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BACHELOR THESIS

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Research Proposal

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Contents

Preface

In this document the reader can find a proposal for designing a course on quantum mechanics in a qCraft learning environment. This is an assignment executed for a bachelor thesis. The document contains a table with general information, a short summary of the assignment, a detailed description of the assignment wth the rationale, the conceptual framework and the relevance, the design approach and a planning.

General Information

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Keywords	Quantum mechanics, Middle school Education, Netherlands
Title	

Summary

Description

This chapter contains a short description of the background of the subject matter on middle schools in the Netherlands, the content of the instruction itself, the technology which will be used for the instruction, and an outline conceptual framework for the literature study.

Background

In the Netherlands, quantum mechanics always used to be a topic which schools themselves could choose to teach or not to teach. The only skill students had to know for the Centraal Eindexamen (the national central exams at the end of high school) which comes close to quantum mechanics is to elucidate the photoelectric and the wave-particle duality, mentioned within point 20 under subdomain E3 (citation eindexamenblad). However, one of the changes in the Centraal Eindexamen of 2016 was the addition of domain F1, which is called Quantum world. For this subdomain the candidate has to be able to apply the wave-particle duality and the uncertainty principle of Heisenberg, and to explain the quantization of energy levels in some examples with a simple quantum physical model. In order to give all candidates a chance of passing this subdomain, schools have to alter their programs in order to meet the expectations of the Centraal Eindexamen.

However, when searching the internet using the search machine Google concerning the implementation of quantum mechanics in Dutch high schools, the quantity and the quality of the results are very low. There are also no results to be found in the Dutch papers. An example is the Dutch site http://www.quantumuniverse.nl/, where teachers can find a small amount of brief courses on fundamental quantum mechanics, and where the forums are very quiet with only 5 discussions, of which 4 are just started threads from the site administrator.

Upon finding this information, an expert was consulted to confirm this conjecture. The expert was researching the implementation of quantum mechanics on middle schools, and she also a first degree physics teacher. She stated that within her school there were no initiatives to bring this topic in their classrooms, and that their school was no exception as well.

The fact that next year domain F1 has to be fully implemented and teached to all vwo students who chose physics as an examination subject is therefore slowly turning into a sword of Damocles. This stresses the urgency for the development of new course material.

Content

Quantum is not the most easy topic to introduce to physics. The subject is very counterintuitive, and still poses headaches to many physicists today. The great physicist Richard Feynman is known for saying: "I think I can safely say that nobody understands quantum mechanics" (1965), and this statement still holds. Quantum mechanics is this counterintuitive because it contradicts a lot of axioms we inherited from classical physics. These contradictions are highlighted by an article written by Einstein, Podolsky and Rosen, which states that the current understanding of quantum mechanics contradict the criterion of reality and the hypothesis of locality.

There are a lot of resources available for teaching quantum mechanics. Most of these resources are academical and focus on teaching the mathematics. Their philosophy is that the student can only really get a grasp on quantum mechanics if he understand the underlying mathematical mechanics. An example of such a resource is Griffiths (2005). These resources are not very usefull when teaching middle school students, because it demands an understanding of mathematics which is beyond the knowledge of middle school students, for example the integration of Schröder equations.

The other way of teaching quantum mechanics is by teaching the key principles of quantum mechanics. A fashion in which this could be achieved is by only considering the perfectly correlating instances. An example of such an instance is quantum teleportation. Zeilinger (2005) explains this phenomenon without having to resort to very complex mathematics, but still explaining the fundamentals of quantum mechanics, namely observer dependency, superposition and quantum entanglement. The instruction will therefore use quantum teleportation to explain these three fundamental principles, so the learner will gain a concepual understanding of quantum mechanics.

Technology

The course will make use of qCraft, a modification made by members of Google for the game Minecraft. This game supports an accessible way for the player to get introduced and to interact with the aforementioned principles superposition,

observer dependency and entanglement.

Minecraft

Conceptual framework

Design approach

A model which describes the process of developing educational resources is the Generic Model (Plomp, Feteris, & Pieters, 1992) (see figure 1). It describes the phases Analysis, Design, Development, Implementation and Evaluation. This model will be partly used for this project. Because of time constraints and the limited size of the project it will only go as far as the horizontal bar of development, this will be elaborated further later in this chapter.
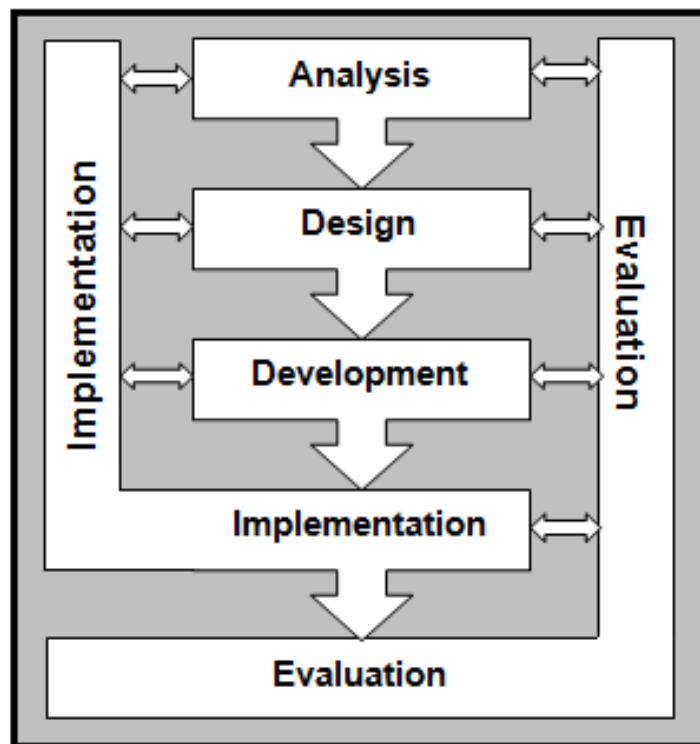

Figure 1: The generic model by Plomp et al. (1992)

Analyses

The first step in the Generic Model (Plomp et al., 1992) is the step Analysis. In this step, data is gathered which is necessary for designing an effective solution. Smith and Ragan (2005) mention three different kinds of analysis, namely analyzing the learning context, analyzing the learners and analyzing the learning task.

Analyzing the learning context

A learning task always takes place in a certain learning context. In this case this is the middle school. It entails not only the place, but also the temporal and social environment (Smith & Ragan, 2005). The analysis of the learning context can provide the instructional needs and a description of the different factors influencing the instruction. With the instructional needs, the designer can establish the main learning goals for the instruction. The description of the learning environment can provide the learning opportunities and constraints which have to be taken into account for the instruction.

Analyzing the learners

The second analysis is that of the learners (Smith & Ragan, 2005). The purpose of this analysis is the characterization of the end user of the instruction, which is in this case the middle school students. For this analysis it is important to determine the similarities and differences between the learners. Smith and Ragan (2005) provide a list of factors which play a role in designing the instruction.

Analyzing the learning task

The final step is analyzing the learning task (Smith & Ragan, 2005). In this analysis the goals from the needs assessment during the analysis of the learning context have to be translated to test specifications, with which the content of the instruction can be established. In order to achieve these test specifications, first the type of learning has to be established. Having this established, the information-processing analysis can be conducted. Every type of learning has its own kind of information-processing analysis. Zeilinger (2005) will be used to conduct this information-processing analysis. The next step is the prerequisite analysis. The outcome of this has to correspond to the outcome of the learner analysis. Finally, the learning objectives can be written, which form the test specifications. Every learning objective has to contain a description of the terminal behavior or actions that will demontsrate learning, a description of the conditions of demonstration of that action and a description of the standard or criterion (Smith & Ragan,

2005). Every learning objective will fall into a catagory of Bloom his taxanomy of learning objectives (Bloom, Englehart, Furst, Hill, & Hrathwohl, 1956), and will use appropriate action verbs.

Literature Study

After the analyses have been conducted, the literature study will take place. Steehouder et al. (2006) state the different steps which go into doing literature research and writing the theoretic framework. The first step of the literature study will be considering the search terms. For this, the results of the analyses will have to be taken into account, especially the characterizations of the learners and the learning task. The search terms will then be expanded by finding synonyms and similar relevant terms by using the Thesaurus. After the search terms are determined, it has to be established which databases will provide useful results. Then a cyclic process will take place in which the amount of results will be assessed with these databases and search terms and then if needed the results are limited or expanded by using more search terms and filters. The results will always be constrained to peer-reviewed articles. Other filters could than be the recency of the articles or the educational level of the test subjects. When there is an appropriate amount of results, they will be filtered manually. First, the articles which seem relevant by their title and keywords will be selected. This will be done in a very broad sense, so only the really irrelevant results will be filtered out. These selected articles will then be skimmed by their abstract, introduction and conclusion and will be filtered out when they actually are not relevant. The remaining articles will then be used for constructing the theoretic framework. It could be that new keywords can be found in these articles. In this case this keyword will be added to the search terms in order to find even more results.

From the resulting articles a literature matrix will be constructed (Steehouder et al., 2006). This matrix will contain research questions in the top row and the resulting articles in the left row. By using this technique, every question can be answered per resulting article. The columns can then be summarized in order to answer every question separately. These answers ultimately are the content of the theoretic framework.

Design

The second phase of the Generic Model (Plomp et al., 1992) is the design phase. In this phase the results from the analyses are used to form design principles, which can be used to develop the instruction. There will be design principles for:

- a pretest for information about the preknowledge and the experience with playing games of the participants;

- the text of the instruction;

- the learning environment within Minecraft;

- the posttest for testing the resulting knowledge of the participants.

Furthermore, a global design plan will be made, which is a distribution of the learning objectives over the course of the instruction. The basic hierarchy of the instruction will consist of the different learning events by Smith and Ragan (2005).

Development

After the design phase comes the development phase, in which all the resources are finally fully developed, based on the earlier made design. This will be the developing of the pre- and posttest, the writing of the text and the developing of the learning environment in Minecraft. The development of the resources will be based on the earlier developed design principles and the global design plan.

Formative Evalutation

After the first development phase, the formative evaluations will take place. These evaluations are derived from the *Evaluation Matchboard* (Nieveen, Folmer, & Vielgen, 2012). After each evaluation, adjustments of the products have to take place as well. First, the resources will be screened to check whether the resources confirm to the design principles. Then, a focus group evaluation will take place. In this evaluation a subject matter expert will be interviewed to check whether the text contains statements which have to be adjusted or corrected with the current knowledge on quantum teleportation. Finally, a micro-evaluation will take place, in which the final product will be tested upon members of the target audience, or people similar to the target group audience. With this evaluation, the actual practicality can be tested by interviewing the participants. The actual effectiveness will also be tested by letting the participants make the posttest.

Implementation and Summative Evaluation

The implementation and summative evaluation will not take place during this project. Implementation would be outside of the scope of the project, and could

only be executed in a follow-up project. When proven to be succesful, the resources developed will be offered to MinecraftEdu, an organisation which has the mission to bring Minecraft into schools.

Because the lack of implementation, a summative evaluation is also out of the question. In order to conduct a succesful summative evaluation, the resources would have to be fully in use in the actual context, which is not the case for this project.

Conclusion and Discussion

When the micro-evaluation has taken place, the resulting data has to be processed and analyzed. With these results, a conclusion will be written down to summarize the advantages and drawbacks of the instruction. There also will be suggestions for improvement and for implementation.

Planning

Analyses	Week 18
Literature research	Week 20
Design	Week 21
Development	Week 22
Formative Evaluation	Week 24
Conclusion/Discussion	Week 25
Presentation	Week 26

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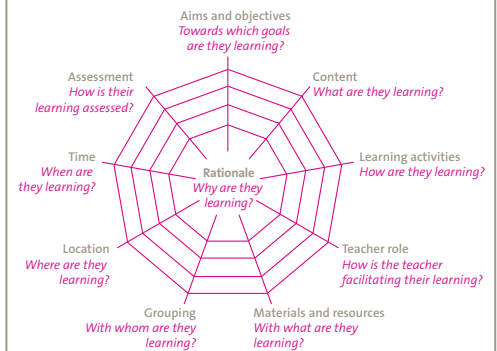
Appendix A: Evaluation matchboard

1 — Stage of development

○ **Design proposal**
General idea of the product.

○ **Global design**
First elaboration of the product.

○ **Partly detailed product**
Parts of the product have been specified and could be used by the target group.

○ **Completed product**
The product is ready for use in practice.

2 — Quality aspects

○ **Relevance**
There is a need for the product and its design is based on state-of-the-art (scientific) knowledge.

○ **Consistency**
The product is 'logically' designed.

○ **Expected practicality**
The product is expected to be usable in the settings for which it has been designed.

○ **Expected effectiveness**
Using the product is expected to result in desired outcomes.

○ **Actual practicality**
The product is usable in the settings for which it has been designed.

○ **Actual effectiveness**
Using the product results in desired outcomes.

3 — Curricular components

Aims and objectives
Towards which goals are they learning?

Content
What are they learning?

Learning activities
How are they learning?

Teacher role
How is the teacher facilitating their learning?

Materials and resources
With what are they learning?

Grouping
With whom are they learning?

Location
Where are they learning?

Time
When are they learning?

Assessment
How is their learning assessed?

Rationale
Why are they learning?

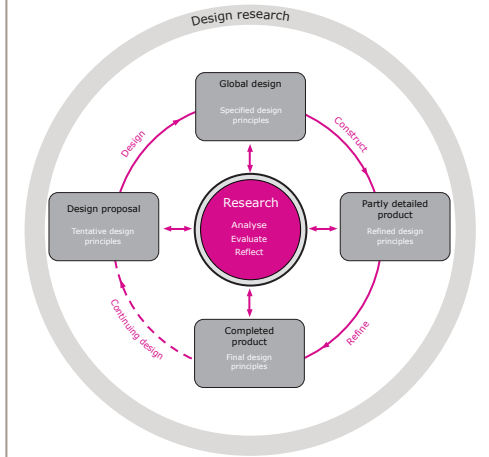## 4 — Evaluation method

○ **Screening**
Members of the design research team check the design with a checklist containing required characteristics of the product.

○ **Focus group**
A group of respondents reacts on a prototype of the product.

○ **Walkthrough**
The design research team and representatives of the target group simulate the use of the product.

○ **Micro-evaluation**
A small group of target users use parts of the product outside its normal user setting.

○ **Try-out**
The target group uses the product in practice.

5 — Activities

○ **Using a checklist**
Using a checklist with required characteristics of the product.

○ **Interviewing**
Asking respondents questions verbally.

○ **Observing**
Noticing what happens in practice and how respondents act.

○ **Administering a questionnaire**
Respondents answer questions on a paper-based or digital questionnaire.

○ **Testing or requesting a report**
Respondents make a test or draw up a learning report.

○ **Requesting logbooks**
Respondents write down their actions and reflections during a certain period.

Design research

Design research

Design

Construct

Refine

Continuing design

Global design
Specified design principles

Partly detailed product
Refined design principles

Completed product
Final design principles

Design proposal
Tentative design principles

Research
Analyse
Evaluate
Reflect

'Evaluation matchboard'

Stage of development (1)				Evaluation method (4)	Activities (5)		Quality aspect (2)					
Design proposal	Global design	Partly detailed product	Completed product				Relevancy	Consistency	Expected practicality	Expected effectiveness	Actual practicality	Actual effectiveness

Recommendation

■	■			Screening	✓		■	■				
■	■								■			
■	■			Focus group	👥		■	■				
	■	■							■			
		■	■							■		
		■		Walkthrough	✓ 👥 👁					■		
		■	■	Micro-evaluation	👥 👁 ? ✍						■	
			■									■
			■	Try-out	👥 👁 ? ✍ ✎						■	■

Remaining possibilities

		■	■	Screening	✓		■	■				
■												
■	■								■			
		■	■	Focus group	👥		■	■				
■		■	■						■			
■	■									■		
			■	Walkthrough	✓ 👥 👁					■		
		■		Micro-evaluation	👥 👁 ? ✍							■

Explanation: On one horizontal row, combine a stage of development (1) with a quality aspect (2) and find an evaluation method (4) with relevant activities (5)

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Nieveen, N., Folmer, E., & Vliegen, S. (2012). *Evaluation Matchboard*. Enschede, the Netherlands: SLO.