. Therefore, there was a 'selective sample'. The sampling method was based on convenience sampling, resulting in the inclusion of all accessible subjects that met the criteria (Marshall, 1996). A newsletter was used to spread a needs assessment survey among the teachers.

Based on email responses followed by the newsletter, teachers of different schools were approached for interviews. In the first rounds of testing, teachers were invited to give their first impressions of a designed instruction. The minimal amount of teachers required for this round was four. Ideally, the different teachers had varying years of experience in the classroom. The results of these interviews were used to further develop the prototype in collaboration with educational experts.

After two rounds of testing with teachers, the design was improved and usability testing took place with the target group: primary school students. The students were approached by asking the teachers that participated in the interviews. Inclusion criteria for students were that they had their own Gynzy iPad and that they were already somewhat familiar with the spelling rule that the instruction discussed. Also, their ability to formulate their thoughts in the interview was judged by their teacher. Initially, in consultation with educational experts and teachers, it was decided that students from grade 3, would be more suitable for participation than students in grade 2. The group of participating students was aimed to have a subdivision in 'good', 'average' and 'bad' spellers, inclusion in any of these groups was based upon achievements in Gynzy iPads and teacher's judgment. Ideally, the three groups were of similar size. Also, it was aimed to have a practically equal number of boys and girls participating in the testing rounds, to create a representative sample. Furthermore, it was decided to test the instruction with students in two rounds with a minimum of eight students per round.

2.3. Instrumentation

2.3.1. Needs assessment questionnaire.

The current situation and needs of teachers working with Gynzy iPads were investigated through a short needs assessment questionnaire (appendix A). This questionnaire was developed based on former need's assessment questionnaires and consultation with educational experts and teachers. It was spread among schools that currently use Gynzy iPads to clarify the context, knowledge, needs and wishes regarding the current situation. Before spreading the questionnaire among the teachers, it was tested and evaluated with a few employees of Gynzy.

2.3.2. Usability testing with teachers

Teachers that use Gynzy iPads in their classroom were asked to discuss aspects of the initial design of the instruction in a semi-structured way. This was done by providing the teachers the first version of a possible instruction on paper and using the 'plus-minus' method (de Jong & Rijnks, 2006). In this method, respondents are asked to evaluate aspects of a text, by putting a plus or a minus at any aspects they consider as positive (e.g. clear, understandable) or negative (e.g. vague, confusing). Research by Sienot (1997) showed that participants can identify more types of problems using the 'plus-minus' method than while using the think-aloud method (Sienot, 1997). Using this method, the process of reading is minimally disturbed. Teachers were asked to think as if they were their students, who would have to use the instruction while working in Gynzy iPads. After this, the plusses and minuses were discussed and additional questions were asked about different topics, based on literature about multimedia learning and consultation of educational experts. Based on the outcomes of these interviews, the design was evaluated and improved.

2.3.3. Usability testing with students

After two rounds of testing with teachers, students were asked to walk through a session of Gynzy iPads, while having the opportunity to use the instruction or the hint. Students worked on their iPads on a session in Gynzy, consisting of 12 items of the spelling rule. They could access the designed instruction or an already available 'hint', by using a button of a light bulb (on paper) that they could 'press' with their hands. After a set number of four errors, students also received a suggestion for a hint or additional instruction.

Observations. An observation scheme was developed (Appendix C), based on the ISTE approach to usability testing (van der Meij, 1997). This method offers a reliable and valid way to observe users. This method of observation has proven to be easy to use and adaptable based on the situation. In the observations, the usability of the design for students is measured.

Interviews. When students finished the session of 12 items, they answered additional questions in a short, semi-structured interview (appendix D). The decision of interviewing students was based on the fact that the effectiveness of spelling programs depends highly on the attitudes of students (Graham, 1983). In this interview, the ideas and opinions of students about the hint and the additional instruction were investigated.

2.3. Procedure

At first, a needs questionnaire (appendix A) was spread to analyze the current situation. Furthermore, one specific spelling rule was chosen to focus on for this research. This rule was chosen based on analyzation data of frequently made errors in Gynzy iPads (see chapter 3) and consultation with teachers. Based on these findings and former research about instructional design, an initial design was then developed. This initial design was discussed through interviews with teachers who use Gynzy iPads in their classroom, using the 'plus-minus' method and additional questions. The findings were evaluated and discussed with educational experts of Gynzy, to further improve and revise the design.

Finally, usability testing with students was conducted. In advance, parents of the students were approached to provide informed consent for the participation of their children in

the study through an informational letter. The actions of the students were observed while using the hint and the instruction. Afterwards, the short interview was conducted and the students received a small present. The usability testing was repeated at least one time, so improvements of the design could be implemented and evaluated. Teachers, students and parents of the students who participate, were fully informed about the background and rationale of the research and could withdraw from the study at any time. Also, teachers and students were asked for permission to record the interviews in advance. Based on the results of usability testing, design guidelines for designing instruction in multimedia drills for spelling, like in Gynzy iPads were developed.

2.4. Data analysis

The data that was generated from this study was qualitative and quantitative data. Therefore, this is a mixed-method study. During the problem analysis, data was gathered through a questionnaire among teachers and file analysis of the most commonly made mistakes for the needs assessment. The responses from this questionnaire are analyzed, by computing percentiles for each question.

During usability testing with teachers, qualitative data was gathered from teachers, using the 'plus-minus' method and additional interviews. The interviews were recorded and transcribed, so that all the originally made statements were maintained, ensuring reliable data. The interviews were analyzed by decoding to discover recurrences. The findings of the interviews were used to further revise and develop the designs. Construct validity was guaranteed by constantly redefining and evaluating designs and interview questions by consulting educational experts.

3. Problem analysis

3.1. Context analysis

Before starting with instructional design, an extensive analysis is needed to become familiar with learners, the learning context and the instructional task (Smith & Ragan, 2005). According to Smith & Ragan (2005), the analysis of the context broadly involves two components: the substantiation of a need for instruction to help learners reach learning goals, and a description of the learning environment in which the instruction will be used.

3.1.1. Needs assessment

The needs assessment was divided into a needs assessment for the teachers and the students who use Gynzy iPads in the classroom.

Teachers. To investigate whether the need also exists among teachers that make use of Gynzy iPads, a short questionnaire with six different questions was developed (Appendix A) and spread among schools in which Gynzy iPads is used in the classroom. Eventually, twelve individual teachers filled in the questionnaire. Because the questionnaire was anonymous, and more than one teacher per school could have filled it in, it was not possible to calculate a response rate. Based on the results of question 1, the opinions about the current instruction varied among the respondents, 50% of the respondents responded with yes and 50% with no, upon the question whether the current explanations or instructions are clearly described within Gynzy iPads. From the answers to question 2, it could be derived that all of the participants (n=12) agreed that at least parts of the (classical) instruction could be integrated into Gynzy iPads (100%). However, teachers differed in their opinions about the amount of instruction that should be integrated. The answers to question 3 showed that 16,67% (n=2) thought the whole instruction could be integrated, 33,33% (n=4) thought a large part could be integrated and 50%(n=6) thought only a small part should be integrated. Teachers mostly agreed upon what should be the availability of the instruction, 100% (n=12) answered that instruction should be accessible by students all of the time. Furthermore, 50% (n=6) of the respondents answered that the instruction should also be accessible before a lesson. For this question, multiple answers were possible. Finally, almost all of the teachers (n=11) answered yes upon the last question if the current instructions/explanations in Gynzy iPads should be adjusted or improved.

Based on these results, it was concluded that in the view of teachers who use Gynzy iPads in their classrooms, the integration of instruction in Gynzy iPads needs to be further explored. There was a high agreement between the teachers upon the most questions, with exception of question about which part of the classical instruction should be included in Gynzy iPads. This could possibly be explained because it might be vague or hard to imagine yet what these instructions would behold. Nevertheless, it became clear that a large amount of the teachers think it's important that integrated instructions should be an addition, instead of a replacement of the classical instruction of the teachers.

Students. Because of the age of the students and feasibility reasons, a needs questionnaire was not conducted with the students. However, logfiles were provided by Gynzy which could be analyzed with respect to microgoals in which spelling errors were most often made. Those microgoals are represented in table 1. In the table, the amount of right and wrong answers and percentiles of wrong answers are provided for each microgoal in spelling. While the reasons why these are the most commonly made errors were not completely clear, some reasons could be ruled out. Because the high diversity of items, the errors should not be due to unclear questions. Also, the different types of items are more or less the same for all of the microgoals. Furthermore, for each microgoal students need to meet specific conditionalities, to have access to these goals. Therefore, it is ruled out that errors are due to insufficient prior knowledge.

Table 1.

Log data of most frequently made spelling errors in Gynzy iPads

Spelling errors				
Name of microgoal	Total amount of answers	Amount of wrong answers	Amount of right answers	Percentile of wrong answers
Persoonsvorm: onvoltooid verleden tijd sterke werkwoorden met stam op ~D of ~T	776	385	391	0.4961
Verkleinwoord na open lettergreep op ~A, ~E, ~O, ~U	1721	988	733	0.5741
Woorden met open klankgroep en lange klank	37394	15022	22372	0.4017
Woorden met gesloten klankgroep en dubbele medeklinkers	23687	10945	12742	0.4621

All of the microgoals in Table 1 had a high percentile of wrong answers. Based on these findings and consultation with educational experts, decisions were made for the focus of the instruction. For the topics of spelling, two goals were found to be most interesting to focus on (goals 3 and 4). This was based on experiences of (former) teachers working at Gynzy, they considered these goals as being experienced as very difficult topics for students. Also, in these microgoals, rules need to be learned. Students could profit from additional support from integrated instructions. Eventually, after consultation with educational experts, goal 3 was chosen to focus on.

3.1.2. Environment analysis

The learning environment in which the instruction takes place is the spelling area of the digital learning environment of Gynzy iPads. Dutch students in grade 2 and 3 (Dutch grades 4 and 5), with ages between 7 and 11 years old are currently working with Gynzy iPads. In figure 3, a screenshot of an item for students is represented.

Figure 3. Example of an item in Gynzy iPads

For Gynzy iPads, a specific learning track was developed by professional educational experts and based on general guidelines and goals for spelling education in the Netherlands. This learning track includes keygoals, subgoals and microgoals and is connected to the goals and content of different learning methods for spelling for primary schools in the Netherlands. There is also an option not to learn with methods, but in so called 'Worlds', or to use both (figure 4). In Gynzy Worlds, there is a wide range of assignments of certain topics that the students can practice with. The worlds exist out of different 'Islands', which represent the subgoals and these Islands exist again of microgoals, called 'Villages'.

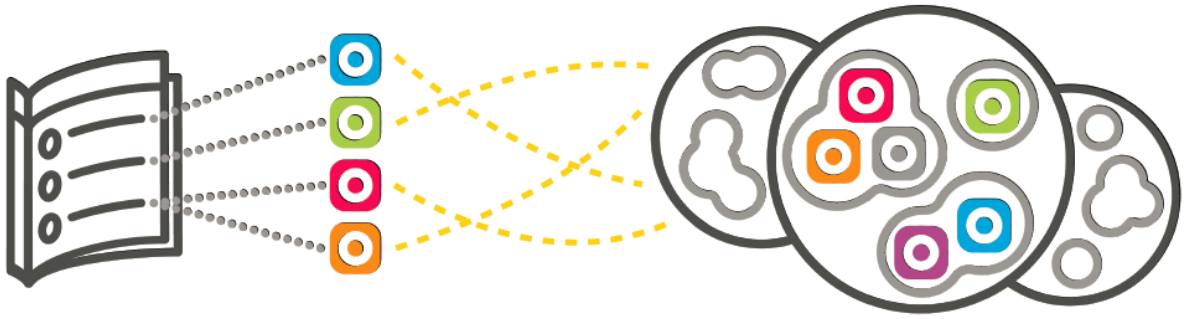

Figure 4. Integrating learning with methods and worlds

The digital environment offers teachers the possibility to analyze the results of their students on specific topics or lessons (see figure 5). This provides insights into the progress of each individual student and about items in which students experience difficulties. Based on this information, teachers are able to provide concrete directed instructions towards the students that are in need of individual instruction or support. In this way, weak learners who might need extra instruction or explanations, as well as strong learners who might experience too little challenge, can be identified. Teachers have the choice to for example give additional classical explanations or offer explanations in small groups. Also, the teacher has the possibility to (un)lock specific goals or lessons, in order to provide focus in their lessons.

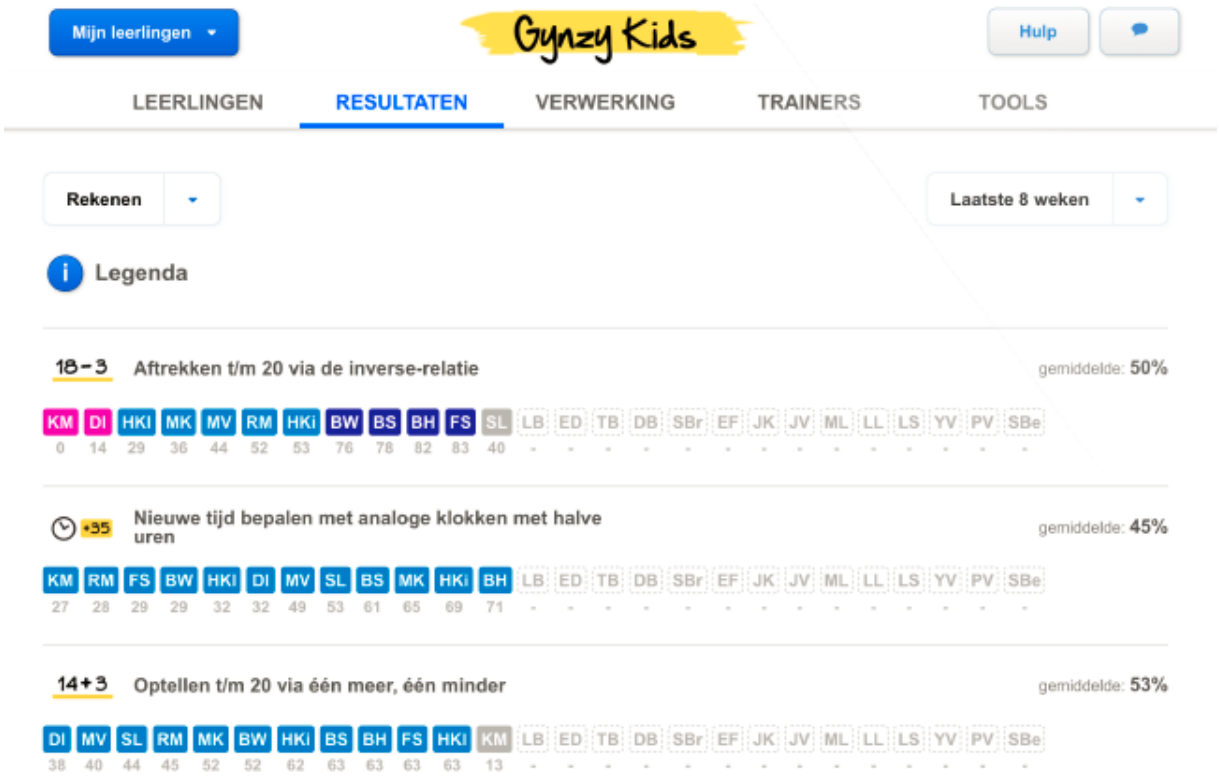

Figure 5. Overview for a teacher of achievements of their students on specific topics

Competition analysis. In a competition analysis, the current status of existing adaptive learning environments was investigated. Other adaptive software that has been developed for adaptive learning in the classroom in the Netherlands called Snappet, Muiswerk and Rekentuin/Taalzee were analyzed. The following things could be concluded from this orientation:

- A lot of digital non-adaptive instruction for learning spelling and arithmetic in primary schools is available (e.g. web pages or instructional videos). Also, learning methods often offer their own digital learning environments to enable students to practice.
- In none of the investigated learning platforms for primary education, integrated instruction about concepts or rules was available.
- For a different audience, software has been developed that provides adaptive instructions to the learner, like TrainTool. In this tool, personal feedback from peers and the trainer is provided and the learner practices with real-life situations through role-playing. Learners can practice as long as they want and are able to share this with their peers and teacher to give feedback. Instruction is provided through a video with a few examples.

3.2. Learner analysis

To get further insights into the target audience, a learner analysis among the students that use Gynzy iPads, was conducted. A learner analysis is important for designing instruction which is effective and interesting to learners (Smith & Ragan, 2005) and includes taking into account all characteristics of the target population.

The target audience exists of boys and girls in primary schools, from grade 2 and 3 (Dutch grade 4 and 5). The age of these students ranges approximately from 7 until 11 years old. There is a high likelihood of differences in language development and social economic status

between the students. Furthermore, it must be taken into account that students differ in their reading levels. Some students might be more visually orientated and some students might prefer speech instead of text.

Cognitive levels and moral development can differ widely among students, especially between students of schools with regular education and schools with 'special' education. The amount of prior knowledge can differ widely among different topics. This is due to some topics being restricted to a certain grade, and some of the topics being 'grade transcending'. Furthermore, this is also something that can differ between schools, because schools differ in what topics are addressed at which grade. Therefore, it is important to take into account differences that might exist in prior knowledge, since students might differ widely in their needs for instruction.

To further investigate the target group, possible scenarios for different kind of spellers were worked out. For each scenario, it was worked out how a certain student, based on spelling performances, would walk through a session of Gynzy iPads and what the possible need for additional instruction would be. Based on these scenario's, it was found that different spellers might be in need of different instructions at different times. A student with little or no difficulties with spelling will make little mistakes and will probably have little need for instruction. Therefore, instructions need to be short and clear and not focus too much on repeating prior knowledge. A hint should be available and optional for the student to refresh the rule of the spelling goal. A student with average or low spelling ability, however, will sometimes experience difficulties and would have sometimes more need for instruction than other times. Sometimes only a hint would be enough, but there should also be a possibility for additional explanations. If this student repeatedly makes errors for certain microgoals, a hint or additional instruction could be suggested as well.

From research, it was found that for students with learning disabilities, it is preferred to use multi sensory techniques for spelling instruction, for example, the 'write and say' method (Fulk & Stormont-Spurgin, 1995; McNaughton et al., 1994; Gordon et al., 1993). Speech is important to add, for poor readers or young children or visually impaired learners. Therefore, in designing instruction, for every line of text, should be the possibility for the student to have the text spoken out loud. It is important that speech is from high quality. In previous research it was found that providing text and sound simultaneously could decrease learning. It would be better to use bullet points or pictures accompanied by speech. Mayer (1997, 2001) found that adding spoken text to printed text might produce an effect of redundancy and fails to produce learning gains while compared to offering only printed text. However, when discussing with teachers, it was often stated that many students, especially weak spellers or students with dyslexia, would benefit from spoken text. Therefore, spoken text should be included as an optional aid.

3.3. Task analysis

A task analysis was conducted to decompose the goals and different steps of the task that need to be done and what student's need to do to achieve the goal (Smith & Ragan, 2005). Information about the tasks that students need to perform in Gynzy iPads, is provided by experts, former research and exploration of the learning environment.

All students that begin with Gynzy iPads, mainly in the second grade of primary school, start at the same level of difficulty. This is the easiest level of difficulty that is available. This is also in line with earlier research stating that experiences of success are motivating for students (Urdan & Schoenfelder, 2006). For every answer that a student gives, an algorithm computes how well the student performs on a certain topic and will constantly calculate which item fits best with the level of the student on a certain topic. This might take some time because only after some practice, a reliable image of the knowledge of the students can be established. Some goals are transcending over the years, which means that they might need to practice the same thing in grade 2 and grade 3, but on a different level of difficulty.

Former achievements are considered in determining the level of difficulty for the individual student. After each item, the next item is computed, based upon a 75% success rate for the student. A lesson exists of a series of multiple items. Every item features a short introduction of what needs to be done (e.g. "Divide the words into sounds. Click between the letters"). After the student answers the question, the software provides feedback and selects the next item. The items vary both in item types and item modes.

A session in Gynzy Worlds normally consists of twelve items. The session can be started, after which the goals that will be practiced are presented to the student. For every item, a short instruction is provided of what needs to be done, for example: *"Press the long sound. Click between the letters"* (figure 6). The items vary in item types and item modes. In some of the items, there is an option to ask for a hint (figure 7). This is often a statement, meant to direct the student towards the right line of reasoning. Until now, limited research about the combination of drills and instruction has been conducted. Alessi & Trollip (2001) stated that drills could include hints, which provide help or a second chance. These hints could improve memorability and motivation of learners.

Furthermore, for the microgoal that this research focuses on (learning how to recognize and spell words with long sounds and open syllables), Gynzy uses different spelling phases in which students can be classified. Every student begins in phase 1, which is about analyzing the word. When a student begins with a certain microgoal, the student is in phase 1 and only receives items for the phase 'Word analysis'. In the specific goal that is used in this research, this is about recognizing 'long sounds'. The second phase is about knowing which spelling category a word belongs to. When the student has reached this phase, items are presented that are about the actual rule. Phase 3 is about finishing words and sentences and in phase 4 students need to write down the words and sentences themselves. In the last two phases, the students need to apply the rules for themselves (respectively 'Finish words/sentences' and 'Write them off'). This means that the items that students receive differ, based on the phase that the student is in.

Figure 6. Example of an item in Gynzy iPads.

Figure 7. Example of a hint in Gynzy iPads

If relevant and possible, the items are supported with pictures and the difficulty of the items adapts directly after an item, based on the achievements so far. There are no limits in pace for answering the different items. Also, the lesson can be ended at any time and data is remembered (temporary termination). Also, if a goal is completed, students do not necessarily have to practice these goals again (permanent termination). When an answer is given, feedback is provided in terms of: *"Well done!"* when the student has succeeded, or: *"Too bad, try again."* when the student has failed on a certain item. A second attempt is then allowed because accidental mistakes such as typos might occur. After two wrong attempts the feedback is*: "Too bad, go ahead".* A third chance is then provided at the end of the session when this attempt is wrong after which the correct answer is shown. At the end of the lesson, the results are shown to the student (figure 8): the amount of right and wrong answers and the goals of the session are represented. After this, suggestions of further practicing in the Gynzy Worlds are shown and the student is provided with insights into his progress on specific learning goals.

Figure 8. Screenshot of a results overview in Gynzy iPads

3.4. Design criteria based on problem analysis

Based on the problem analysis, the following design criteria should be taken into account while developing the first design:

- The instruction is relevant for students between 7-11 years old
- The instruction should be able to account for differences in reading ability and preferences for speech or text
- The instruction should take in account prior knowledge of the students
- Students should be able to get little directions (like a hint) or more extensive instruction
- Offer the possibility for the student to have the text spoken out loud

4. Development & design

4.1. Design process

The process of the design started with the development of an initial concept, based on design criteria (figure 9) that followed from the problem analysis and previous research, as described in the next paragraph. Together with an educationalist of Gynzy, the decisions were discussed, leading to a paper prototype of the initial design (Appendix E). In the first rounds of usability testing, five teachers were asked about their opinions of the different aspects of the design. Based on outcomes of the consultation with educationalists, it was decided that there should be more than just one instruction, to fit the needs of different students. Therefore, three paper prototypes were developed for the second round of usability testing with teachers. This last round of usability testing with teachers took place with 2 teachers at the same time. Again, the outcomes were discussed, based on which adaptations were made. After this, the first round of usability testing with the actual users, students, took place. Based on the observations and interviews with the students, adjustments were made for the final testing round. In both rounds, 8 students participated.

4.2. Justification of first design

Before developing the first design (Appendix E), initial design criteria were developed. These initial design criteria are for a large part based on the outcomes of problem analysis and consultation of educational experts. The paragraph below explains theoretical foundations for other design criteria.

4.2.1. Theories of instruction

In an article of Reigeluth (2013), instructional theories are defined as: "theories that explicitly support the learning and development process of the learner." There have been many theories of instruction developed and there are many ways to define instruction as well. Gagné (1970), is well known for his learning theories. He differed between different learning results: learning facts, concepts, principles and procedures. He also stated the importance of preventing overload of the short memory and referring to pre-existing knowledge, while designing for instruction.

Alessi & Trollip (2001) defined instruction as "the creation and use of environments in which learning is facilitated". More specific, this can be about, for example, learning concepts, procedures, principles or rules. Instruction can be strictly directed, as well as more open ended. According to Alessi & Trollip, four phases are needed to provide effective learning & efficient learning in classroom instruction: 1) Presenting info, 2) Guiding learner, 3) Practicing and 4) Assessing learning. One or more of these phases could also be used in multimedia learning. For phase three, "practicing", drills are often used.

4.2.2. Instructional design

Snelbecker (1974) compared different theories of instructional design and specifically focused on the differences between the theory of design and the practice of design. In his theory, researchers are 'knowledge producers' and practitioners are 'knowledge users'. He advocates a critical analysis of different theories that are relevant for scientists and practitioners and to interpret the theory in the right perspective.

Cognitive load theory. Decisions in instructional design are often based on the theory of cognitive load. Overviews of this theory were provided by Sweller, van Merrienboer & Paas (1998), Mayer (2002) and Mayer and Moreno (2003). The cognitive load theory states that there are three forms of cognitive load: intrinsic, extraneous and germane load.

Intrinsic cognitive load relates to the difficulty of the subject matter (Cooper 1998; Sweller & Chandler 1994) and is often considered as not being able to change through instructional interventions. However, newer insights mention that intrinsic cognitive load can be influenced, by offering information in sequences (van Merrienboer, Kirschner & Kester, 2003),

starting with few elements and gradually building up complexity or training partial tasks separately.

According to van Merrienboer and Sweller (2005, p. 150): ‘‘Extraneous cognitive load, in contrast, is load that is not necessary for learning (i.e., schema construction and automation) and that can be altered by instructional interventions’’. Extraneous load may also arise when the instructional design uses only one of the subsystems, visual and auditory parts, of working memory. The ‘‘modality principle’ ’implies that material can be more efficiently presented when visual and auditory material are combined (Savoji, Hassanabadi, & Fasihipour, 2011). Cognitive resources can be freed by using the “redundancy principle”. This principle relates to including just one of the two (or more) sources of information.

Thirdly, germane cognitive load is the load that is caused when schemas are constructed through interpreting, exemplifying, classifying, inferring, differentiating, and organizing (Mayer 2002). The load that is imposed by these processes is denominated germane cognitive load. Instructional designs should, of course, try to stimulate and guide students to engage in schema construction and automation and in this way increase germane cognitive load.

There are two important recommendations that could be derived from cognitive load theory for instructional design. Firstly, it is important to present material which is in line with the prior knowledge of the learner (intrinsic load) Furthermore, it is important to avoid information that is non-essential or confusing (extraneous load). While the principles of cognitive load have been used in the early years of educational design, this area is still widely being investigated.

4.2.3. Designing instruction for learning to spell

From previous research, clear directions were derived for effective spelling instruction. Instructions need to be direct and explicit (Bosman, 2016): students need to know ‘why words are spelled, the way they are spelled’. Also, students learn better when they have practiced to speak what is written, then to speak what it sounds like (Schiffelers, Bosman, & van Hell, 2002). Furthermore, students need to practice until they have ‘overlearned’. This requires a structured method, with useful spelling categories.

Already in 1983, Graham defined principles to achieve effective spelling instruction. He stated that contemporary classroom instruction did not account for the wide range of spelling abilities and achievements, that can appear at every level and that many students do not profit from instruction in large groups. Also, he mentioned that instruction of spelling in the classroom was often based on traditional practices, in contrast to results from research, while spelling is among the most researched areas. From his view, effective spelling programs contain individualized instruction, because different spelling problems exist between children. Also, the effectiveness of spelling programs highly depends on the attitudes of students.

4.2.4. Designing for multimedia drills

Content. The instructions of different spelling methods were analyzed. Most of the methods used relatively the same steps to explain this specific spelling rule. Furthermore, it was decided to use the example for the children that was already available in the hint, again to be consistent, to illustrate the spelling rule that needs to be learned. This could lead to better transfer. Butterfield & Nelson stated already in 1989 that a good choice of examples could be beneficial for the transfer of knowledge.

Learner control. There is a lot of controversy in research about the amount of control that learners should have (Alessi & Trollip, 2001). The amount of control often depends on the level and complexity of the task. Things that learners should at least be able to control are sequence and pace. In learning procedures and simple tasks and for people with little prior knowledge and children, less learner control and more program control should be provided. When there are

existing differences between the reading ability of learners, it is also important to offer the choice between text or speech.

Regarding sequence, students should be able to go back- and forward in instruction at any time. Based on this, buttons can be provided for navigating back- and forward. Buttons have the advantage that they are visual. They can also be distracting and they take space and should be minimalized. The function of the buttons should become clear by using text or pictures. Furthermore, the pace is important in user control. Students should be able to control how fast they go through the instructions as it attributes to their autonomy (Artino, 2008; Liaw, Huang, Chen, 2007).

Representation. It was decided to use text, to represent the information in the instruction. While video is sometimes preferred, it is also expensive and time-consuming (Alessi & Trollip, 2001). However, the length of the instruction was based on the guideline for video instruction, which said that it should generally take no longer than 20-30 seconds to watch or read. Of course, this is still subjective and it depends on how long a student needs to process the text.

When using text, it is important to be consistent, for example in the use of terminology (Alessi & Trollip, 2001). However, while exploring different spelling methods, it was found that terminology differed widely over different spelling methods. In consultation with Gynzy, it was decided to use the terms that Gynzy uses in the software and the already available hint, in order to maintain consistency. Also, the layout of text should be consistent with how text is normally read, from left to right and from top to bottom. Furthermore, lines and words should not be abruptly ended and the screen should be filled. Blank spaces could be used to divide paragraphs.

Important text that needs attention can be highlighted by making it bold (Alessi & Trollip, 2001). This is preferred over underlined text because underlined text might be confused with hyperlinks. While red and blue were found to be difficult for learners to process, blue was used to be consistent with already available hints in Gynzy iPads. Color has been found to be useful to attract attention towards important information (Schneiderman & Plaisant, 1998; Durret, 1987) and to be effective for attracting attention when used in moderation (Alessi & Trollip, 2001). It is also important to provide contrast in background and foreground. Also, it is important to use no more than a few colors and to be consistent with the use of colors.

***Providing help*.** In consultation with teachers and educationalists, it was discussed whether the instruction should be optional, or forced. In both groups, it was agreed upon that instruction should always be available for the students and not forced towards them. Forcing could lead to demotivation towards the use of Gynzy iPads. However, it was suggested that for students who make many errors, the instruction could be 'suggested'. It would still be optional but might give them a reminder of the ability to use the instructions.

Multiple studies have been conducted towards the use of (animated) pedagogical agents. The outcomes of these studies show conflicting outcomes. It was found that animated pedagogical agents can be beneficial for learning, decrease anxiety and positively influence the attention of students towards key elements (Clark & Choi, 2005; Gulz, 2005). From other research, however, it seemed that agents don't necessarily lead towards more effect than only a spoken voice (Moreno, Mayer, Spires and Lester, 2001). In a recent meta-analysis (Schroeder, Adesope & Gilbert, 2013), small, but significant positive effects of pedagogical agents were found. It was found that pedagogical agents which communicated using on-screen text, facilitated more learning than agents that only provided narration. In general, the use of pedagogical agents was found to lead to higher cognitive performance of students than systems without agents. It was presumed that this was caused by a feeling of social interaction between agents and learners. Since Gynzy already uses a certain agent for other components of the software, this 'agent' (called Virko) could be used for the instruction as well.

4.3. Design criteria

From the learner analysis (chapter 3) and theoretical foundations as described in the previous paragraph, design criteria for developing the first design were derived.

The final list (table 2) consists of 10 criteria which are categorized in 'content', 'learner control', representation' and 'providing help'. The point 'account for differences' from the learner analysis, was combined with 'provide individualized instructions' in 'differentiation' (2) the design criteria. Furthermore, " take into account prior knowledge of the students" from the learner analysis was integrated into with "present information in line with prior knowledge" in point 3.1. of the criteria. Finally "offer the possibility for the student to have the text spoken out loud as an option" from learner analysis was integrated with "provide a choice between text or speech" in point 7 in the design criteria.

The design criteria could be categorized in four categories: learner control, content, representation and providing help. In figure 9, an overview of the categories is shown.

Table 2.

Final list of design criteria.

		Design criterium
Content	1.	Provide relevant information
	2.	Prevent overload of short term memory:
	2.1.	Information based on prior knowledge
	2.2.	Offer information in sequences
	2.3.	Exclude redundant information
	3.	Use relevant examples
Learner control	4.	Provide control in sequence and pace
	4.1.	Clear buttons
	5.	Choice between text and speech
Representation	6.	Be consistent
	6.1.	In terminology
	6.2.	In layout
	7.	Highlight important text
	7.1.	Use few and consistent colors
	7.2.	Mark important words as bold
	8.	Keep explanations short
Providing help	9.	Keep instruction always available
	9.1.	Suggestions
	10.	Use a common animated agent

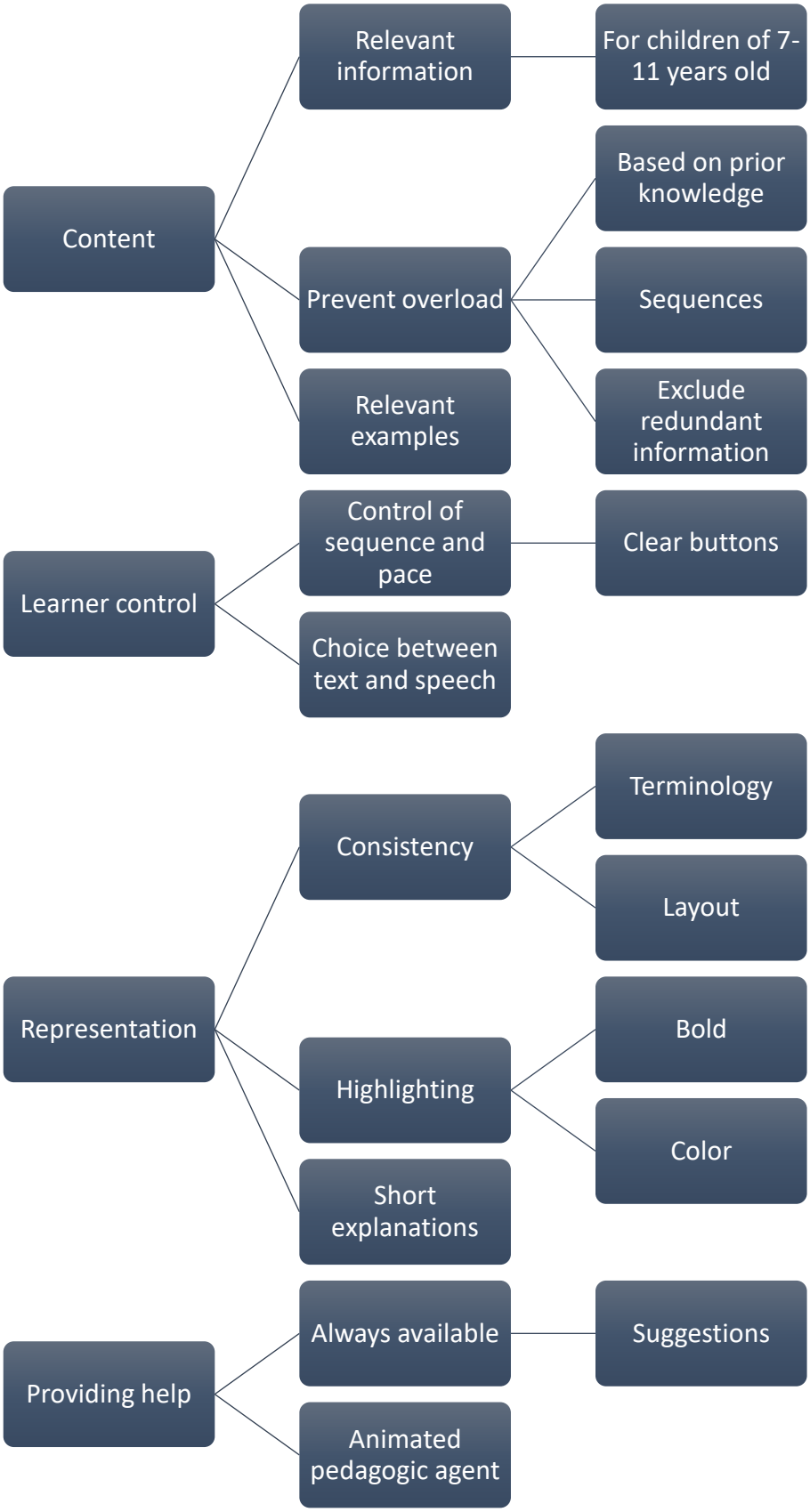

Figure 9. Initial design criteria

Based on these guidelines, the first design for an instruction was developed. Figure 10 shows one screenshot of the first design, see Appendix E for the complete instruction.

Figure 10. Screenshot of first design

4.4. Demographic variables

4.4.1. Teachers

For the first round of usability testing with teachers, five teachers from across the country were provided with the design of the initially developed instruction and asked to provide their opinions using the 'plus-minus' method. A complete overview of the demographic variables of all the teachers that participated in this study (round 1 & round 2), is shown in Table 3. From this teachers, six were female and one was male and the age ranged from 31 to 56 with a mean age of 41.1 years. Furthermore, the amount of teaching experience ranged from 8 to 35 years, with a mean of 19.8 years. Due to practical reasons, some teachers were interviewed as a pair.

Table 3.
Demographic variables of participated teachers

Teacher (*N*=7)	Round	Gender	Age	Region*	Grade	Teaching experience	Experience with Gynzy	Method(ology)
T1**	1	F	36	Middle	3	16 years	January 2017	Zo leer je kinderen lezen en spellen
T2**	1	M	37	Middle	3	17 years	January 2017	Zo leer je kinderen lezen en spellen
T3	1	F	56	South	2	35 years	September 2016	Taal op Maat
T4	1	F	41	North		15 years	August 2016	Staal
T5	1	F	36	South	2	14 years	November 2016	TaalActief***
T6**	2	F	31	North	2	8 years	September 2016	Taal op Maat
T7**	2	F	51	North	3	30 years	September 2016	Taal op Maat

*The region relates to the part of the Netherlands in which the school is located. **: Teachers 1 and 2 and teachers 5 and 6 were interviewed as pairs. *** This school only used the arithmetic's part of Gynzy iPads, not the spelling part.

4.4.2. Students

In the first round of usability testing with students, eight students (S1 – S8) were observed and interviewed about the designs. In this round, five girls and three boys participated. In the second round of usability testing with students, eight students (S9 - S16) were observed and interviewed about the designs. In this round, four girls, as well as four boys participated. The total mean age of the students was 7.56 years old. The demographic variables of the students can be found in table 4.

Table 4.

Demographic variables of participated students (round 1)

Student (*N*=8)	Gender	Age	Grade	Type of speller
S1	F	8	3	Weak
S2	F	9	3	Average
S3	M	9	3	Weak
S4	F	8	3	Weak
S5	F	8	3	Average
S6	M	9	3	Strong
S7	F	8	3	Average
S8	M	8	3	Strong
S9	F	7	2	Weak
S10	M	7	2	Weak/average
S11*	F	8	2	Weak/average
S12	F	7	2	Weak
S13	M	8	2	Weak/average
S14	F	9	3	Weak
S15	M	9	3	Weak
S16	M	8	2	Weak/average

*This student did not give permission for recording the interview.

4.5. Results

4.5.1. Usability testing with teachers and adaptations

In general, all of the teachers valued the paper prototype of the instruction as positive and clear. However, it was often mentioned that some things were overdue and that text was too small. The symbols were found to be clear. Another common finding in the interviews was that instructional videos were preferred over text-based instruction. Also, teachers stated that children pick up new things very quickly and that it does not take much time for them to find new functions in the learning environment. Furthermore, all teachers valued the choice for an animated agent as positive. They mentioned that the agent 'Virko' is recognizable for the students. Another positive aspect was the option to have the text read out aloud. All teachers stated the importance of a short instruction, in which the main elements of the spelling rule are clearly explained. Also, teachers mention that learning in clear, distinguishable 'steps' is important.

Two teachers were wondering if the 'backward' button would have value. Two of the mentioned statements were: "But I wonder if many children would click on this."[T1] and "The 'going back button' doesn't have to be in there for me. You just need to finish the full instruction." [T2] This issue was included in the consultation with experts.

After usability testing with teachers, the outcomes were discussed with educationalists of Gynzy and based on this, a few adaptations were made. The second designs can be found in Appendix F. It was decided to divide the instruction into three designs, for three possible phases (as was explained in paragraph 3.3). Phase 3 and 4 were combined because students need the same instructions for these phases, namely the rule and how to apply it. Teachers and experts both stimulated the use of clear and short sentences. Based on these views, the 'pages' of the designed instruction were further shortened. Furthermore, the instruction was shortened by removing redundant text. The words and text box were enlarged and the color of the background was made darker to minimize distraction. The highlighted parts were replaced with another color blue to be more in line with the corporate identity of Gynzy.

Although teachers would prefer video instruction, it was chosen to focus on a text-based instruction for this research. The main reason was that it would be easier for children to navigate through the instruction and minimizing the actions they need to conduct. For the same reason, it was decided to keep the 'backward' button. In this way, students would be able to go back and forwards in the instruction whenever they want. It was considered as an interesting point to observe in the usability testing with students. If it would turn out that this button would never be used, it could still be suggested to delete the button. Furthermore, while some of the teachers preferred to have a picture with the text, it was decided to not include this, because this could lead to distraction and extraneous cognitive load (Paas, Renkl & Sweller, 2003). Also, based on the advice of a language expert, capital letters in words were erased if they were not in the beginning of a sentence.

4.5.2. Usability testing with students (round 1) and adaptations

Observations. In the first usability testing round with students, only one student pushed the button for a hint. After the hint was given, the student was able to move on and did not ask for additional instruction. Furthermore, none of the students made four or more errors, which were needed to receive a suggestion for a hint.

Almost all of the students were in phase 3 or 4 at the end of the session. Therefore, only the instruction for the last phase could be shown to the students. For example, a certain student could begin in phase 1, which is about 'recognizing long sounds', but when answered enough items correctly, the student will move on (because of the adaptive character of the software) to a next phase, during the session of twelve items. While shown the additional instruction, two of the students had trouble understanding the function of the arrows for navigating back and forward through the instruction. One student suggested in the interview: "Maybe it could be that you put here for example 'go further' and here 'back' or something like that.." [S7].

Interviews. After the students completed the session, they were shown the hint and the instruction, which were both valued positively. Many students appreciated the fact that explanations were available: "That you can get explanations about quite a lot of things. And then you can move on." [S5] The one student that actually used the hint, pointed out that it was a good thing that "there was an explanation in the first place" [S3].

Sometimes, students showed a preference for the additional instruction, compared to the hint. For example, one student, who was not in need of a hint or extra instruction himself, commented on the hint: "Sometimes children still don't understand this" [S6]. The interviewer asked why. S6 answered: "It is not clear enough." After the additional instruction was shown, this student mentioned: "This one is a lot more clear. Here you have the full explanation". One student related to her own experience with the hint: "I have used it before and then I still didn't understand it" [S1]. In the additional instruction, she pointed out a benefit of the arrows: "If you still don't understand the previous page and you accidentally continued, you can also go back again" [S1]. Another student said about the additional instruction: "I think this one is better. Because it also explains all of things and has other things here" [S4]. One student [S5] mentioned about the hint that the text should be bigger: "There is slightly smaller text on that one. For

example this could be a little bit bigger". A similar comment was: "I like this one more. The text is bigger. And there are exclamation marks" [S8].

Another student, [S1] positively valued the font size and colors in the additional instruction: "Because often people write with too small font sizes and here there are also bigger font types" and "I think it's useful that the colors that are important in a text, are blue/purple-ish". Another student mentioned: "I think it's useful that you also put words in italic and bold and in other colors" [S7]. One student mentioned that the blue colors could be more distinctive: "I like the color but it might maybe be a little bit more clear if it's a little bit brighter" [S7]. One student mentioned the colors and the presence of an example as positive things: I think it is good that the words that are important are bold. And that there is an example" [S8].

All of the students liked the pedagogic agent called Virko, almost all of them recognized it from a game that Gynzy offers as well. A lot of the students called the agent "funny". "One student said: "I think it's good. Maybe it makes children happier" [S6].

The audio button for spoken text wasn't used by the students while reviewing the hints and the additional instructions. However, two students mentioned something about the audio symbol. S7: "I would like it, if I could click on that" Another student mentioned that he liked "that there is a sound thing" [S8].

Adaptations. After this test round the blue colors were made slightly brighter and text was placed on the arrows, so students would better understand their function. The final designs can be found in Appendix G. Also, for the next testing round, children were approached who did not master this specific spelling goal yet, because it was expected they would profit more from this additional instruction.

4.5.3. Usability testing with students (round 2)

Observations. Of the eight students, four of them [S9; S10; S15; S16] pressed the 'hint' button on own initiative, one of them pressed it twice [S15]. Two of them [S9; S16], asked for additional instruction after this hint.

Four students [S9; S12; S14; S15] received a suggestion for more instruction after four wrong answers in a row. One of them [S09] pressed "No, I would like to practice more", one of them [S14] pressed: "Yes, I would like a hint" and two of them [S12; S15] pressed "Yes, I would like additional instructions".

Another observation was that many of the students read the instructions aloud by themselves [S12; S13; S15; S16]. Two of them pressed the audio button [S12; S16] to have the text read aloud.

One thing that stood out from both testing rounds, was that during the student interviews, all of the students seemed to understand the explanations, even though they might use different spelling methods in their school, including different terminology. Furthermore, during testing, it was not noticed that students were distracted by certain aspects.

Interviews. In the final testing round, the mean age of the students was lower (M=7.88), which was noticeable in the interviews. For many students, it was hard to explain their thoughts, for example about why they liked something or not.

Most of the student positively valued the hint as well as the additional instructions. For example, student 14 mentioned that she liked the fact "that they explained it well". Furthermore, student 15 said about the additional instruction: "This one is more" and "More is better". One student mentioned about the example in the hint: "I know this one, referring to the word 'hammer'. But I don't understand this" [S9]. She then pressed "Extra instruction". Afterwards, she mentioned about the different examples in the additional instruction: "At first I understood it a little. And because of this, I fully understood".

Again, most of the students valued the agent as positive. One male student mentioned something about gender: “It’s good. It’s a boy” [S13]. And another student mentioned that she recognized the figure: “This one is already in Gynzy. Most of the times. So the figure is good.” [S9].

Furthermore, the audio button was valued as important. Indirectly, this might relate to the fact that some children were not good at reading: “even more to read, I’m not that good at reading” [S12]. One student did not directly mention the audio button, but pointed at it, after he was asked about what was good about the instruction [S16].

4.6. Design guidelines

Finally, based on the results of the design process, design guidelines were developed (figure 11) in addition to the initial design criteria (figure 9). The paragraph below will further explain the decisions for the different concepts, as represented in the figure.

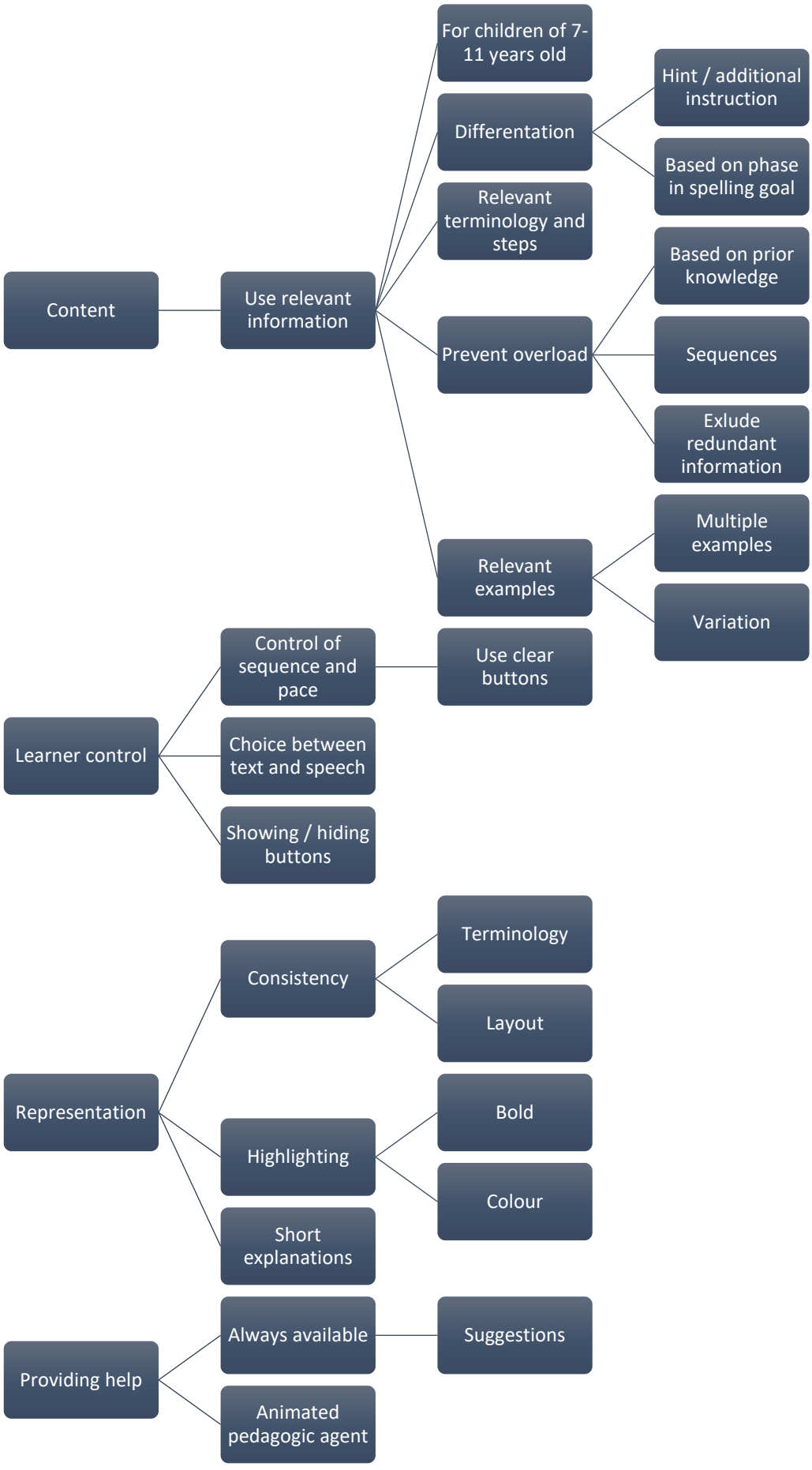
Content
Use relevant information
For children of 7-11 years old
Differentation
Hint / additional instruction
Based on phase in spelling goal
Relevant terminology and steps
Prevent overload
Based on prior knowledge
Sequences
Exlude redundant information
Relevant examples
Multiple examples
Variation
Learner control
Control of sequence and pace
Use clear buttons
Choice between text and speech
Showing / hiding buttons
Representation
Consistency
Terminology
Layout
Highlighting
Bold
Colour
Short explanations
Providing help
Always available
Suggestions
Animated pedagogic agent

Figure 11. Organization of final design guidelines

In the final guidelines, all of the initial design criteria are included. Those criteria were not rejected during the research, some of them were additionally supported. Furthermore, additional guidelines were derived. Again, the guidelines were categorized in 'content', 'learner control', 'representation' and 'providing help'. The most important findings for each category are described in the paragraph below.

4.6.1. Content

Differentiation. In the first design of the instructions, there were not many aspects that enabled to differentiate between different spellers, except the availability of an audio button for the more audio-oriënted students or weak readers. After a few rounds, the instruction was focused on the different phases. Currently, Gynzy differentiates based on the level of difficulty. Therefore, it is recommended to also base instructions on these different phases. From usability testing with students, it became clear that a small number of students actually needed the additional instructions and some of them needed only a small hint. Therefore, it is stimulated to keep the hint as short as possible and offer extra instruction only after the hint.

It was found that some students were still in a lower phase of the specific spelling goal and therefore the current hint was too extensive. Therefore it is recommended to also adapt the hint, based on the matching spelling phase for each individual student. The prior knowledge influences the content because based on which phase that the student is in, content might change. It was found from research, that to be able to differentiate in instruction, it is important to consider pre-existing factors that could influence instruction. Based on the phase that a student is in, he or she should be able to receive relevant hints or instructions. Therefore, prior knowledge influences the content of the instruction.

Terminology & steps. For the initial instruction, the terminology that Gynzy uses was chosen for the instructions. The steps were based on different spelling methods, which broadly use the same steps to explain the spelling rule. In the interviews with teachers, the steps were positively valued and in usability testing with students, no striking observations were made in relation to the steps. However, many teachers mentioned that the terminology from Gynzy sometimes differed from the terminology of the spelling method they use and were concerned this might lead to problems for students in understanding the instructions. However, in usability testing with students, this was not found to be a problem. While students use methods with different terminology, they did not seem to have trouble understanding the words or phrases in the instruction or the hint. Therefore, it is recommended to decide which terminology and steps are most relevant and to be consistent in using these in the learning environment. Several teachers as well as students praised the fact that explanations were presented in divided steps.

Relevant examples. The example that was used in the developed instruction, was the same example that was already used for the hint in Gynzy iPads. It was found that some students, did know how to apply the rule with the given example, but that it was not always possible for them to transfer this knowledge for other words. Therefore, it is recommended to use more examples or to vary with the examples (Butterfield & Nelson, 1989; Alessi & Trollip, 2001).

4.6.2. Learner control

Showing/hiding buttons. In usability testing, students sometimes had troubles understanding the buttons (arrows) for navigating through the instruction. After the arrows were supported with text for the second round of testing with students, no problems were detected relating to this issues. Therefore, in case of vague or ambiguous symbols, text could be used to support the arrows. It might, however, be due to unclearness of the form of the arrows, therefore it should be investigated as well if other arrows would be more clear, to avoid redundancy by adding text. Based on the statements of the teachers and observations with students, students quickly get used to symbols. Therefore, it should be well considered if guided text is really necessary.

Choice between text and speech. Speech was added in the additional instruction as an optional addition. While not many children used the audio button in usability testing, it is recommended to keep this button, because of the many statements teachers gave about their students using it. All of the interviewed teachers praised the ability to play audio and some of the students did as well. Also, the possibility to hide buttons could be considerd, for students that never make use of it, to minimize the number of symbols on the screen.

4.6.3. Representation

Highlighting. To be consistent with the colors that Gynzy uses, the color blue was chosen for highlighting important letters or words and marked in bold. Teachers and students both reacted positively to the highlighted letters, words or phrases. However, one student tried to click on a word in the final testing phase. It is therefore suggested that it should be made clear if a word is a hyperlink or not. This could be done by changing the mouse when going over a hyperlink. Furthermore, the color blue could be reconsidered, because of findings that colors red and blue were found to be difficult for learners to progress (Alessi & Trollip, 2001). Students mentioned they liked that the text was in a big font size. Teachers also mentioned that text should be large and the whole screen should be used.

4.6.4. Providing help

Always available – suggestions. Based on consultation with teachers and educationalists, it was decided that instruction should always be available for the students and not forced towards. Forcing could lead towards demotivation of the use of Gynzy iPads. However, it was recommended that for students who make many errors, the instruction could be 'suggested'. In this case, using additional instruction would still be optional, but might give students a reminder of the ability to use the instructions. In the testing with students, it was observed that after a suggestion, students often choose to read the hint or instruction

Animated pedogogic agent. An animated pedagogic agent was chosen for guiding the students through the additional explanations. Since Gynzy already uses a certain agent for other components of the software, it was decided to use this agent (called Virko) for the instruction as well. Most teachers and children reacted positively on the agent, only one student did not really care for it. However, during testing, it became clear that the used agent was the male version and that there is also a female version(called Valetta) available in Gynzy iPads. It could be considered to offer children a choice between the female and male version of the agent.

5. Discussion

5.1. Research question

The main goal of this research was the development of guidelines for designing instruction for learning environments, containing multimedia drills for students in primary schools. The following research question was addressed: *"Which guidelines are important in developing textual spelling explanations in multimedia drills for students in grade 2 and 3 of primary school?"*

The initial criteria that were developed, were mostly confirmed in usability testing. In addition, the most important guidelines that were found were:

- *Use multiple examples, and/or vary with the examples*. It was found that by using the same example repeatedly, students became 'used' to this example. Therefore, it is recommended to vary with examples.
- *Choose the most relevant terminology.* While many teachers mentioned that they disliked the fact that terminology often differed between the spelling methods and Gynzy iPads, it was experienced that students know a lot of flexibility according to terminology. Student's showed no difficulties with the terms, even though the spelling methods used in their schools, used other terminology.
- *Use stepwise instructions*. The representation of instruction in divided steps was valued by teachers as well as students.
- *Adapt hint and additional instruction based on phases for spelling goals.* For some students, the current hint was too extensive. Therefore, adapting the hint, based on the matching spelling phase for each individual student, is recommended.
- *Offer choices in showing or hiding buttons.* While many teachers and some students praised the availability of the audio button, for some students this seemed not to be necessary. Therefore, it could be an option to give the option to hide this button, which is in line with the principle of redundancy.

In general, both students and teachers had positive attitudes about the instruction that was designed for getting additional explanations. In the final testing round, younger and more low ability spellers were included. This lead to more use of the hint and the additional explanations. In this final testing round, students used the instructions and very little additional problems were detected. The additional explanations were useful for some students, for which the hint was not sufficient. For other students, a hint was enough to move on with the items. It seemed that children that already controlled the specific spelling goal, would profit most from a short hint with the optional possibility to gain extra explanations. Therefore, it is suggested that hints would be developed for the specific phases of spelling that children use, to adapt to prior knowledge (Gagné, 1970) and prevent extraneous cognitive load (Paas, Renkl & Sweller, 2003). Therefore, both a short hint and additional explanations, are useful to integrate into digital learning environments, like Gynzy iPads.

Students seemed to be very flexible in using the buttons. In usability testing, this was confirmed. Students were very fast in finding out what to do and where to click on. This is in line with the predictions of teachers and also with the statements of Alessi & Trollip (2001) that states that little directions should be provided for repeated users. It might also have helped that the design of the additional instruction was also consistent with the current learning environment of Gynzy iPads. During testing, it became clear that the used pedagogical agent was the male version of two agents and that there is also a female version available in Gynzy iPads. However, a meta-analysis of Schroeder Schroeder, Adesope & Gilbert (2013) showed no striking findings regarding the gender of animated agents and further research should be conducted to investigate the influence of using a male or female voice for agents. Therefore, in designing instruction, there are no guidelines relating to the gender of animated agents. It might be used as learning control by providing a choice for students for a female or male agent or voice.

Many teachers mentioned that the presence of an audio button was important, especially for the 'weak' readers. In the first testing round with students, however, audio wasn't used by the students while reviewing the hints and instructions, but mentioned as important by two students. In the second testing round, the instructions, including the audio button were actually used also mentioned as important by the students. This in line with other research, stating that the ability of spoken text is important, especially for young children or poor readers (Alessi & Trollip, 2001). This is also in line with research towards the modality principle, which states that instructions in multimedia are more effective when verbal information is provided auditory instead of visually (Kalyuga, Chandler & Sweller, 1999; Tindall-Ford, Chandler & Sweller, 1997).

However, as mentioned earlier, while learning spelling rules is mostly about transfer, this research did not investigate the value from the explanations for transferring to other situations. From one interview it became clear that the used example was already known and that the student understood it, but not with other words. In this case, clearly, no transfer was achieved. The effectiveness of the explanations for transfer to other situations could not be concluded and should be further investigated. It is however recommended to use multiple relevant examples. Already in 1989, Butterfield & Nelson stated that variation in learning materials and good choice of examples are positively contributing towards transferring knowledge.

It should be mentioned that, according to many researchers, digital learning environments should function as an additional tool and not try to replace teachers (Etherington, 2008). Teachers fulfil an important role in the development of students, while contributing to their motivation to learn (Schuit, de Vrieze & Sleegers, 2011). It was found that the motivation for students to learn with digital tools was often dependent on how much teachers focus on process and the amount of differentiation in their teaching (Verbiest, 2003).

5.2. Recommendations

5.2.1. Recommendations for practice

Because until now, no research has been conducted towards the integration of instruction in online multimedia drills, it is recommended that the developed guidelines are taken into account while developing such instructions. Until additional research has been conducted, these guidelines can serve as a basis for the design of instructions in multimedia drills. The guidelines are based on the outcomes of the usability testing with teachers and students and often confirmed with findings from previous research. Furthermore, it is recommended to companies who develop adaptive learning material, to relate to more pre-existing aspects of students, besides the phase that the student is in (specific prior knowledge), that could be differentiated upon in instruction, like the ability to read, interests or talents (Oaksford & Jones, 2001). It would be helpful if teachers would have insight in the instructions, so they could classically discuss these as well. Furthermore, if teachers could notice if students have seen the instructions, teachers know whether they already tried to find solutions by themselves.

5.2.2. Recommendations for further research

It might be likely that in the future, more research is conducted towards the integration of instruction in multimedia drills for primary schools. For this research, it would be recommended to include a larger group of students. It is recommended to include different types of spellers, mostly from in the higher groups (from Dutch grade 3/4). It seemed that while the instructions were useful for the younger students, they were not able to express their thoughts more deeply during the interviews. This could be due to the fact that from the age of six children begin to actually "reason" in the common sense meaning of the word (Eccles, 1999). Therefore, at 7 or 8 years, they are still at the beginning of this development.

If possible, an experimental and control group could be included as well, to be able to investigate the effectivity of instructions. Moreover, experimental groups could be used to test more designs, for example, a design for video-based instruction versus text-based instruction.

Also, for this research, a certain moment was chosen to suggest a hint or additional explanations (after 4 errors). However, this choice was not based on scientific evidence and therefore, this finding should be treated with caution. Therefore, before adding suggestions, the right moment for providing this suggestion should be further analyzed. To conclude, more research needs to be done about the flexibility of students in switching between terminology.

5.3. Limitations and strengths

As in every other research, this research has its limits and strengths. The main aim of this thesis was to derive general guidelines for designing integrated instruction for multimedia drills. However, the sample size was very small and therefore it is not possible to completely generalize the findings. It might be possible that other reactions or usability issues would arise when testing with a larger sample size. Because of this small sample, it was also not possible to measure actual effects of the designed instruction, for example, compared to a lesson without additional instruction. Additionally, it was not possible to prevent children from giving socially desirable answers upon the questions of the interview. Therefore, the results of the student interviews should be treated with high caution.

Furthermore, only one small goal of the many spelling goals that exist was used in this research. More research should be conducted to be able to know what the general guidelines for learning spelling in multimedia drills would be. Also, it was recommended to differentiate between the phases of spelling that students are in. The different phases contain different types of learning. While phase 1 is about learning a concept, this research was about rule learning (relating to phase 2 to 4). However, during usability testing, the developed guidelines were found to be relevant for both types of learning.

Another finding was that student's sometimes made multiple errors because the pronunciation of the words was not completely right. Therefore, the large percentile of errors for this goal could still have multiple causes. However, many teachers recognized the topic of the instruction as a topic many students struggle with, so this is not expected to be a high contributing factor in the errors that students make.

A limitation of this study was that the usability of the hint was only tested with the students, not with the teachers. However, it was only after the testing with students was prepared that it seemed useful to have the hint included as well and this was found to be a valuable choice.

5.4. Final conclusion

Despite the limitations, this research gives first insights into the different views of teachers, students and experts relating to designing instruction for learning environments containing multimedia drills. Most of the guidelines that were developed in this research adapt well to earlier findings in research, on which the initial design criteria were based. In this research, a small sample was used to test instructions for learning a specific spelling rule. Therefore, generalization is difficult and more research should be conducted to further investigate this matter for different problems as well. For different subjects, different guidelines should be developed and investigated.

This research provided first insights about developing designs for offering explanations in multimedia drills for learning spelling rules at primary school. Using these guidelines may lead towards minimilizing the inclusion of aspects that would be deemed unnecessary, unusable or undesirable by the different stakeholders, in instruction. A first step that future research can build upon.

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Appendices

A: Questionnaire needs assessment

Dear teacher,
Attached, you will find a short questionnaire about the use of Gynzy iPads. The questions are mostly related to the instruction or explanations from the software, towards the students. Please try to answer the questions for yourself, as honestly as possible. There are no wrong or good answers. Please contact the researcher if you have any questions via l.c.groen@student.utwente.nl. Thank you in advance!

1. ***Do you think that concepts, rules or procedures (for example explanations about different kinds of verbs) are clearly described for students in Gynzy iPads?****

   Yes / No

2. ***Do you think that certain components of your classical instruction could be integrated in Gynzy iPads?****
   Yes / No

3. ***Suppose that there will be offered more instruction/explanations towards students in Gynzy iPads, how would you like to see that (multiple answers possible)?***

- Students have access to instructions on forehand
- Students have access to instructions when they struggle with certain subjects
- Students have access to instructions at any time

4. ***Which part of your instruction could be integrated in Gynzy iPads?****

- Everything
- A large part
- A limited part
- None

5. ***Do you think that the current instructions/explanations in Gynzy iPads should be adjusted or improved?****
   Yes / No

6. ***If yes, what should be adjusted or improved?***

7. ***Do you have any other remarks or suggestions?***

Thank you for your coorperation!

B: Usability testing with teachers: interview scheme

Theme	*Content*
Introducing and background	▪ Introducing ▪ Background: This research for the University of Twente and Gynzy, studies the ways instruction can be integrated in Gynzy iPads. Therefore, I'm developing a prototype which could eventually serve as a basis for the integration of instruction in Gynzy iPads. This specific prototype is about explaining a spelling rule in Gynzy Worlds.
Goal of interview	▪ From needs assessment, it became clear there was a strong need among teachers to have parts of the instruction integrated in Gynzy iPads. ▪ By this interview, deeper insights about these needs and preferences of teachers are investigated.
Practical issues	▪ There are some practical issues I need to mention: ▪ The interview will take no longer than an hour. ▪ At any moment, you have the right to quit the interview. ▪ Because there is a possibility I would miss things, when writing down, I would like to record this interview. ▪ The recording will be fully anonymized and exclusively used fort his research. After the research, the recording will be deleted. ▪ Do you agree?
Start	▪ Do you have any questions before we begin?
Walkthrough with plus/minus method	▪ -
Questioning plusses and minusses	▪ For which reason did you add a plus/minus? Possible reasons: ▪ (un)clear ▪ (un)important/relevant ▪ recognizability ▪ (un)appealing ▪ agree/disagree
Possible additional questions	▪ What do you think about the content? (e.g. correctness, structure, clarity, different steps, terminology, use of examples, etc.) ▪ What do you think about the agent? (e.g. is it useful, recognizable) ▪ What do you think about the length? (e.g. of the texts, total instruction) ▪ What do you think about te symbols? (e.g. clarity, amount) ▪ At what moment should children need this instruction? (e.g. before new topics, after a few errors, at any time they need it) ▪ What do you think about the visuals / audio? ▪ What do you think about the amount of control children have (choices) ▪ What do you think about the amount of interaction? (e.g. should there be more interaction?)
Other questions	▪ What do you think instruction in Gynzy iPads should contain? ▪ What do you think adaptive education should ideally look like? ▪ Do you think that the instruction should connect to the different phases of spelling that Gynzy uses?
Demographic variables	▪ What is your age? ▪ Since when do you work as a teacher? ▪ Since when do you work with Gynzy iPads? ▪ In which way do you work with Gynzy iPads? ▪ Which method do you use for spelling?
Conclusion	▪ Thank you for participating ▪ Explaining follow-up process

C: Usability testing with students: observation scheme

Item 1	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 2	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 3	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 4	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 5	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 6	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 7	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 8	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 9	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 10	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint

Item 11	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 12	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 13	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 14	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint
Item 15	Audio	Skip	Scan	Read	Click	Type	Correct	Wrong	Hint

Hint	Audio	Skip	Scan	Read	“I get it”	“Extra instruction”
Extra Instruction (1-3)	Audio	Skip	Scan	Read	Backwords	Forwards
Extra Instruction (2-3)	Audio	Skip	Scan	Read	Backwords	Forwards
Extra Instruction (3-3)	Audio	Skip	Scan	Read	Backwords	“I get it”

D: Usability testing with students: interview scheme

Demographic variables

Gender: M / F
Age:
Grade (Dutch): 4 / 5 / 6
Type speller: Weak / Average / Strong
Spelling phase: 1 / 2 / 3 / 4

Theme	*Content*
Introduction and background	*Introduction* Thank you for helping me out today. Right now, we are making something for Gynzy, so that students can get explanations at any time, without calling their teacher. To make this as good as possible, I need your help to test it! After we are done, I would like to ask a few more questions and you will receive a little gift.
Practical issues	There are some practical issues I need to mention: ▪ It will take no longer than 20 minutes. ▪ At any moment, you have the right to quit the interview or take a short break. ▪ Because there is a possibility I would miss things, when writing down, I would like to record this interview. ▪ The recording will be only used by me to be able to listen again what you have told me. I will not let anybody else hear it and after the research, it will be deleted. Do you agree?
Explanations	*Explanation* When we will start, you can make a few assignments in Gynzy Spelling Worlds on your iPad, just like you do sometimes in the classroom. When you think 'I would like to have some explanations', you can push this paper button of a lamp. It might be a little funny to do this on paper, but you can pretend just like it's on your iPad! Do you understand that? ▪ Do you have any questions before we begin?
Before testing	• What do you think about working with Gynzy iPads in school? (What is good/less good?) • What do you think about working with Gynzy Worlds? (What is good, what is less good?) • What do you think about spelling? (Why?) • Do you think spelling is easy or hard, or does it depend?
Testing	-

After testing	Questions about hint (shown when not used): ▪ What do you think about this? (Why?) ▪ What do you think is good / useful? ▪ What do you think is less good / useful? ▪ What do you think about the text? ▪ What do you think about the colors? ▪ Did it help you? / Would it be helpful if you didn't understand it? ▪ Was there something missing? ▪ Is there something we could do to make it better? Questions about additional instruction (shown when not used): ▪ What do you think about this? (Why?) ▪ What do you think is good / useful? ▪ What do you think is less good / useful? ▪ What do you think about this, compared to the previous one (hint)? ▪ What do you think about the text? ▪ What do you think about the colors? ▪ What do you think about this figure (agent)? ▪ Did it help you? / Would it be helpful if you didn't understand it? ▪ Was there something missing? ▪ Is there something we could do to make it better?
Open question	Is there anything else you would like to talk about?
Conclusion	Thank you for your help!

E: Screenshots of first design

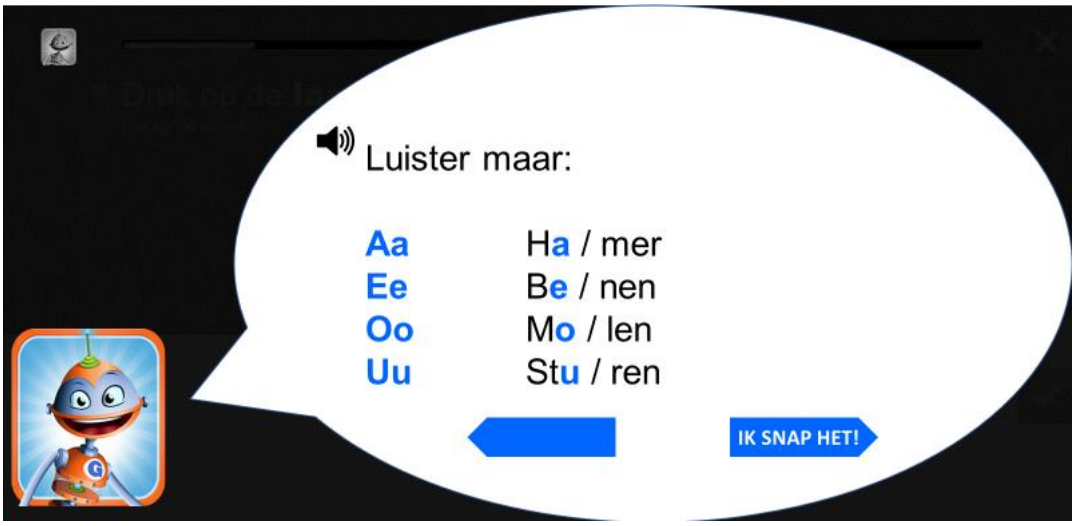

Druk op de lange klank.
Klik op de letters
Je hoort een lange klank: waa / ter
Hoor je aan het eind van een klankgroep een lange klank, dan schrijf je aan het einde van deze lettergreep één klinker.
Je schrijft de klankgroepen zo: wa / ter


Druk op de lange klank.
Klik op de letters
Een klankgroep die eindigt op ~a, ~e, ~o, of ~u noem je een open klankgroep.
Aan het einde van een open klankgroep schrijf je één klinker.

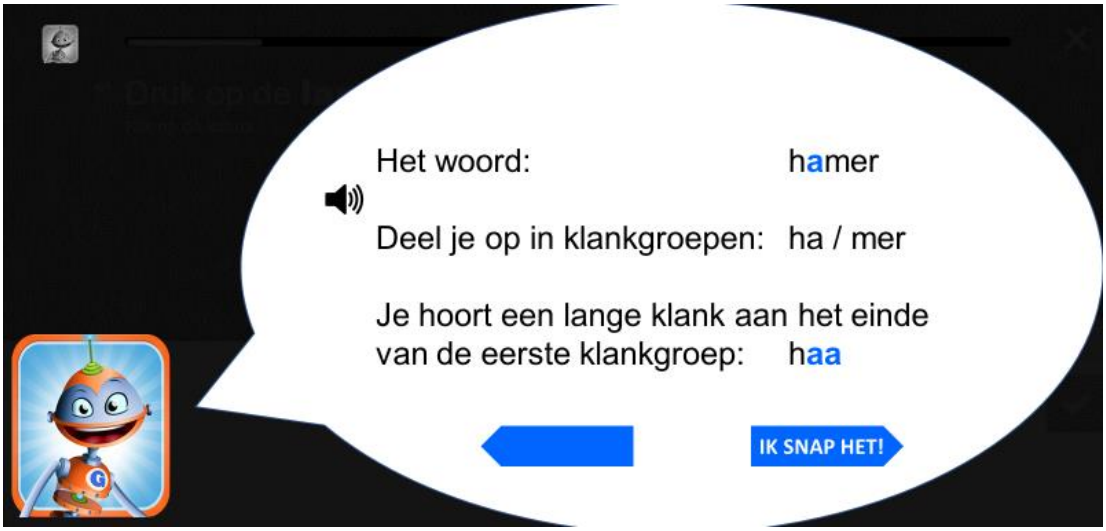

Druk op de lange klank.
Klik op de letters
Dus:
Hoor je een lange klank? waa / ter
Dan schrijf je aan het einde van de klankgroep één klinker: water

F: Screenshots of second designs

Second design for phase 1



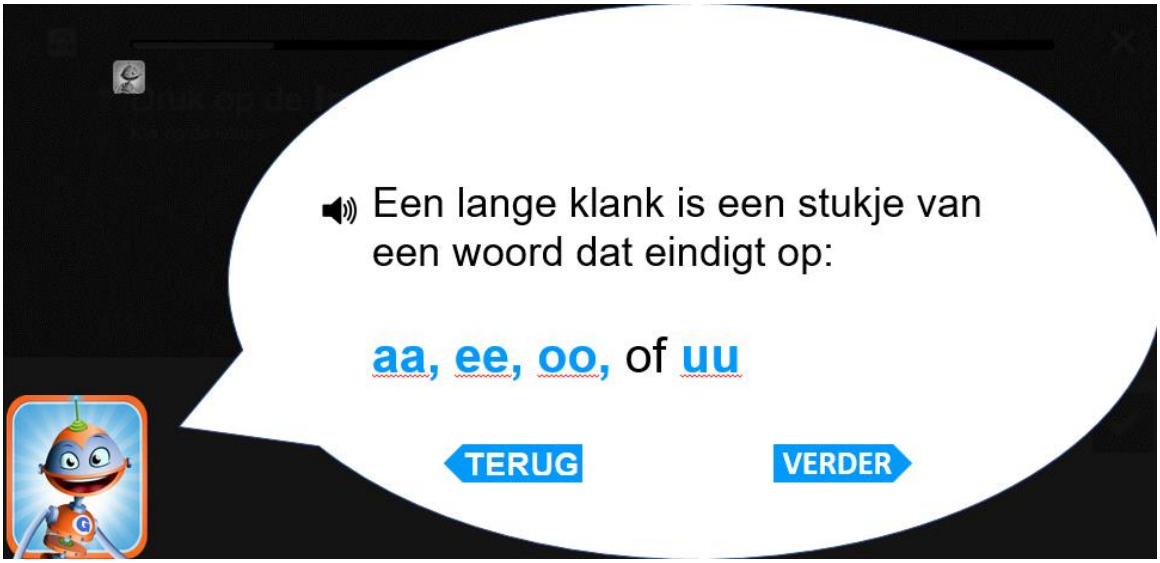
Second design for phase 2



Second design for phase 3-4

G: Screenshots of final designs

Final design for phase 1:



Final design for phase 2, 3 and 4