UTRECHT UNIVERSITY

The Conditions For Invention

Determining the fit between constructionism and future education

by

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"The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge."

Seymour Papert

UTRECHT UNIVERSITY

Abstract

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Education needs to adapt in order to keep up with a changing society. This process needs to be well informed in order to succeed. By finding theoretical foundations that support these changes, the chance that these reforms improve education increases. This thesis analyses the degree in which the constructionst learning theory can be applied to guide educational reform. Defining the future education based on the 'Ons onderwijs 2032' project allows for a comparison with constructionism. Analysing this comparison leads to a conclusion about the suitability of constructionism as a foundation for future education.

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Chapter 1

Introduction

Education is an interesting phenomena, it defines the knowledge and base of a society and plays a major part in most people's life. Thus, when a society changes, so should its education. But how can a well established system like education keep up with the fast and hard to predict changes that society undergoes? Government policies, academic research and educators are among the parties that try to define the future of education. All these parties have their own ideas and schools of thought about the way education should evolve. Meanwhile every individual educator has its own interpretation and implementation of these theories. This paper will try to describe whether Constructionism, an educational theory, can help to achieve a more 'future proof education'. By looking at established goals defining the future of education and finding the fit between those goals and the constructionist theory, this thesis aims to provide an answer to the question "Does the constructionist learning theory provide the means to reach the goals of future education?".

As a student of artificial intelligence (AI) I first discovered constructionism by researching different learning strategies that are a central part of AI. The main origin of constructionism is associated with the work of Seymour Papert, a famous AI researcher concerned with the use of the learning algorithm known as the *perceptron*. However, when researching Papert's work one might quickly notice a shift of subjects in his later writings. Most of Papert's work puts focus on the learning that humans do instead of that of machines. He clearly expresses this link by saying "In order to make a machine capable of learning, we have to probe deeply into the nature of learning. And from this kind of research comes the broader definition of artificial intelligence: that of a cognitive science" [1].

This field of research interested me and caused a change in my primary focus during my education. By using the theories that originated from AI combined with the new knowledge of constructionism, I founded a company named *Mindmingle*[1]. The main focus of Mindmingle is to provide constructionist education to schools and learners. Mindmingle tries to accomplish this by teaching students, guiding teachers and informing schools about this unique style of education. I hope to utilize the experience I gathered during thess lessons to make this thesis more meaningfull and more intimate. Because, as we will see, according to constructionists this is a powerful way to convey an idea.

In order to be able to answer our question we start with giving an overview of constructionism by describing its history, theory, current state and tools. Then in order to define the future of education, we look at goals established by the project 'Ons onderwijs 2023' (in English: Our education 2023). This project was initiated by the Dutch Ministry of Education, Culture and Science[2] and provides concrete goals that define future education. We conclude with answering our main question by determining the overlap and fit between constructionism and these goals.

[1] `http://www.mindmingle.nl`

[2] `https://www.government.nl/ministries/ministry-of-education-culture-and-science`

Chapter 2

Constructionism

This chapter briefly introduces *constructionism*, the main educational theory and central theme of this paper.

First the history and origin of constructionism will be discussed. With this historical context in mind we can delve deeper into the theory and finally look at the current state and applications of constructionism.

2.1 History and origin

Constructionism was first mentioned by Seymour Papert in the 1980's. At that time he had spent four years working directly with the swiss developmental psychologist and philosopher Jean Piaget. Before this time he was mostly researching the field of Artificial Intelligence. Most notably he wrote the book 'Perceptrons: an introduction to computational geometry' [2] together with Marvin Minsky. He is also the co-founder, together with Minsky, of the Artificial Intelligence Lab at the Massachusetts Institute of Technology (MIT)[1].

Papert, when doing research together with Piaget, became interested in the field of education. Piaget's theory, called *constructivism*, strongly influenced Papert's views on education. It is no coincidence that Papert's own theory is named after Piaget's. Edith Ackerman compares the two educational views stating that "Piaget and Papert are both constructivists in that they view children as the builders of their own cognitive tools, as well as of their external realities. For them, knowledge and the world are both constructed and constantly reconstructed through

[1] `http://web.mit.edu/`

personal experience." [3]. Later, Papert became a founding member of the MIT Media Lab to focus on researching education and constructionism.

Papert's educational research is mostly based on two things, his learning theory and the programming language *Logo* that supported his theory and research. Logo was created by Papert together with Wally Feurzeig and a handful of other researchers. It aimed to provide children with an environment to experience the constructionist approaches Papert had researched. The design of this programming language was heavily influenced by Papert's theory and used by Papert and other constructionist researchers to test and experiment with the constructionistic approach. Logo is used as a case study in many papers that Papert has written and still has an influence on the design of many educational tools today. The creation of Logo was intended to provide an environment where learners could experience mathematics in what Papert would call 'math land' [1]. However it is best remembered for it's use of turtle graphics that allowed the user to manipulate a turtle on a screen by using simple commands. The turtle was able to draw a line and this in turn allowed the user to create drawings using programming.

Papert continued developing his theory and kept publishing about new insights he gained. Using Logo as his constructionist tool, he would experiment at different schools to further define and construct his learning theory.

2.2 Theory and Ideas

In order to provide the reader with a proper understanding of the constructionist theory, an effort needs to be made to understand contructivism because of the influence it has on constructionism. After this has been made clear this thesis will look at the ideas that seperate constructionism from constructivism. However, as we will later see, by trying to define this theory we end up in a paradoxical situation where we counteract the theory as a whole. As Papert himself states"[...] it would be particularly oxymoronic to convey the idea of constructionism through a definition since, after all, constructionism boils down to demanding that everything be understood by being constructed." [4].

The theory of constructionism is often referred to as 'learning by making' [4]. However this is an oversimplification of the main theory that concern constructionism. We will see that the ideas and practices of this learning theory are more broad and multifaceted. A good starting point would be the definition by Mitchell Resnick and Yasmin Kafai, both active pioneers in the field of constructionist educational research. "[constructionism] builds on the constructivist' theories of Jean Piaget, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed by the mind of the learner. Children don't get ideas; they make ideas. Moreover, constructionism suggests that learners are particularly likely to make new ideas when they are actively engaged in making some type of external artifact, [...] which they can reflect upon and share with others" [5]. With this definition in mind we will first look at the 'constructionist' aspect that lies at the base of the 'learning by making' definition to form a foundational understanding of constructionism.

Construction of Knowledge

According to constructionism a learner acquires knowledge by construction rather than by instruction. This idea originates in the constructivist theory wherein learning is not something done to the learners, but rather something done by learners [6]. Piaget theory states that the views of learners (especially children) are extremely coherent and robust but nevertheless continually evolving. In order to abandon a current functional theory, and thus learning or accepting a new one, there needs to be a more convincing force than just exposing a learner to a better theory. Construction allows the learner to 'discover' knowledge rather than receiving it. This approach fits the Piagetian ideas of *assimilation* and *accommodation*. Assimilation of knowledge allow a learner to 'fit' a new idea into the knowledge already available and accommodation requires the learner to actually adapt their own knowledge and add the idea to their own knowledge. This observation changes the way education should handle the transfer of knowledge in three main ways [7](*in* [3]).

First, the role of the teacher is indirect (guiding) instead of direct (instructional). A learner interprets information based on their own knowledge and experience to find a good fit. Teachers should guide this fitting process and try to use the knowledge of the learner instead of trying to 'overwrite' it.

Next, the transmission model of human communication does not suffice for education. Knowledge can not be coded to and encoded from words. Instead, construction is needed to acquire knowledge. By interacting with the world, people, and things the learner is able to construct the knowledge and acquire skills and experiences.

Finally, ignoring resistances in a learner is not a good idea. As Piaget shows, children have good reasons to not immediately change their views or ideas when exposed to new knowledge. Not thinking about those reasons and trying to force a learner into learning is deemed ineffective.

This basic idea of constructivism is shared by Papert and Piaget, however Papert's constructionism differentiates in the fact that it has a greater focus towards learning through making. Expressing ideas by making them tangible allows for an intimate connection between learner and subject. Furthermore, the shareability of these products allows for discussions and communication with other learners which in turn sharpens these ideas. To further explain the ideas that differentiate constructionism from other learning theories (such as constructivism), we will look at four aspects that are essential to a constructionist learning environment. These four aspects are designing, personalizing, sharing, and reflection [6].

Designing

Designing is arguably the most important aspect of the theory and probably why constructionism is often simplified to learning by making. By trying to design and create, the learner gets forced into the process of iterative thinking, problem-solving and critical creativity. All of which can serve as a foundation for learning [8]. The usage of the computer is a choice and not a necessity to enable designing, however the medium itself provides a wide range of contexts that enable constructionist learning and designing activities [8]. Adding to the idea of knowledge construction from the constructivist theory, Papert states that this style of learning becomes even more powerful when the learning is *situated*. This means knowledge should not be detached from the situations wherein it is constructed and actually applied, whether it is a sandcastle on the beach or a theory of the universe [4]. By making knowledge and learning situated, it removes the abstract and distant parts of knowledge and allows for a close and concrete interaction with these concepts. This is most obviously seen in the usage of Logo for mathematics. Children could work with mathematics in a context that makes sense to the child. By manipulating a Logo turtle on screen using mathematics instead of doing small abstract assignments allow the learner to experience the usage of mathematics.

Personalizing

Personalizing is the second core concept of constructionism. In contrast to the established educational methods wherein large class sizes and homogeneous curriculums are common, constructionism focuses on the individual learner by considering engagement on different levels of cognitive skill [6]. This form of personalized learning takes in account personal learning styles and differences between learners. Learning is done by (and not to) the learner, thus it is a personal experience that should be guided and encouraged. The next big advantage of personalization is that it motivates learners, especially young ones, to learn. This is most apparently seen in the stories Papert cites in his publications. Most of these stories describe children actually wanting to continue on projects that they created themselves. This self-incentive provides powerful learning moments to learners. Papert, after watching children working on soap sculptures during art lessons, noted that the continuity of such a sculpture was very different from the way mathematics was teached to children. Instead of doing small assignments and solving little problems on the fly, the students spend multiple weeks on their sculptures. This form of working allowed for time to think, to dream, to gaze and to try new ideas, very unlike a math class [4]. From this insight, the idea of 'soap-sculpture math' took a center spot in his research and he started to develop ideas and workflows to enable this form of personalized education in math classes. See one of the many papers that Papert produced for examples of his achievements in this subject[2].

Sharing

The next aspect that characterises constructionist learning environments is that of sharing. As we stated before, personalization is a big part of constructionism but learning is also a social process wherein multiple learners (communities) support each other. Different forms of support can be gained from this sharing process such as collaboration, sharing of discoveries and the possibility to discover new ways of thinking. Teachers might collaborate with students to progress their projects and discover new ways to solve problems. Students can collaborate with other students by showing their work, or discussing new ideas and possibilities. Learning from those with greater experience and expertise enables learners to take on greater challenges and further develop themselves and their personal style.

[2] `http://www.papert.org/works.html`

Next to the direct influence of sharing on learning, there is also a social nature that serves as an essential motivation and support for young people to understand each other's practices and norms. From technical to emotional support, the social nature of learning can benefit learners as much as teachers [9](*in* [6]) .

Reflecting

When studying papers written by constructionist researchers a big subject is 'thinking about thinking'. The titles of Seymour Papert's papers 'You Can't Think About Thinking Without Thinking About Thinking About Something' and 'Teaching Children Thinking' clearly shows the importance of reflection about a learner's own thought process. Sometimes referred to as *metacognition*, this part of constructionism tries to enable a learner to learn better by learning to learn.

"It is usually considered good practice to give people instruction in their occupational activities. Now, the occupational activities of children are learning, thinking, playing and the like. Yet, we tell them nothing about those things. Instead, we tell them about numbers, grammar, and the French revolution; somehow hoping that from this disorder the really important things will emerge all by themselves" [1]

This focus on learning to think is mostly seen in the design of the Logo programming language. Papert suggested that the academic field of computer science is not properly named as most of it's science is not the science of computers, but the science of descriptions and descriptive languages [1]. Where the field of educational research had not worked on developing formalisms to empower thinking, the field of computer science had developed many of these descriptive languages. Papert drew inspiration from them and (together with other researchers) developed the Logo programming language. This language is still used by many (including myself) constructionist educators today. It's design is elegant in a way that it encourages metacognition and serves as a tool for children (or older learners) to think with. Doing an assignment in Logo will force learners to ask certain questions about their own creativity and thinking. Questions such as 'What do I want to create? What do I need to create it?' arise quickly and force the metacognitive process in the learner [6] .

With these four aspects the reader should now have a fairly complete overview of the constructionist theory. Although we did not evade the paradoxical space that we are forced to enter when trying to define constructionism, the reader now has a proper overview of the main ideas that constructionism conveys.

2.3 Current state

While most publications about constructionism date from before 2000, constructionism is still actively researched by educators and academics. The next overview names the trends and development of modern constructionism.

A prominent agent in the field of constructionist research is the *MIT Media Lab's Lifelong Kindergarten research group*[3]. Seymour Papert is one of the founding members of this research group. It develops and researches education on a constructionist level through publications and the development of new technologies to engage people [10]. The research group's main focus lies on physical applications that enable learning "Our research with digital manipulatives follows this tradition. But rather than creating new virtual objects (like the screen-based Logo turtle), we are embedding computation in traditional children's toys (like blocks, balls, and beads), which children can manipulate directly with their hands." [11]. This research has led to the creation of multiple tools and projects that support constructionist education. Alumni of this learning group often continue to focus their research on constructionist applications and learning. Karen Brennan, indeed an alumnus of the Lifelong Kindergarten, puts focus on the support and guidance of teachers in providing constructionist education. Her research places focus on the usage and understanding of learning communities in a constructionist fashion [6].

Next to this research on constructionism and its applications there are several trends in education that are either inspired by or based upon constructionism. One of these trends is the notion of *21st Century Skills*. A series of skills, abilities and definitions that focus on education in the 21st century. A different but related trend is found in design thinking for education[4]. Design thinking puts focus on the process that accompanies design tasks and how learners can increase their abilities to accomplish these design tasks. Maker education[5] is a new trend that puts focus on the creation of physical products and the educational value of those projects. This type of education identifies with the design aspect of constructionism [12].

[3] `https://llk.media.mit.edu/`
[4] `http://www.designthinkingforeducators.com/`
[5] `http://makered.org/`

We complete the overview of the constructionist landscape by describing the tools that are used by or based on constructionism in the next part of this thesis.

2.4 Tools

To gain further insight in constructionism we take a look at the tools used by constructionist educators. The theory originates from 1980 and there exists a broad range of tools and applications that support constructionist learning.

When constructionism was being developed, the idea of personal computers in education was nothing more than fiction. This has obviously changed, now most (if not every) primary- and highschools have access to computers. The ratio between students and computers also changed for the better, with some schools employing a ‘bring your own device’ strategy and others supplying their students with devices. Computing is available to everyone, projects like Arduino[6] (a complete microcontroller and sensor ecosystem) and the Raspberry Pi[7] 35,- computer) make it possible for everyone to experiment with computation and programming. These products all focus on education and the use of computer science. There is a clear connection between these developments and constructionism in that these tools provide learners with an extensible environment with a focus on creation and designing.

Beside this democratization of computations and the required tools, there are also projects that build upon the constructionist theory in order to enrich and improve education. The most prominent among these tools is the Scratch programming language[8]. Launched in 2007 in combination with an online platform, Scratch provides a learning platform for millions of users, as of March around 11 million subscribers, where they can program, share and collaborate their interactive stories, games and animations using a block based programming environment. This platform was created by the MIT Media Lab’s Lifelong Kindergarten research group. Mitchel Resnick, head of the Lifelong Kindergarten, states the influence of Logo on Scratch very clearly “Learning lessons from Papert’s experiences of Logo, we’ve designed Scratch to move beyond Logo along three dimensions, making programming more tinkerable, more meaningful, and more social.” [13].

[6] http://www.arduino.cc/
[7] https://www.raspberrypi.org/
[8] `https://scratch.mit.edu/`

As constructionism evolved, so did Logo. Different researchers and companies took the Logo programming language and attempted to improve it. This has led to an ecosystem of Logo environments of which some are still actively maintained to this day. Languages like StarLogo and NetLogo offer Logo in a multi-agent fashion wherein it is possible to program a swarm of turtles instead of the classical single turtle Logo. Other versions of Logo focus on physical computing where learners are able to manipulate motors and read sensors to connect their projects with the real world. The Logo foundation[9] provides a complete overview and support for most of the modern Logo environments available.

Based on the idea of a floor turtle, a robot that would accept Logo commands in order to make it draw on real paper, the Lifelong Kindergarten teamed up with the LEGO company to create LEGO/Logo. This collaboration eventually led to the LEGO Mindstorms kits. These kits provide the parts to build physical projects based on the modularity and simplicity of LEGO that can be controlled using a Logo like language. These kits are used in the 'First LEGO League'[10], an international competition for primary schools where children get challenged to solve puzzles using their own custom robots.

Of course this is not an exhaustive list of all the tools that constructionism uses. Nevertheless, it serves as a good starting point in order to understand the influence that the theory has on education. All tools listed are based on creation and discovery and support learning in a constructionist manner. The next chapter describes the 'Ons onderwijs 2032' project and the goals that it defines. These goals are then used to help answer our question by making a comparison with constructionism.

[9]http://el.media.mit.edu/logo-foundation/
[10]http://www.firstlegoleague.org/

Chapter 3

The ‘Ons onderwijs 2032’ goals

In order to answer our question this chapter finds a feasible definition of future education along with its goals and problems. By defining these goals the comparison with constructionism can be made in order to answer our main question. The course of education is often defined by government policies and through funding (often times also provided by governments). The Dutch Ministry of Education, Culture and Science attempts to guide and steer the path that education should take by creating a project that allows for public discussion between all parties involved in determining the future of education.

3.1 The ‘Ons Onderwijs 2032’ project

On 12 November 2014 the Dutch Ministry of Education, Culture and Science started a project called ‘Ons Onderwijs 2032’ (in English: Our Education 2032). The aim of the project was to initiate public debate concerning the future of education. This project was separated into different stages, each phase further defining the vision and ideas that the project wanted to achieve. On the 23th of january 2016 the final advice [14] was presented to the public and the Ministry of Education, Culture and Science. This unique way of setting up a debate allowed many educational experts, educators and other involved parties to participate in forming a new vision for education in The Netherlands.

The plan that resulted from the project includes advice and ideas about the path education in The Netherlands should take to stay relevant in the future and make for a solid foundation. Regarding the form and method used to achieve this plan, it can be considered as a plan generally accepted by society to keep education ‘future-proof’ since it originates from a public debate.

This thesis will take this plan and try to determine whether constructionism is a good fit to achieve these goals. The plan includes a set of general properties that future education should have as well as an overview of the new visions for different subjects that are part of the *core-curriculum* in Dutch education. In order to limit the scope of our subject, this thesis will only take a look at the general goals established in the plan.

These goals are of course subject to personal interpretation and ambiguity, therefore we will now take a look at each individual goal and define what interpretation this thesis will use when comparing them with the constructionist theory.

3.2 Overview of the Goals

The final advice produced by the 'ons Onderwijs 2032' plan includes five general goals that a future educational system should achieve. We will take a look at these goals and try to further define them using the document that makes up the final advice [14] as a guide.

First, let's introduce the list of goals*(Translated from [14])*.

(I) The learner develops knowledge and skills by utilizing creativity and curiosity.

(II) The learner develops his personality.

(III) The learner learns to handle his freedom and responsibility and looking across borders.

(IV) The learner learns to utilize the changes of the digital world.

(V) The learner receives meaningful education made to fit.

These goals all focus on the chances and needs of students and can be considered as general goals for the future of education. They were distilled from the public debate, scientific research, inspiration from other countries and external factors that were part of the 'Ons onderwijs 2032' project.

The first goal (I) focuses on creativity and curiosity, and the chance for a learner to develop her/himself. By stimulating curiosity, the student learns to ask and answer critical questions. Creativity plays a role in making a learner leave their 'comfort zone' and encourages the designing and creation of new products and ideas. The ability to adapt to new changes and developments allows learners to keep developing their knowledge and be able to discover new theories and ideas. Being able to use knowledge from different domains of knowledge will also contribute to this goal.

Goal number two (II) encourages learners to develop and define themselves in relationship to others. A main focus point lies on removing the fears that accompany collaboration. Fear to be proud, taking responsibility and making decisions should not hold the learner back. Acknowledgement of the learner's position and needs aswell of those of others, help to improve collaboration. The goal also emphasizes the broadening of horizons and coming into contact with new ideas from other peers.

The next goal (III) has a social focus and prepares learners for the rapid changes in a modern world. According to this goal, a learner should be able to handle feedback and critique. Education should also provide the learner with knowledge on their rights and those of others, social problems (how to approach them) and cultural diversity. Being able to judge their own actions will help the learner to become a responsible person, while an international orientation will help to look across borders.

As the fourth goal (IV) emphasizes, the use of technology and the digital world, programming and computational thinking is part of future education. *Computational thinking* enables a learner to apply logical reasoning and the processing of information. Motivated by the quickly changing playing field of technology in personal and professional life, a learner should be able to cope with the increasing amount of information available through technology.

The final goal (V) can be seen as two connected parts. The first one states that education should be catered to students. This implies the need for a personalized curriculum that considers the student's individual skills and restrictions. In turn, this requires a variating offer of subjects to the student and the ability to develop oneself towards their own interests and learning strategy. The goals clearly state that it does not intend to allow students to only do 'fun' subjects, every student should have a solid base of knowledge and skills that allows him or her to participate in higher education and (eventually) society. The second part states that 'Students want to know why they learn what they learn' and that students are motivated by learning about things that they deem interesting. According to the research that was done during the preparation for 'Ons onderwijs 2032', students want to learn in a 'real world environment' and think that there should be a better connection between education and the real world.

This concludes our overview of the goals that are encapsulated in the 'Ons onderwijs 2032' final advice. Keep in mind that these goals can vary in interpretation per reader since they are not precisely defined. The complete advice can be found on the 'Ons onderwijs 2032' website[1].

With this definition of the general goals we will now continue this thesis by trying to answer its main question "Does the constructionist learning theory provide the means to reach the goals of future education?".

[1] `http://onsonderwijs2032.nl/`(dutch)

Chapter 4

Analysis

Now we determine the overlap and thus the fit between constructionism and the goals that are defined in the 'Ons onderwijs 2032' final advice. For every goal an analysis is made by looking at the aspects of constructionism that comply with the defined goals.

To begin, let us focus on the creativity and curiosity aspects of the first goal (I). We can find good support for this type of learning in the first aspect of constructionism, which is designing. This part of the learning theory serves as a foundation and a mean to reach this goal. At one end, constructionism gives way to a large number of creativity based learning problems. Learners are enabled to participate in soap-sculpture mathematics which allows them to define and create their own projects (within a given context). But also in solving smaller sub-problems the learners are able to apply their creativity. One aspect of these assignments is that they can organically grow with the learner's curiosity.

I have seen this during my own classes, students of whom their teacher was convinced to have no interest in 'creative' work would surprise that same teacher by coming up with creative and meaningful projects. The medium might have been different but the process we observed during these assignments closely resembled that of the 'creative' lessons in which these students did not seem to excel. After learning about Scratch and given the freedom to come up with their own project, they not only showed immense creative capabilities but also showed that they were able to grow with their project by further expanding its capabilities towards their own curiosity and interests. These students would become 'domain-experts' of their project's subject. Their creativity might not have been triggered during traditional art classes, because they did not identify with the tools and subjects that were offered. When exposed to an universal programming tool (like Scratch in this case) and given the freedom to define their own assignment within a given domain, their minds were able to use their creativity in order to solve problems. This form of creativity reminded me of the creativity that mathematicians show when they solve a complicated formula or proof, not visual on paper, but rather in a mental form that shows creative problem solving skills and high level abstractions. Observations like these are found throughout various papers written by Constructionist researchers.

Most constructionist assignments and projects produce end-products. Something that learners are able to show and share. This motivates students to think about the creative value of their work. Some students value the aesthetic part of their projects higher than their technical complexity. The combination of students that focus on the visual part and students that have a more technical focus allows for an exchange between different forms of creativity. Students working together in this fashion support each other in order to create technical as well as aesthetically pleasing projects. They often express that in order to complete a project they need to participate with each other and allow different ways of thinking and approaching problems. We conclude this analysis of the first goal by noting that constructionism provides the means that enable learners to employ creativity and curiosity. Constructionist learning tasks are essentially creative processes wherein different forms of creativity and curiosity are required to achieve successful projects.

Considering the second goal (II) about the development of personality and participation, we find a direct link between this goal and the different aspects of constructionism. A central theme in constructionism is sharing and collaboration and these concepts are supported by the learning theory. Learners participate on projects and need to work with each other in order to complete these projects and their sub goals. To receive a constructionist form of education also means that learners are stimulated to share and collaborate with their peers. This model of working allows students to identify aspects of their work that are perceived different by their peers. The aspect of reflecting tries to force students to learn and reason about their own thinking which allows them to define roles and responsibilities in a collaborative setting. Being able to clearly define problems, explain solutions and identify important challenges the learners need to overcome will help them to participate and know on which parts of a project their skills and abilities can be useful. The goals also matches with the notion of 'learning-styles'. The notion of learning styles is mentioned in the final report of the Brookline Logo Project [15]. The researchers noticed that different students developed different styles in approaching Logo projects. Some would prefer a top-down approach by starting from a concrete plan, while other students showed a bottom-up approach by organically growing their project towards the requirements of the projects. No doubt there will be more diverse types of these styles in a student's approach to a certain project. Constructionism facilitates these different styles trough it's personalizing aspect. The discovery of these styles even served as a starting point for Papert's research in constructionism [4]. Making students aware of their own personal style will support students in their learning process. The second goal thus finds a good fit with the constructionist theory. Through sharing, reflection and introspection of learning style, a student is enabled to better define its own personality.

The focus of the third goal (III) can be linked to the sharing and reflecting aspects of our learning theory. Being able to reason about one's own way of thinking and learning strategy allows for a better understanding of feedback a learner may receive from its peers. Combined with the focus on collaboration, the metacognitive skills that develop in a constructionist learner allows for a more conscious image of oneself in relation to other, especially considering knowledge and skills. Students aware of their own limitations and abilities will also acknowledge those of others. This effect leads to an improved form of collaboration with respect to other student's skills and capabilities. A great example of this can be found in an interview with Seymour Papert where he answers the question "What do you think of cooperative learning?". He responds by saying "I think it's very bad when students are forced to work in groups. But, when the collaboration comes around naturally, some of the best things happen. For example, there was one class that I was involved with that had a student who worked hard to be the very best at everything [particularly math]. As it turns out, when the class received computers, he wasn't the best anymore. This led him to get together with another student who wasn't as good in math, but was very good in music. By getting together, what rubbed off in the long run was that they both got a much deeper sense of communication. This was a good example of a collaborative experience in which two kids did something that neither of them could do alone. This was different from making six kids work together who have nothing in common." [16]. While the international focus of this goal finds no direct support from the constructionist theory, the practical environments such as Scratch that make use of the global and international character of the world wide web allows learners to come into contact and interact with their international peers. This international interaction is described and actively supported by the Scratch maintainers [17]. Although a more social focussed goal, the constructionist framework serves as a solid foundation for learners to learn about the freedom and responsibilities concerned with participating in communities. Both offline and online collaboration can be used in a constructionist sense in order to achieve this goal.

The use of technology and interactions with the digital world defined in goal number four is the goal (IV) that is best fulfilled by constructionist education. As its medium of choice is the computer and programming languages and its origin lies in computer science there is a high degree of overlap with the goal. Not only does the theory provide a way of teaching and learning with computers, it also allows for the computer to become a part of all subjects and courses that a learner might come into contact with. Be it a language course or a mathematical course, constructionism motivates the use of computers to create projects and learn from these projects. Because of the heavy focus on creating and designing, constructionism is able to make computational thinking a part of the mental toolkit of the learner. This form of thinking becomes something that can be re-applied to every challenge or project the learner might work on. Eventually, the learner acquires the skills that programming needs. Teachers are then able to design programming projects without taking the learning curve of programming in consideration. Much in the same way that mathematics play a supporting role in most science subjects that are tought in high schools. This approach of education turns the computer in a tool for learning that can be used troughout the curriculum. By integrating computer science into different subjects throughout the educational career of learners it will allow them to grow their understanding of the computer and its capabilities.

This chance can cause a shift, especially in the way young learners use and experience computers, changing them from consumers to producers. Often the term 'digital natives' is used to describe the new generation of children whose life is technological centered [18]. However, this term does not focus on the difference between consuming technology and being a producer of technology. In particular, creative activities such as designing and making with digital technologies are relatively uncommon in the practices of young people [6]. A constructionist style of education allows for a more producing style, forming a technological consciousness about the uses and implication of technology. To sum up, there is a strong support from constructionist education that allows for the use of computers in a meaningful way that is both active and multi-disciplinary. By providing students with this powerful medium in a constructionist way, the relation between child and computer shifts from a consumer to a producer perspective.

Meaningful education made to fit is the main subject of the final goal (V). Looking at personalization and situated learning we find that the constructionist theory shares the focus on these ideas. Allowing learners to engage on their own cognitive level and skill with projects they care about seems to be a central idea that constructionists care about. Papert noticed this powerful form of knowledge, that is personalized and situated, and used it as the foundation for his learning theory. The goal mentions that learners express the need for personalization and relevance in the things they learn and the way they are teached. Papert notes that an educator must be an anthropologist. He or she should understand which trends are taking place in culture and meaningful education should be based on these trends [1]. A central theme can also be found in the gab between study and subject. For example, physics and math curricula tend to focus on theory rather than application. Learners are forced into studying theory while the interesting part, the application of a given theory, is often lost. By detaching theory from practice most students do not find motivation to learn [1]. By allowing learners to create meaningful projects this detachment is removed and a new *learning path* is offered. According to Papert, the idea of prerequisites blocks most interest: a learner that wants to study the exciting applications of aerodynamics is first confronted with a mathematical learning path that does not offer any practical value (yet). This learner with a steep learning curve that tries to seperate theory from practice. By integrating these prerequisites into practical assignments, the learning path becomes active and connected. In this new learning path the learner is able to start constructing knowledge and learn theory in a practical fashion. The constructivist roots of constructionism act as a solution to this goal. The situated and practical approach offers a framework to create meaningful and relevant education.

For every goal defined we are able to find support in the constructionist theory. One might argue we have found the answer to our question and could state that constructionism is indeed a solution to reach the goals for future education. However, to finalize our verdict we have to take a look at the parts of constructionism that researchers have found to be problematic in the next part of this thesis.

Chapter 5

Comments on constructionism

We have studied constructionism and its relation to the future of education. However, the theory has been around since 1980 and contains a vision of education that was both revolutionary and innovative, but most schools still do not employ this theory to improve their education. Also, the term constructivism is familiar to most educators but constructionism is not [6]. Taking a look at the parts of constructionism that are deemed problematic by researchers and educators provides an explanation.

At the official Logo conference of 1986, Brian Harvey ended his keynote asking the question “Whatever happened to the revolution?”. He aimed this question at the Logo community and wondered why the big changes that Logo (and constructionism) promised were not being achieved. Schools did not embrace the constructionist philosophy and Logo was not used in many of them. Mitchel Resnick expresses the same concern by stating that a part of Papert’s vision has become reality. Computers have become accessible for everyone, including children. However Papert’s dream, in which children not only use these technologies but become truly fluent with them and in this process learn the important problem-solving skills and project-design strategies, has not been achieved [13]. When computers became accessible for schools in the early 1980’s there was a big interest. However, the implementation was not succesfull and schools stopped trying to employ Logo. “Thousands of schools taught millions of students to write programs in Papert’s Logo programming language. But the initial enthusiasm didn’t last. Many teachers and students had difficulty learning to program in Logo, since the language was full of non-intuitive syntax and punctuation. To make matters worse, Logo was often introduced through activities that did not sustain the interest of either teachers or students. Many classrooms taught Logo as an end unto itself, rather than as a new means for students to express themselves and explore what Papert called powerful ideas. Before long, most schools shifted to other uses of computers. They began to see computers as tools for delivering and accessing information, not for designing and creating as Papert had imagined. Today, most educators view computer programming as a narrow, technical activity, appropriate for only a small segment of the population." [13]

According to Resnick Logo failed to become a part of education because of an improper usage. This problem can be directly related to the idea of technocentrism mentioned by Seymour Papert around 1980. He used this term to describe the observation that conversations about technology and learning too often begin and end with the technology itself [6]. This phenomena causes technology to become the center of attention instead of education itself. Constructionistic education employs technology as a mean to educate, it plays a facilitating role in the learning process but is not the main goal of education. This means that education should adapt to technology and learn how to employ it instead of adapting technology to the current state of education. Papert himself clearly states this misinterpretation of his theory by describing experiments where students get exposed to 30 hours of logo. Before and after this exposure the students were tested on their problem-solving ability. He then talks about papers that were written on "'the effects of programming (or of Logo or of the computer)' as if we were talking about the effects of a medical treatments" [19]. He also mentions that "It did not occur to me that anyone could possibly take my statement to mean that learning to program would in itself have consequences for how children learn and think." [19]. Both these observations indicate that schools attempted to integrate technology in their education by focussing on the technology instead of thinking about how they could improve their education by using the technology. Schools did not change their own educational views but attempted to adapt the technology to their existing system. This collection of problems with the introduction of a new form of education has made the adaptation of constructionism problematic and difficult.

Besides this difficulty regarding the introduction of the theory there are more concerns and problems regarding constructionist education. Most of these concern the role of the teacher and the validation of knowledge. Allowing students to choose their own projects and relying on the knowledge that is acquired this way the role of the teacher becomes less defined. Compared to curriculum based education the teacher has to change from a knowledge supplier to an educational facilitator. Guiding students through knowledge discovery instead of providing them with knowledge is a big change. For many teachers this chance is problematic because they might lack the knowledge that is needed. Karen Brennan acknowledges this problem and states that "A description of constructionism, no matter how detailed, is insufficient for teachers to translate the theory of constructionism as educational philosophy to the practice of constructionism in designing learning experiences." [6]. Brennan researches and supports teachers in their attempts to provide constructionist education. Her research also led to the creation of a new online platform named ScratchEd[1] where teachers can join a community of educators and find support that helps them to realize meaningful constructionist education.

There also exists the problem of validating the knowledge that learners acquire. The classical curriculum driven educational approach relies on milestones of knowledge with a clear path defined on what should be teached when, this creates a strong contrast to constructionism that relies on learners aquiring knowledge based on their personal interests. Again, Brennan offers research on the subject. Brennan refers to this problem as the tension between direction and instruction and the ScratchEd platform tries to facilitate teachers in tackling this problem. By providing proper direction and 'steering' learners teachers are able to partly overcome this problem. Papert himself believed that a curriculum-based instruction counteracted the effect of learning, as he states "What is worst about school curriculum is the fragmentation of knowledge into little pieces. This is supposed to make learning easy, but often ends up depriving knowledge of personal meaning and making it boring." [20]. Providing constructionist education requires the acceptation of the fact that learning will be discovery based and thus that a degree of control is lost. From my own teaching experiences I accepted this loss and found it rather interesting. And I saw that the children enjoyed the gathering of knowledge that they needed for their projects. They associated learning with 'fun' and asked which directions they could expand their knowledge. Schooling and teacher support such as ScratchED are tools that do not only improve and guide teachers towards constructionist education, but are also required in order to achieve change and counteract the tendency of education to adapt those changes to existing systems.

The problems we discussed need to be overcome before starting the implementation of constructionist ideas in education. Some of the solution may be found in teacher education, guidance and most important by public debate like the one we see in the 'Ons onderwijs 2032' approach. We have now seen that constructionism is not without shortcomings and that there are multiple causes that

[1] `http://scratched.gse.harvard.edu/`

delayed its widespread acceptance in education. Next this thesis looks back at the material we covered to answer our main question.

Chapter 6

Conclusion

By looking at the history, theory, application and shortcomings of the constructionist theory we can answer our question 'Does the constructionist learning theory provide the means to reach the goals of future education?'. The theory itself provides a framework as well as the theoretical foundation for a different type of education. The goals defined by 'Ons onderwijs 2032' can be seen as the goals that the future of education should achieve. Learning by making, designing, reflecting, sharing and personalizing facilitate these goals and thus constructionism can serve as a basis on which we define the future of education. Most aspects of the goals are integrated in the learning philosopy of constructionism. It provides tools, information and guidance that help to set up a new form of education.

As an educational theory, constructionism has shortcomings that need to be overcome. In order to not fall into the same trap that constructionist educators experienced, this reform should be well informed and put focus on the correct aspects that define education, thinking about goals first and tools afterwards. Solutions include teaching and guiding of teachers in order to help them overcome this problem. Most constructionist research dates from a time when technology was more limited. This implies the need for further research into the new possibilities that can extend and update the theory according to new findings in education.

By approaching artifical intelligence as a cognitive science it is favorable to research education. As both fields attempt to understand different learning mechanisms. Both can apply the knowledge gathered from this research in their own methods and solutions. This collaboration enables education to improve their educational foundation and allows artifical intelligence to improve the learning strategies it employs.

As an educator myself, I am convinced that constructionism is an inspiring form of education to teach and apparently to be teached. If education aims to reach the point where learning becomes fun, meaningfull and relevant, constructionism offers a way.

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