Innovative approaches to in-service training:
A training course for technical workers in the Netherlands

Onno van den Hoed
S4121643
25-06-2024
MSc. Science Education and Communication, C-Track
Supervisors: L. Avraamidou & F.J. Castillo Hernandez

Index

Index 1
Summary 3
Introduction 4
Framework 6
1. Social constructivism 6
1.1 Steps of Social Constructivist Learning 6
1.1.1 Exploratory activities 6
1.1.2 Concept/procedure introduction activities 7
1.1.3 Knowledge structuring activities 7
1.1.4 Application activities 7
2. Project-based learning 7
2.1 Steps of Project-Based Learning 8
2.1.1 Formulate a driving question or problem to be solved 9
2.1.2 Identify facts and formulate hypotheses 9
2.1.3 Identify gaps in current knowledge 10
2.1.4 Engage in self-directed learning as well as skills training 10
2.1.5 Apply newly obtained knowledge/skills to the problem 10
2.1.6 Evaluate 10
2.1.7 Reflect 11
2.2 Teachers' role in the project-based learning process 11
3. Skills training 11
3.1 Microlearning 11
3.2 VR in microlearning 12
4. Artificial intelligence for education 12
Methodology 13
5 Design-based research 13
5.1 Preliminary research 14
5.2 Development phase 14
5.2.1 Prototyping 15
5.3 Evaluation phase 16
Results 16
6.1 Answers ten questions 16
6.1.1 Rationale: Why are they learning? 16
6.1.2 Aims & Objectives: Towards which goals are they learning? 16
6.1.3 Content: What are they learning? 16
6.1.4 Learning Activities: How are they learning? 17
6.1.5 Teacher Role: How is the teacher facilitating their learning? 18
6.1.6 Materials & Resources: With what are they learning? 18
6.1.7 Grouping: With whom are they learning? 18

6.1.8 Location: Where are they learning? 19
6.1.9 Time: When are they learning? 19
6.1.10 Assessment: How is their learning assessed? 19
6.2 First Prototype 19
6.3 Focus Group 30
6.3.1 Analysis 30
6.4 Final Prototype 34
Conclusions 48
References 50
Appendix A Focus group template 53
Appendix B Focus group results 72
Answers to questions 72
Open discussion 74

Summary

At present and in the coming years, the job market in the Netherlands is and will keep being plagued by a shortage in technical personnel, because of both less people taking jobs in the technical sector and technical personnel getting older. Current in-service training is often analogue, not-personalized, passive for students and theoretical. Here, we create a new in-service training course to improve on the current training courses available. The new training course is based on a social constructivist framework, using project-based learning and microlearning to facilitate learning. A design-based research approach was used in designing the in-service training course and it was assessed through a focus group with educational experts.

Introduction

At present and in the coming years, the job market in the Netherlands is and will keep being plagued by a shortage in technical personnel (Heyma et al., 2022). Before delving into the details of this shortage such as possible causes and solutions, it is important to define exactly what is defined as technical personnel. According to the National Technology pact 2020, technical personnel are: People who use one or more technologies practically or in reality. They work, for example, as IT professional, researcher, instrument makers, industrial designer, planner, plumber, engineer, operator or analyst. They possess the knowledge necessary to build certain devices and to perform maintenance on installations. They keep technological systems working and develop and implement new technologies. They can combine disciplines (beta-beta and beta-gamma) and translate knowledge and technology into useful innovations for various societal areas, from healthcare and food to sustainability, energy and IT (Rijksoverheid, 2020).

In recent years, the amount of available jobs in the technical sector in the Netherlands has increased substantially, especially in the IT and energy sectors. In fact, the IT sector has grown 60% since 2010. The amount of available jobs in the construction industry and industry has also been increasing since 2016 and these two sectors together are responsible for about 80% of all the jobs in the technical sector. The amount of job vacancies in the technical sector has more than doubled between 2010 and 2021. From 20 to 50 job vacancies per 1000 jobs. The shortage in technical personnel is especially big in IT (80 vacancies per 1000 jobs), the construction industry (73 vacancies per 1000 jobs) and the energy sector (55 vacancies per 1000 jobs). Especially technical jobs that require MBO (secondary vocational education) education have a lot of open vacancies, these jobs include tasks such as operating machines and electrical devices, operating vehicles, or maintaining and repairing electrical and mechanical devices. Jobs that require less or more education have less vacancies, that is not to say there are no shortages in those jobs, but the biggest shortage exists in MBO jobs (Heyma et al., 2022).

Not only that, but personnel in technical sectors have also been increasingly getting older. The number of technical workers over 55 years old has increased from 16 to 23 percent between 2010 and 2021. This will not only lead to an increase in the shortage of technical personnel, it also has an impact on the education/training of technical personnel. There is already a shortage of teachers that will likely only get bigger as current technical personnel get older and closer to retirement age (Heyma et al., 2022).

That means that we not only need to find ways to recruit new technical personnel to fill the jobs in the technical sector that are currently not being filled. But also have to find ways to effectively educate/train technical workers that are already in the technical field (Heyma et al., 2022). This is called in-service training and could be a potential solution to the shortage of technical personnel if used effectively. However, current material for in-service training has several problems.

A lot of the material used for in-service training is analogue as opposed to digital. In engineering and construction fields, graphical representation is extremely important. Without it, a project can only be visualized mentally, which is not always accurate. It is not entirely impossible to have analogue graphical representation but it has some hard limits compared to digital graphical representation, in which one can make full use of 3d to allow for easy studying of digital objects. De Carvalho et al. (2021) looked into the preferences of students on analogue vs digital teaching material. Students always preferred digital material over analogue material but the preference for digital over analogue was a lot bigger when it concerned practical approaches compared to theoretical approaches.

Furthermore, the material does not seem to be directed towards individual learning needs. Learning in a classroom is as of yet still the dominant form of education in these in-service training classes. This also means that there is no optimal connection between the general education material and individual learning needs. The individual competences of people participating in in-service training are already very different and it’s likely that this is only going to increase, when more people with a limited technical background come into the technical field. Given these large differences in individual competences it is especially important to have education focused on individual learning needs, to avoid classes being impossible to understand for one student while simultaneously being far too easy for another student. Analogue as opposed to digital material also plays a role again here. It is far easier to personalize digital teaching material compared to analogue teaching material, especially when you make use of artificial intelligence tools (Tapalova & Zhiyenbayeva, 2022).

Furthermore, as mentioned, learning in a classroom setting is the dominant form of education in these trainings. This also leads to teachers being the only active participant in the learning process, students are allowed to simply receive information and be passive (Cakmakci et al., 2020).

As of yet, the in-service training classes in MBO-institutions are often very theoretical which leaves students without the practical, company-specific knowledge that is asked for in the job market. This leads to the company having to provide in-service training on top of the training from the MBO-institutions. On top of that, a lot of these training classes are simply not flexible enough to really connect to real world situations, which also has to do with the lack of practical material (Heyma et al., 2022).

All-in-all it is clear that there is a need for improvement in these in-service training classes to promote more personalized and cooperative learning. To this end, we aim to design a training course for in-service training of technical workers. To achieve this, we answer the following question: What are the characteristics of an effective teaching and learning strategy aimed at providing in-service training to technical workers already employed in the technical field at MBO level in the Netherlands?

Framework

1. Social constructivism

Considering the presented problem, the field of didactics enlightens us on the crucial facets for effective learning, fundamental in enhancing training processes. The theoretical framework upon which this study is based is social constructivism. In social constructivism, the learner's construction of knowledge is the product of social interaction, interpretation and understanding (Vygotsky, 1962). It views learning as a social process. It does not only take place within an individual, nor is it a passive development of behaviors that are shaped by external forces (McMahon, 1997). Meaningful learning occurs when individuals are engaged in social activities like interaction and collaboration. Knowledge is formed first on an inter-psychological level before becoming internalized and existing intra-psychologically (Adams, 2006).

Both the teaching and learning situations in this approach are fundamentally different from those in conventional approaches such as lectures and presentations. In these conventional approaches, it is up to the teacher to provide information to the students, allowing the students to be passive throughout the process (Cakmakci et al., 2020). However, in social constructivism both teacher and students are active participants in the learning process, students learn by discussing among themselves and with the teacher in relation to a certain content, which is the object of study (Jorba & Sanmartí Puig, 1994). The focus in this approach is on learning itself, rather than performance through tests, and teacher and students form a relationship based on guidance rather than strictly on instruction (Adams, 2006).

1.1 Steps of Social Constructivist Learning

Within the social constructivist framework, Jorba & Sanmartí Puig (1994) suggest four specific types of activities to achieve effective learning. These are:

- Exploratory or initial explicitation activities.
- Concept/procedure introduction or modeling activities.
- Knowledge structuring activities.
- Application activities.

1.1.1 Exploratory activities

In exploratory activities, students identify the problem posed and formulate their own point of view. These activities serve to determine the starting point of each student and allow a teacher to evaluate what should make it possible for the students to evolve their learning. Students themselves should, through these activities, discover that they don't all share the same point of view (Jorba & Sanmartí Puig, 1994). The current beliefs of students, whether correct or incorrect, are important (Rannikmäe et al., 2020).

1.1.2 Concept/procedure introduction activities

Concept/procedure introduction activities are meant to help students identify new points of view in relation to the topic/problem being studied, ways of solving the problem posed, characteristics that allow the student to define the concepts and relationships between previous and new knowledge (Jorba & Sanmartí Puig, 1994).

1.1.3 Knowledge structuring activities

Knowledge structuring activities are intended to allow students to formulate their own way of expressing their knowledge. This knowledge is generally the result of guidance by the teacher and interaction with peers but the synthesis and adjustment of this knowledge is done by each student individually. Students should formulate their own way of expressing their knowledge, different from that of their peers, textbook or those used by the teacher to illustrate (Jorba & Sanmartí Puig, 1994).

1.1.4 Application activities

Finally, application activities exist because in order for learning to be meaningful, it is necessary to provide opportunities to students to apply their revised conceptions/knowledge to different situations or contexts. It also allows students to compare their current point of view to their initial one to see how their understanding has evolved (Jorba & Sanmartí Puig, 1994).

The teaching principles of the social constructivism approach can be applied in different teaching approaches. One of these approaches is project-based learning (PBL), which will be used in this project.

2. Project-based learning

In a technical field, one of the teaching methods often used by educators is the project method, developed in 1918 by William Kilpatrick. The project method focuses on hands-on learning also known as experiential learning. Project-based learning was introduced around 1990 when Bransford and Stein (1993), Blummenfeld (1991) and Buck Institute for Education (1998) provided the definition and guidance of the implementation of PBL (Handrianto & Arinal Rahman, 2018).

PBL is a student-centered form of teaching. It engages learners in knowledge construction by having them accomplish meaningful projects and develop real-world products (Guo et al., 2020). In project-based learning, students are allowed to investigate questions, propose hypotheses and explanations, argue for their ideas, challenge other ideas and try out new ideas, with instructors playing a supporting role to assist in the learner's learning process (Krajcik & Shin, 2014). This connects exceptionally well to the principles discussed above for the social constructivist teaching principle. Both are focused on the active participation of the learner, social interaction and learning itself, rather than performance through tests.

According to Krajcik & Shin (2014) PBL environments share six key features:

- A driving question or a problem to be solved
- A focus on learning goals
- Learners explore the problem by engaging in scientific practices
- Learners, teachers and community members collaborate to find solutions to the problem
- Learners are scaffolded with learning technologies
- Learners create tangible products in solution to the problem.

2.1 Steps of Project-Based Learning

Using these key features, a set of seven concrete steps can be formulated to define how teaching using a project-based learning approach works. One should keep in mind that the technical classes we are aiming to improve should include practical elements. To add to that, technical problems are oftentimes a largely practical issue as well.

That being the case, we’ve opted for a combination of suggested approaches by Hmelo-Silver (2004), Lu et al. (2014), and Jalinus et al. (2017) to make sure there is sufficient focus on both theoretical and practical knowledge. Using this combination, the seven steps of project-based learning are the following:

1. Formulate a driving question or problem to be solved
2. Identify facts and formulate hypotheses
3. Identify gaps in current knowledge
4. Engage in self-directed learning as well as skills training
5. Apply newly obtained knowledge/skills to the problem
6. Evaluate
7. Reflect

Figure 1. The seven steps of project-based learning

2.1.1 Formulate a driving question or problem to be solved

An interesting and sufficiently complicated problem is necessary for good project-based learning. After all, it is the problems that make the learning process meaningful, learners are learning not just to obtain knowledge and skills and remember these, but to actually use this knowledge and these skills. By channeling learning through a project, learners not only obtain new knowledge and skills but also immediately learn where this knowledge and these skills can be used (Larmer et al., 2015).

Learners should ideally be supplied with minimal information about the problem to allow them to gather most of the facts themselves (Hmelo-Silver, 2004).

2.1.2 Identify facts and formulate hypotheses

In this step, learners should gather information and identify facts about the problem they've been presented with. This information can be obtained through questioning the one who supplied the problem, whether that be the teacher or a third party. Simple questions that can help learners in coming up with targeted questions are for example: 'What do we know about the problem?' and 'What do we need to know to formulate a hypothesis?'. Based on the information obtained during this step, learners can come up with one or several hypotheses about the problem. (Hmelo-Silver, 2004; Larmer et al., 2015).

2.1.3 Identify gaps in current knowledge

When learners have gathered the relevant facts to the problem at hand, they should broaden the scope of the questions they previously asked to identify what knowledge and/or skills they are missing to solve the problem. Example questions would be: 'What do we need to know to solve the problem?' and 'What knowledge/skills are we missing to solve the problem?'.

2.1.4 Engage in self-directed learning as well as skills training

When it is clear what knowledge/skills the learners are missing they should engage in self-directed learning (SDL) and skills training independently, at the end of this step the learners should regroup and share their new insight with one another, there is also an opportunity here for learners to reconsider their hypothesis or formulate an entirely new one based on their new learning (Hmelo-Silver, 2004).

Self-directed learning is an important feature of project-based learning, it is initiated through discussions in the previous steps. Learners have discussed the problem based on their initial knowledge and have assessed gaps in their knowledge and/or skills. With those gaps clear, learners can guide their own research and actively evaluate if their learning matches their learning goals (Lu et al., 2014).

However, given the more practical nature of the technical projects that would likely be supplied in the training courses we are discussing, it might not always be sufficient to have learners engage in theoretical research. Oftentimes, learners might need certain practical skills to solve the problem supplied. In this case, skills training should be provided to allow learners to obtain the skills necessary for solving the problem (Jalinus et al., 2017).

2.1.5 Apply newly obtained knowledge/skills to the problem

When learners have obtained the knowledge and skills necessary to solve the problem provided, they should apply this knowledge and these skills to actually solve the problem. The result should be a tangible product as a solution to the problem (Krajcik & Shin, 2014).

2.1.6 Evaluate

As learners finalize their project they should be able to evaluate whether or not their goals have been attained and whether or not the project was a success. On top of thinking about this individually and in their project group it can be beneficial to have learners present their project in front of the class. This allows for discussion between the project group and the other learners as well as the teacher (Hmelo-silver, 2004; Jalinus et al., 2017).

2.1.7 Reflect

Finally, reflection is an important part of the PBL approach. Reflection helps learners to relate their newly obtained knowledge to their prior knowledge, mindfully abstract knowledge and understand how their learning and problem-solving strategies might be applied again in the future (Hmelo-silver, 2004). Learners already reflect on their process a few times before this step, such as at the self-directed learning step, but in this step they should reflect on the project as a whole.

2.2 Teachers' role in the project-based learning process

In PBL, a teacher's role is to guide the learners' learning process, rather than providing direct instruction through a lecture or other form of instruction (Lu et al., 2014). Skills training is an exception to this, as it is often too practical to be grasped through self-directed learning. That said, recent development in fields like artificial intelligence (AI) and virtual reality could help alleviate the burden on the teacher and could allow learners to freely choose the skills they want to learn without having to worry or think about teacher availability. Please refer to section 3.2 for concrete examples of the opportunities VR provides in regards to skills training and section 4 for concrete examples of the opportunities AI provides in regards to skill training.

Teachers can guide learners in the learning process, for example by highlighting critical steps in a process as learners are performing them. Teachers can also ask questions, asking learners why they need specific information can help learners focus on a specific goal rather than just look for all available information on a topic. And asking learners to explain their thought process can help learners make their thinking visible and lead to reflection and discussion (Lu et al., 2014).

3. Skills training

Skills training in particular almost always requires an instructor to be present, due to the far more practical nature of a large part of skills training compared to the often completely theoretical research done in self-directed learning. Furthermore, learning to work with unfamiliar electronics can be very dangerous if not done under supervision of an expert. This makes it very difficult for skills training to be completely self-directed like the other parts of the PBL approach.

That being the case, we suggest another learning method to be used in combination with the PBL approach for the specific purpose of the skills training part of step 4, microlearning.

3.1 Microlearning

Microlearning has been gaining popularity over the past several years. Social media has changed people's information-seeking and consuming behaviors. Shifting their preference to single, discrete topics that are presented in a short duration to meet their moment of learning need (Taylor & Hung, 2022). Generally, microlearning can be described as a form of e-learning delivered in small chunks, focused on delivering skill-based and just-in-time knowledge (Zhang & West, 2020). Just-in-time knowledge can be defined as delivering the right knowledge at the right time (Taylor & Hung, 2022).

Microlearning can be delivered in the form of videos, documents and other varieties of learning created by learning professionals. Or, it can be developed by peers as user-generated content. The type of instruction varies in format and instructional purpose, but microlearning always provides bite-sized amounts of information that are easily and quickly consumed, learner-driven, and on-demand in nature (Taylor & Hung, 2022).

This makes it perfect for skills training in step 4 of the PBL approach in technical worker education. If learners have access to a catalog of content created by professionals in the field explaining and demonstrating the desired and required skills this could cut down on the need for instructors to be present for skills training drastically.

3.2 VR in microlearning

There are, however, limits to instruction through a video. After all, learners are still only observing how to perform certain tasks, rather than practicing performing these tasks themselves. Virtual reality can help make this learning more engaging.

VR can be used to simulate virtual work environments in which learners can practice practical skills through quick bite-sized lessons without the risk of damaging equipment or any of the danger that can come with working with unfamiliar equipment. In the meantime, instructions can be shown on the side in video, textual or other visual formats (Windelband, 2023). This allows learners to practice their skills in safe virtual environments that prepare them for work in the real world. Learners can take their time without risking potentially dangerous situations.

4. Artificial intelligence for education

It is clear that the education sector plays a vital role in solving the technical worker shortage here in the Netherlands. But the sector is not without its challenges. The challenge faced by the education sector during the COVID-19 pandemic has been clear (Ahmad et al., 2021). But there are other, more permanent challenges for the education sector, specifically in regard to technical worker education in the Netherlands. One such problem is the potential shortage of teachers discussed in section 1.3. The recent developments in the field of artificial intelligence (AI) could provide solutions to these problems and make teaching more personalized and efficient.

As discussed in section 1.4, in-service and retraining classes are often not personalized enough as of yet. Project-based learning as a whole already alleviates this problem quite well through self-directed learning. But, nevertheless, it can be difficult for a single instructor to serve as multiple learners' guide through the learning process, especially when learners have completely different levels of knowledge going into the learning process.

AI can be of help in creating more personalized learning for each individual learner during their self-directed learning. AI-powered chatbots can be used to guide learners through the process of self-directed learning much like an instructor would by answering any questions a student might have about the self-directed learning process or the problem they are facing (Ito et al., 2021). This way, self-directed learning can be made easier and more personalized. It is important for these chatbots to be supplied with correct and relevant information to ensure they are able to give proper guidance to the learners.

AI can also be used by learners to quiz themselves on certain topics. Intelligent tutoring systems (ITS) can then be used to analyze the learner's answer to the questions and change learning content based on these answers (Ito et al., 2021). This works especially well for more structured learning activities, such as memorizing the steps of repairing or operating a certain machine. If the learner answers a certain question wrong, the AI can then change the subsequent learning material to focus on the knowledge required to answer the question the learner didn't get right.

Methodology

5 Design-based research

Design-based research (DBR) was used to design an effective in-service training course for technical workers at MBO level. The goal of design-based research is to develop research-based solutions for complex problems in educational practice. The goal is not only to develop solutions, but also to contribute to the body of scientific knowledge (Plomp, 2013) Design-based research is cyclical in character, as illustrated in figure 2.

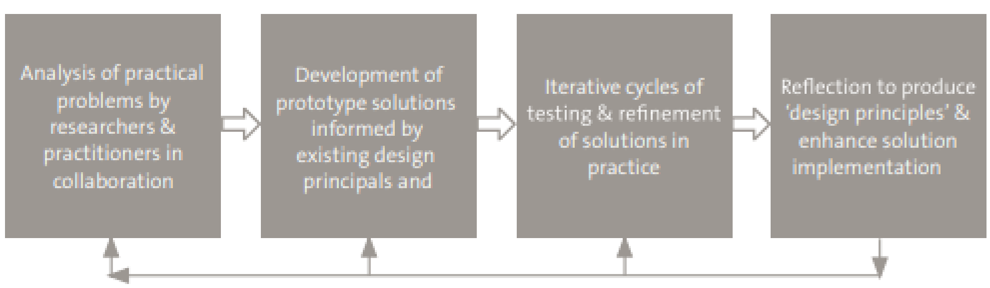

Figure 2. Design-based research approach (Plomp, 2013)

Exact details on design-based research vary from author to author but it is generally agreed upon that three phases are key in designing a training course in design-based research. These phases consist of the following 1) preliminary research 2) development phase 3) assessment phase (Nieveen & Folmer, 2013).

5.1 Preliminary research

The preliminary research phase is meant to gain insight into the existing problem and the possibilities for improvement and innovation. It also serves to identify the tentative features of the course (Nieveen & Folmer, 2013). To achieve this, we conducted a literature review. The literature review served to gain insight into various teaching approaches and to determine which approach would be most suitable to provide in-service training to technical workers. On top of that, it served to gain insight in the potential application of AI and VR in the course. Throughout the literature review we used various keywords to obtain the relevant information. For example, 'Social constructivism', 'Project-based learning', 'Microlearning' and 'Design-based research' were all used as key search terms in databases such as the education resources information center (ERIC) and google scholar to gain insight into the main concepts used in the course. Special attention was paid to the context in which the articles were written, articles that focused purely on university or high school level education were excluded from the literature review as they were not relevant to the course we designed. To gain insight in the use of AI in education search terms like 'Artificial intelligence' were used in databases like ERIC. Furthermore, all search terms were combined with 'Vocational education' in an attempt to obtain information that closely matched the context of our course. To gather information about the shortage of technical workers we used official numbers from the Dutch government, obtained through the database of the Rijksoverheid.

5.2 Development phase

The development phase follows the preliminary research phase and serves to develop the training course. To create an effective course we first addressed ten specific questions about the planning of student learning. In DBR these questions are often visualized as a spider web known as the curricular spider's web (Fig 3.) (Nieveen & Folmer, 2013; Van den Akker, 2013).

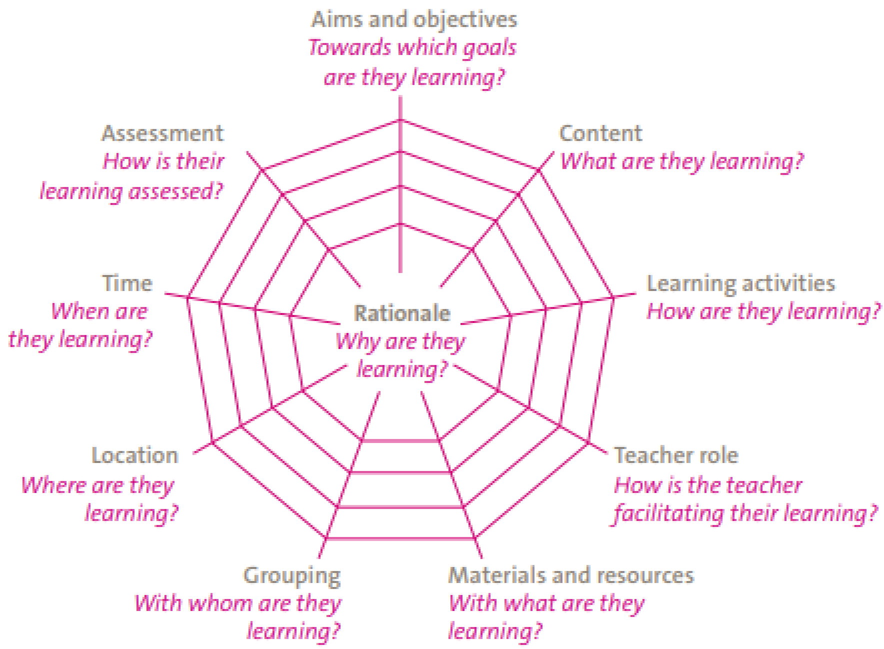

Fig 3. Curricular Spider's Web (Van den Akker, 2013)

5.2.1 Prototyping

Prototyping is also an important part of the development phase, due to the limited time frame of this project we were unable to create multiple prototypes. Instead, a first prototype was made and this prototype was refined to the final version through a focus group. This focus group was an hour long and featured educational experts as participants. We asked participants to analyze the prototype of the teaching and learning sequence we designed and asked them to focus on the internal coherence of the sequence, to find out if the prototype aligned with our teaching approach and learning objectives. To this end we created several questions for them to answer:

1. Does the teaching and learning sequence generally align with the project-based learning and microlearning approach?

2. What improvements do you think should be made in the TLS to make it align even better with our PBL and microlearning approach?

3. Does the teaching and learning sequence generally align with the learning objectives?

4. What improvements do you think should be made in the TLS to make it align even better with our learning objectives?

5. Is it clear what is expected from the students and the teachers in the TLS?

6. Is there anything else you think we should improve in the TLS towards the final version?

Furthermore, the focus group included an open discussion in which participants discussed their answers to the questions and general thoughts with one another. The full template that was given to the participants is included in appendix A.

5.3 Evaluation phase

The evaluation phase serves to determine the actual effectiveness of the complete training course. The focus is on the extent to which the implementation of the training course leads to the desired outcomes (Nieveen & Folmer, 2013). However, due to the limited scope of time available for the current project, we were unable to perform this evaluation in an actual in-service training setting.

Results

6.1 Answers ten questions

To design the in-service training course, we combined the knowledge obtained from the preliminary research phase with the information obtained from answering the ten questions in the curricular spider's web.

6.1.1 Rationale: Why are they learning?

As has been discussed before in the introduction section, there is an increasing shortage of technical workers in the Netherlands. The course serves to efficiently and effectively provide in-service training to people. Learners are learning to obtain the additional knowledge and skills required to do a different job in the technical field.

6.1.2 Aims & Objectives: Towards which goals are they learning?

The goal of the training course is to supply learners with the theoretical knowledge and practical skills they require to work in the technical field at a MBO level. The course should not only just provide the learners with the knowledge necessary, but should also provide them with ways to learn how to apply this knowledge in a practical setting. On top of that the course should provide learners with various skills they can use in the field.

6.1.3 Content: What are they learning?

Throughout the course learners will obtain the knowledge and skills required to complete various projects in the technical field. On top of that, learners will learn how to complete projects working together in a team and what to expect from clients/employers when working on such projects. More specifically, this prototype is based on a set of specific content that needs to be taught during the course. This content consists of simple electrotechnical operations, more specifically, the course includes the following content: Creating a lighting system using a technical drawing, to do this learners will be taught about voltage, electricity, resistance and capacity, DC and AC voltage and 1 and 3-phase networks. Next they will be taught how to bend PVC-pipes, attach pipes, install distribution boxes, pull wires and weld them, install and wire electrical outlets, install and wire light switches and lamps, and provide the installation with electricity. On top of that, learners will be taught about a few different types of circuits, these being the series connection, hotel switch and the cross connection.

Content of the course	
Theoretical Knowledge	Practical Skills
Understanding voltage, electricity, resistance and capacity	Bending PVC-pipes
Understanding DC and AC voltage	Attaching pipes
Understanding 1 and 3-phase networks	Installing distribution boxes
Understanding how series, hotel and cross connections work	Pulling wires
	Welding wires
	Installing and wiring electrical outlets
	Installing and wiring light switches & lamps
	Providing an installation with electricity
	Creating a series, hotel and cross connection

6.1.4 Learning Activities: How are they learning?

Learners will learn in the course through completing actual projects in the technical field, using project-based learning as a base. They will also obtain skills through short lessons using micro learning as a base. In these lessons learners will not only answer concrete questions about maintenance and repair of installations, they will also perform these actions themselves in virtual reality.

6.1.5 Teacher Role: How is the teacher facilitating their learning?

The teacher plays a supporting role in the teaching of the course as well as an active role in the organization of the course. Teachers should function as a guide to guide learners through the learning process. They can, for example, highlight critical steps of a process as learners are performing that process or ask learners questions to get them to think more in depth about why exactly they need the information rather than simply accepting they need the information without knowing why. The teacher is also responsible for designing the teaching and learning situations and adapting them to the students. Furthermore, the teacher should provide students with materials when necessary.

6.1.6 Materials & Resources: With what are they learning?

Learners are free to use whatever resources they can find for their self-directed learning. On top of that, an AI-powered chatbot will be available for learners to ask questions they think of during self-directed learning.

Furthermore, an online learning environment based on micro-learning will be available. Here, learners can watch videos teaching them about basic concepts as well as how to maintain and repair installations they are likely going to come across in the future. They will also answer questions about these concepts and processes. An intelligent tutoring system will be used to change or reorder the learning material based on correct or incorrect answers to these questions.

Finally, a VR program will be available where learners can practice maintaining and repairing installations without risking their own safety or any expensive equipment. This program can be used by learners to obtain the skills necessary for their project but it can also be used to practice or learn skills not required for their current project.

In the VR program, components will be available to tinker with virtually. This way, learners will be able to virtually construct electrical installations and test if they work the way they want them to.

6.1.7 Grouping: With whom are they learning?

Learners will be working and learning in groups of 4-8 students, depending on the scope of the project and the size of the class.

6.1.8 Location: Where are they learning?

Learners will largely be learning in the classroom. Though project-based learning allows them to work on the project wherever they want. Furthermore, they will likely have meetings with the client/employer on site.

6.1.9 Time: When are they learning?

Learners will be learning during the course. These people are either already involved in a technical field, but require extra training to fill the job vacancies available or these people have been trained for a different job and want to be retrained to fill the job vacancies in the technical field.

6.1.10 Assessment: How is their learning assessed?

Learning is assessed by the teacher and the other learners in their class through presenting the results of their project work. Not only that, learning is also assessed by the group itself after certain steps in the project-based learning approach.

On top of that, the questions and VR simulations for skills training are easy to assess. The questions simply have correct and incorrect answers. The VR simulation will be able to tell learners when they have made a mistake.

6.2 First Prototype

Through the knowledge obtained from literature in the preliminary phase and the answers to the ten questions posed in the development phase of the design-based research method, we were able to create a first prototype for the in-service training course. To show the first prototype, we have created a table. The table includes a week by week description of the teaching and learning sequence. It includes activities for both the teacher and the students as well as the objective of these activities, the content that will be covered and the materials that are required to carry out the activity.

WEEKS	ACTIVITIES	OBJECTIVE	CONTENT	MATERIALS
1	**Teacher -** The beginning of the course is dedicated to setting the foundation for the project-based learning approach. The teacher begins by explaining the philosophy and expectations of PBL, emphasizing the importance of self-directed learning. To give learners a sense of the practical skills they'll develop in the course, the teacher provides a brief overview of the essential electrotechnical skills involved. This overview acts as a preview, establishing context for the projects that will follow	Providing learners with an overview of the course so they know what to expect.		Projector and screen
	Teacher - Ideally, clients or employers present the available projects to the learners. Having this real-world connection brings a sense of authenticity and motivates learner engagement. The careful selection of projects ensures they align with the skills and content of the course while giving learners a sense of choice and ownership over their learning journey. In the case of this prototype, only one project is available. The project is outlined above in section 6.2.2.3.	Introducing learners to the projects available to work on in the course to allow them to make an informed decision on what they want to work on.		Projector and screen
	Students - A1. Form groups of 4 and decide which project you want to work on. When you have decided as a group, share your decision with the rest of the class.	Forming the group you will be working with for the duration of the project and picking the project you will be working on.		
	Students - A2. Discuss with your group what	Formulating the driving		

	you think the driving question of your project should be. Driving questions are likely to be along the lines of: What sort of electrical installation needs to be created to fulfill the needs of the client?	question of your chosen project.		
	Teacher - To conclude the first class the teacher should instruct the groups to think about the knowledge and skills they still require to successfully work on the project. They should do this individually between now and the next class. Examples of the knowledge and skills learners are likely to come up with are knowledge about voltage, electricity, resistances and connections. As well as the ability to design, wire and install electrical circuits.	Getting learners to think about the knowledge and skills they want to learn about during the course.		
2	**Students** - A3. Talk with your group about the knowledge and skills you came up with that you think are necessary to complete the project.	Coming to an agreement on the skills and knowledge you want to obtain through the course with your group.		
	Teacher - The teacher should engage the groups in discussion while they are discussing among themselves and guide them in the right direction through simple questions if necessary.	Making sure all groups arrive at the right knowledge and skills required to successfully complete the course.		
	Students - A4. Together with your group, formulate a hypothesis about the project based on the knowledge and skills you came up with. A likely hypothesis would be something along	Coming up with an hypothesis about the project.		

	the following lines: To fulfill the needs of the client we need an electrical installation that includes a series, hotel and cross connection.			
	Teacher - To facilitate self-directed learning, an AI chatbot program and micro-learning environment are used. It is important for the teacher to introduce both of these to the class as a whole and show them the basic functions of both programs.	Introducing learners to two of the learning tools used in the course so they can successfully engage with these when they need to.	.	Projector and screen
	Students - A5. As an individual, decide on one piece of knowledge you thought you were lacking that came up during your group discussion (it is best to start simple. e.g. Voltage) and use the AI chatbot program and micro-learning environment to delve into that topic. The AI chatbot program and micro-learning environment are discussed in more detail further up in section 6.2.2.6	Getting familiar with the learning tools introduced before while studying a simple topic such as Voltage.	Voltage	Computer, laptop or phone
	Teacher - To conclude the second class the teacher should instruct the class to individually study the basic concepts (voltage, electricity, resistance and capacity) using the self-directed learning tools provided. To this end they will have to engage with the AI chatbot program and answer questions about the topics in the micro-learning environment.	Getting learners to engage with the learning tools introduced earlier to obtain basic knowledge they will need in the course.	Voltage, electricity, resistance and capacity	Computer, laptop or phone
3	**Teacher -** During this class, the learners are going to create a simple light installation. The teacher should start the class with an explanation of the VR program meant for skills	Introducing learners to the VR program tool used in the course so they can successfully engage with it		VR headsets

	training. The VR program is discussed in more detail further ur in section 6.2.2.6	when they need to.		
	Students - A6. Individually, use the VR program to walk through the following lessons: Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity. The lesson on installing and wiring electrical outlets for example would show learners a video on how to properly execute the task before simulating the components and allowing the learners to try it for themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity.	VR headset
	Students - A7. As a group, use the knowledge you obtained through the VR program to create a simple light installation based on a simple technical drawing. The installation should include 1 lamp that can be controlled with a switch from a fixed point.	Using the knowledge and skills obtained through the VR program to create a simple light installation that can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity.	Electrical components, technical drawing of the installation
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would	Assisting learners should things go wrong or if learners can't figure something out. The		

	be able to figure out the installation themselves.	installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp can be turned on and off using the switch of the installation.	Evaluating the work of the learners.		
	Teacher - To conclude the third class the teacher should instruct the class to individually study AC and DC voltage as well as 1 and 3-phase networks using the self-directed learning tools.	Getting learners to engage with the learning tools introduced earlier to obtain more knowledge they will need in the course.	AC/DC voltage, 1 and 3-phase networks	Computer, laptop or phone
4	**Teacher -** During this class, learners are going to create a light installation with a series connection. The teacher should start the class with a basic explanation of a series connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Series connection	Projector and screen
	Students - A8. Individually, use the VR program to walk through the lesson about series connections. Again, learners would be shown a video on how to properly create a series connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Series connection	VR Headset
	Students - A9. As a group, use the knowledge you obtained through the VR program to create a series connection light installation based on a simple drawing. The installation should have 2	Using the knowledge and skills obtained through the VR program to create a series connection light installation that	Series connection	Electrical components

	lamps that need to be controlled from 1 place, both lamps are supposed to be able to turn on and off in turn.	can be evaluated by the teacher.		
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the 2 lamps in the installation can be controlled by the switch and can be turned on and off in turn.	Evaluating the work of the learners.		
5	**Teacher -** During this class, learners are going to create a light installation with a hotel connection. The teacher should start the class with a basic explanation of a hotel connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Hotel connection	Projector and screen
	Students - A10. Individually, use the VR program to walk through the lessons about hotel connections. Again, learners would be shown a video on how to properly create a hotel connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Hotel connection	VR Headset
	Students - A11. As a group, use the knowledge you obtained through the VR program to create a hotel connection light installation based on a simple drawing. The	Using the knowledge and skills obtained through the VR program to create a hotel connection light installation that	Hotel connection	Electrical components

	installation should have 1 lamp that can be controlled by 2 switches in different locations.	can be evaluated by the teacher.		
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be controlled individually by the 2 different switches.	Evaluating the work of the learners.		
6	**Teacher -** During this class, learners are going to create a light installation with a cross connection. The teacher should start the class with a basic explanation of a cross connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Cross connection	Projector and screen
	Students - A12. Individually, use the VR program to walk through the lessons about cross connections. Again, learners would be shown a video on how to properly create a cross connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Cross connection	VR Headset
	Students - A13. As a group, use the knowledge you obtained through the VR program to create a cross connection light installation based on a simple drawing. The installation should have 1 lamp that can be	Using the knowledge and skills obtained through the VR program to create a cross connection light installation that can be evaluated by the	Cross connection	Electrical components

	controlled by 3 switches in different locations.	teacher.		
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be turned on and off by the 3 different switches in the installation.	Evaluating the work of the learners.		
7	**Teacher -** During this class, learners will work in their group to use the knowledge and skills they have obtained to create a light installation that fits the requirements of the project. This means the light installation has to include a series, hotel and cross connection. The teacher should start with an explanation of what is expected.	Introducing learners to the assignment they will work on during this class so they know what to expect.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Students - A14. As a group, reflect on your hypothesis and driving question. Using the knowledge and skill you have obtained during the course, evaluate if the hypothesis is still accurate or needs to be revised.	Evaluating if the hypothesis your group came up with is accurate or if it needs revision.		

	Students - A15. As a group, create a light installation with all the elements to satisfy your driving question.	Using the knowledge and skills obtained throughout the entire course to create a light installation that satisfies your driving question and can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	Electrical components
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the installation contains all three of the different connections that it should (series, hotel and cross) and if the installation works as it should.	Evaluating the work of the learners.		
	Teacher - When the groups are finished, the teacher should introduce a malfunction into the system while the groups are on break.	Testing learners' understanding of the workings of the installation they created by introducing a malfunction for them to find and solve.		
	Students - A16. As a group, figure out what is wrong with your system and repair the malfunction to restore the system back to normal.	Putting your knowledge to work in solving a malfunction in your system and restoring it to normal.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets,	

			installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the learners found the malfunction and repaired it properly, restoring the installation back to proper function.	Evaluating the work of the learners.		
	Teacher - To conclude the class, the teacher should instruct the groups to create a presentation about their project before the next session.	Getting learners to think about what they want to discuss about their project with the rest of the class.		
8	**Teacher -** During this class, the groups will present their projects one by one. The teacher should decide on an order of presentation.	Creating an order of presentations so learners know when they are supposed to present.		Projector and screen
	Students - A17. As a group, present your project. Discuss with the teacher and rest of the class about what went well and what could have gone better.	Discussing together with the teacher and other groups what could have been done to make the project easier to complete.		Projector and screen
	Students - A18. As a group, discuss the project among yourselves. Focus the process of the project and reflect on what you would use this knowledge for in the future.	Discussing together with your group about what you have learned and what you can use this knowledge for in the future.		

6.3 Focus Group

6.3.1 Analysis

Based on the answers to the questions and the open discussion (which can be viewed in full in appendix B), we formulated a few main points of improvement:

Point 1

The first point of improvement that came up in the answers to the questions as well as in the open discussion at the end was that students' misconceptions and misunderstandings should be addressed in the teaching learning sequence.

> **Examples**
>
> **Answers to questions**
>
> Collect students' prior knowledge and misconceptions so you can be sure they collect the correct information.
>
> When the students are asked to learn individually about the concepts, the teacher needs to make sure they understand the concepts correctly and misconceptions do not exist.
>
> Based on the literature about misconceptions and challenges, prepare a plan for inputs that can facilitate their building of understanding the knowledge and skills they need to implement in order to solve the problem.
>
> PBL is aligned with constructivist perspectives, so how is the project ensuring that no misconceptions around electricity arise?
>
> **Open discussion**
>
> **Participant 4:** I think you should also be aware of misconceptions. Although these students are well to some extent familiar with the concepts because, well, they come from a technical field and they know the concepts of resistance, voltage and current. But there is a lot of literature about possible misconceptions about these concepts.
>
> **Participant 2:** What I think I miss is the role of the teacher as a facilitator during these small inquiries. The chat bot will probably be programmed to facilitate this. But I missed the explanation of how, for example, they do the problem definition at the beginning and it's very nice that they have to identify for themselves the knowledge and the skills that they have to apply to solve this problem. But do we have a plan if they don't find the

suitable knowledge and skills that are needed? How we will address this gap if they don't.

I think this part should be first as a way to collect their misconceptions and then build on that with different pathways for each group. Or for each one of them somehow, to help them reach finally the proper knowledge and skills that they need to acquire to to solve the problem.

From the examples it is clear that the participants are worried about misconceptions creating problems in the teaching and learning sequence. As participant 2 noted, there should be a plan in place for when students do not find the correct or suitable knowledge and skills required for the project. Without it, students might not obtain the knowledge they require.

Point 2

The second point of improvement that came up was that safety precautions should be more specifically addressed in the teaching learning sequence.

Examples

Answers to questions

Safety regulations are not clear, you are working with voltage and power here, these should be clearer than “the installation is simple enough that things won't get dangerous”.

Open discussion

Participant 4: What I missed was, but I didn't read it very carefully because there was not sufficient time for that, but about safety because that's very important when you work with electricity, safety regulations are very strict here.

The participants think that safety regulations are not clear enough or even absent throughout the teaching and learning sequence. Participant 4 mentions the importance of safety regulations in the Netherlands. This is an excellent point, safety regulations when it comes to electrical work are very strict and should be mentioned in more detail.

Point 3

The third point of improvement was the mention that the expected duration of the activities should be provided.

Examples

Answers to questions

Before students work on the project, the teacher needs to explain how long it takes to finish it.

More logistical aspects about project time limitations should be mentioned.

From the two answers above, it is clear that the participants believe there should be indications of time in the teaching and learning sequence. Both for the activities, so students know how long they have to finish certain parts of the project. But also for the teacher, so they know how long they can take for their interactive sessions.

Point 4

A fourth point of improvement was that the teacher currently has too prominent of a role in the project for it to truly be project-based learning.

Examples

Answers to questions

Sentences as the teacher should start with a basic explanation of hotel connection conveys a traditional idea of learning not aligned with PBL.

Open discussion

Participant 4: Well, I think well, you made a lot of useful remarks about the project. Well, first, the examples I know of project-based learning are more well students work rather independently and I think here the teacher has a very prominent role in explanation in instruction, so I would say it is not my idea of project-based learning.

From the answer to the questions and the open discussion it is clear that the participants are not sure if the way the teacher gives instruction aligns with project-based learning. The participants feel like the current way of instruction aligns with traditional learning, rather than project-based learning.

Point 5

The fifth point for improvement that came up was the fact that the client should be more involved in the project.

Examples

Answers to questions

The clients should be more involved with the project, not only the teacher. Maybe every few weeks the client can come and see how the project is going and give advice about the project to the students.

Open discussion

Participant 5: Also, the teachers supervise but maybe it can be more of a real world problem if the client also comes a few times, not only in the first time to supervise and explain.

Participant 3: Yeah, or not even explaining, but also more elaborating, if you're going to test it with materials and it's going to break down, it's going to cost us this much money.

From the answer to the questions and the open discussion it is clear that participants think it would be good to have the client more involved in the project. As participant 5 mentions, it could turn the project into more of a ‘real world problem’ and connect the students to the clients and the field beyond their project.

Point 6

The final main point that came up through the questions and the open discussion was the mismatch between the scientific inquiry cycle used in the teaching and learning sequence and the field of engineering.

Examples

Answers to questions

The selected structure of PBL is based on an inquiry process (with hypothesis, research, etc.). The aim to develop technical knowledge is not aligned with a scientific inquiry. Therefore, the project should be guided for technological driving questions. ‘How can different available technologies help me to address this client issue?’

Open discussion

Participant 1: Yeah, I don't know if I completely agree with everything because we're thinking about it from a very scientific perspective maybe so we're thinking ohh they need to explore the misconceptions and then from that developed scientific ideas. But here we are talking about more engineering skills. They should test differently so opportunities to develop like this engineering practices should be part of the project and here the structure, the model that you use for project based learning. It's kind of you getting engaged in a scientific inquiry rather than having an engineering problem and a design process.

Participant 2: Probably he could use an engineering design cycle instead.

It is clear that the participants believe there is a mismatch between the scientific inquiry cycle used in the teaching and learning sequence and engineering. Changing this is outside of the scope of our current project but it will be addressed and discussed in more detail in the discussion of this paper.

6.4 Final Prototype

The first prototype was adjusted using the insights obtained from the focus group to create the following final prototype.

WEEKS	ACTIVITIES	OBJECTIVE	CONTENT	MATERIALS
1	**Teacher** (1h) **-** The beginning of the course is dedicated to setting the foundation for the project-based learning approach. The teacher begins by explaining the philosophy and expectations of PBL, emphasizing the importance of self-directed learning. To give learners a sense of the practical skills they'll develop in the course, the teacher provides a brief overview of the essential electrotechnical skills involved. This overview acts as a preview, establishing context for the projects that will follow	Providing learners with an overview of the course so they know what to expect.		Projector and screen
	Teacher (2h) **-** Ideally, clients or employers present the available projects to the learners. Having this real-world connection brings a sense of authenticity and motivates learner engagement. The careful selection of projects ensures they align with the skills and content of the course while giving learners a sense of choice and ownership over their learning journey. In the case of this prototype, only one project is available. The project is outlined above in section 6.2.2.3.	Introducing learners to the projects available to work on in the course to allow them to make an informed decision on what they want to work on.		Projector and screen
	Students (30m) **-** A1. Form groups of 4 and decide which project you want to work on. When you have decided as a group, share your decision with the rest of the class.	Forming the group you will be working with for the duration of the project and picking the project you will be working on.		
	Students (1h) **-** A2. Discuss with your group	Formulating the driving question		

	what you think the driving question of your project should be. Driving questions are likely to be along the lines of: What sort of electrical installation needs to be created to fulfill the needs of the client?	of your chosen project.		
	Teacher (30m) - To conclude the first class the teacher should instruct the groups to think about the knowledge and skills they still require to successfully work on the project. They should do this individually between now and the next class. Examples of the knowledge and skills learners are likely to come up with are knowledge about voltage, electricity, resistances and connections. As well as the ability to design, wire and install electrical circuits.	Getting learners to think about the knowledge and skills they want to learn about during the course.		
2	**Students** (1h) - A3. Talk with your group about the knowledge and skills you came up with that you think are necessary to complete the project.	Coming to an agreement on the skills and knowledge you want to obtain through the course with your group.		
	Teacher (1h (simultaneously)) **-** The teacher should engage the groups in discussion while they are discussing among themselves and guide them in the right direction through simple questions if necessary.	Making sure all groups arrive at the right knowledge and skills required to successfully complete the course.		
	Students (30m) **-** A4. Together with your group, formulate a hypothesis about the	Coming up with an hypothesis about the project.		

	project based on the knowledge and skills you came up with. A likely hypothesis would be something along the following lines: To fulfill the needs of the client we need an electrical installation that includes a series, hotel and cross connection.			
	Teacher **(1h)** **-** To facilitate self-directed learning, an AI chatbot program and micro-learning environment are used. It is important for the teacher to introduce both of these to the class as a whole and show them the basic functions of both programs.	Introducing learners to two of the learning tools used in the course so they can successfully engage with these when they need to.	.	Projector and screen
	Students **(2h)** **-** A5. As an individual, decide on one piece of knowledge you thought you were lacking that came up during your group discussion (it is best to start simple. e.g. Voltage) and use the AI chatbot program and micro-learning environment to delve into that topic. The AI chatbot program and micro-learning environment are discussed in more detail further up in section 6.2.2.6	Getting familiar with the learning tools introduced before while studying a simple topic such as Voltage.	Voltage	Computer, laptop or phone
	Teacher **(30m)** **-** To conclude the second class the teacher should instruct the class to individually study the basic concepts (voltage, electricity, resistance and capacity) using the self-directed learning tools provided. To this end they will have to engage with the AI chatbot program and answer questions about the topics in the	Getting learners to engage with the learning tools introduced earlier to obtain basic knowledge they will need in the course.	Voltage, electricity, resistance and capacity	Computer, laptop or phone

	micro-learning environment.			
3	**Teacher (1h) -** During this class, the learners are going to create a simple light installation. To start the class, the teacher should host an interactive session with the entire class in which the teacher facilitates a discussion in the class about the basic concepts (voltage, electricity, resistance and capacity) the students were told to study individually in the last class. Students should talk about what they've learned about these concepts with one another while the teacher makes sure the discussion stays on track and no misconceptions are created.	Confirm that learners have the correct and same knowledge about the concepts they studied individually.		
	Teacher (1h) - After the first interactive session the teacher should give an explanation of the VR program meant for skills training. The VR program is discussed in more detail further ur in section 6.2.2.6	Introducing learners to the VR program tool used in the course so they can successfully engage with it when they need to.		VR headsets
	Students (2h) - A6. Individually, use the VR program to walk through the following lessons: Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity. The lesson on installing and wiring electrical outlets for example would show learners a video on how to properly execute the task	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps	VR headset

	before simulating the components and allowing the learners to try it for themselves in virtual reality.		and providing an installation with electricity.	
	Students (30m) **-** A7. As a group, use the knowledge you obtained through the VR program to create a simple light installation based on a simple technical drawing. The installation should include 1 lamp that can be controlled with a switch from a fixed point. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	Using the knowledge and skills obtained through the VR program to create a simple light installation that can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity.	Electrical components, technical drawing of the installation, rubber gloves
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp can be turned on and off using the switch of the installation.	Evaluating the work of the learners.		
	Teacher (30m) **-** To conclude the third class the teacher should instruct the class to individually study AC and DC voltage as well as 1 and 3-phase networks using the	Getting learners to engage with the learning tools introduced earlier to obtain more knowledge they will need in the course.	AC/DC voltage, 1 and 3-phase networks	Computer, laptop or phone

	self-directed learning tools.			
4	**Teacher** **(2h)** **-** During this class, learners are going to create a light installation with a series connection. The teacher should host an interactive session with the entire class in which the teacher facilitates a discussion in the class about the concepts (AC and DC voltage, 1 and 3-phase networks) the students were told to study individually in the last class. Students should talk about what they've learned about these concepts with one another while the teacher makes sure the discussion stays on track and no misconceptions are created. After this, the teacher should introduce the series connection through another interactive session. The teacher should ask the students what they think a series connection is and ultimately arrive at the correct explanation through back and forth conversation with the students.	Confirm that learners have the correct and same knowledge about the concepts they studied individually. Introducing learners to the concept that will be at the center of today's class in an interactive session so they know what to expect.	Series connection	Projector and screen
	Students **(1.5h)** **-** A8. Individually, use the VR program to walk through the lesson about series connections. Again, learners would be shown a video on how to properly create a series connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Series connection	VR Headset
	Students **(1.5h)** **-** A9. As a group, use the	Using the knowledge and skills	Series connection	Electrical components, rubber

	knowledge you obtained through the VR program to create a series connection light installation based on a simple drawing. The installation should have 2 lamps that need to be controlled from 1 place, both lamps are supposed to be able to turn on and off in turn. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	obtained through the VR program to create a series connection light installation that can be evaluated by the teacher.		gloves
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the 2 lamps in the installation can be controlled by the switch and can be turned on and off in turn.	Evaluating the work of the learners.		
5	**Teacher (1h) -** During this class, learners are going to create a light installation with a hotel connection. The teacher should introduce the hotel connection through another interactive session. The teacher should ask the students what they think a hotel connection is and ultimately arrive at the correct explanation through back and forth conversation with the students.	Introducing learners to the concept that will be at the center of today's class in an interactive session so they know what to expect.	Hotel connection	Projector and screen

	Students (1.5h) **-** A10. Individually, use the VR program to walk through the lessons about hotel connections. Again, learners would be shown a video on how to properly create a hotel connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Hotel connection	VR Headset
	Students (1.5h) **-** A11. As a group, use the knowledge you obtained through the VR program to create a hotel connection light installation based on a simple drawing. The installation should have 1 lamp that can be controlled by 2 switches in different locations. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	Using the knowledge and skills obtained through the VR program to create a hotel connection light installation that can be evaluated by the teacher.	Hotel connection	Electrical components, rubber gloves
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be controlled individually by the 2 different switches.	Evaluating the work of the learners.		

6	**Teacher** **(1h) -** During this class, learners are going to create a light installation with a cross connection. The teacher should introduce the cross connection through another interactive session. The teacher should ask the students what they think a cross connection is and ultimately arrive at the correct explanation through back and forth conversation with the students.	Introducing learners to the concept that will be at the center of today's class through an interactive session so they know what to expect.	Cross connection	Projector and screen
	Students **(1.5h) -** A12. Individually, use the VR program to walk through the lessons about cross connections. Again, learners would be shown a video on how to properly create a cross connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Cross connection	VR Headset
	Students **(1.5h) -** A13. As a group, use the knowledge you obtained through the VR program to create a cross connection light installation based on a simple drawing. The installation should have 1 lamp that can be controlled by 3 switches in different locations. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	Using the knowledge and skills obtained through the VR program to create a cross connection light installation that can be evaluated by the teacher.	Cross connection	Electrical components, rubber gloves
	Teacher - The teacher should be available	Assisting learners should things		

	to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher (1h) **-** The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be turned on and off by the 3 different switches in the installation. Ideally, the client also comes back into the class to evaluate the progress the students have made.	Evaluating the work of the learners.		
7	**Teacher** (30m) **-** During this class, learners will work in their group to use the knowledge and skills they have obtained to create a light installation that fits the requirements of the project. This means the light installation has to include a series, hotel and cross connection. The teacher should start with an explanation of what is expected.	Introducing learners to the assignment they will work on during this class so they know what to expect.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Students (30m) **-** A14. As a group, reflect	Evaluating if the hypothesis your		

	on your hypothesis and driving question. Using the knowledge and skill you have obtained during the course, evaluate if the hypothesis is still accurate or needs to be revised.	group came up with is accurate or if it needs revision.		
	Students **(2h)** **-** A15. As a group, create a light installation with all the elements to satisfy your driving question. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	Using the knowledge and skills obtained throughout the entire course to create a light installation that satisfies your driving question and can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	Electrical components, rubber gloves
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the installation contains all three of the different connections that it should (series, hotel and cross) and if the installation works as it should.	Evaluating the work of the learners.		
	Teacher **(30m)** **-** When the groups are finished, the teacher should introduce a malfunction into the system while the groups	Testing learners' understanding of the workings of the installation they created by introducing a		

	are on break.	malfunction for them to find and solve.		
	Students **(1h)** **-** A16. As a group, figure out what is wrong with your system and repair the malfunction to restore the system back to normal. This is simple electrical work. Even so, safety precautions should be taken to avoid potential accidents and injuries. In this case, providing students with rubber gloves to wear will suffice.	Putting your knowledge to work in solving a malfunction in your system and restoring it to normal.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	Rubber gloves
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the learners found the malfunction and repaired it properly, restoring the installation back to proper function.	Evaluating the work of the learners.		
	Teacher **(30m)** **-** To conclude the class, the teacher should instruct the groups to create a presentation about their project before the next session.	Getting learners to think about what they want to discuss about their project with the rest of the class.		
8	**Teacher** **(30m)** **-** During this class, the groups will present their projects one by one.	Creating an order of presentations so learners know		Projector and screen

	The teacher should decide on an order of presentation. Ideally, the client should also be present for these presentations.	when they are supposed to present.		
	Students (Depends on class size) - A17. As a group, present your project. Discuss with the teacher and rest of the class about what went well and what could have gone better.	Discussing together with the teacher and other groups what could have been done to make the project easier to complete.		Projector and screen
	Students (30m) - A18. As a group, discuss the project among yourselves. Focus the process of the project and reflect on what you would use this knowledge for in the future.	Discussing together with your group about what you have learned and what you can use this knowledge for in the future.		

Conclusions

Throughout this project we aimed to improve on the currently existing in-service training classes by promoting more personalized and cooperative learning. To this end we designed a training course for in-service training of technical workers. To achieve our goals with this training we formulated and answered the following research question: What are the characteristics of an effective teaching and learning strategy aimed at providing in-service training to technical workers already employed in the technical field at MBO level in the Netherlands?

We used a social constructivist framework because in this framework the learner's construction of knowledge is the product of social interaction, interpretation and understanding (Vygotsky, 1962). It views learning as a social process and does not only take place within an individual, nor is it a passive development of behaviors that are shaped by external forces (McMahon, 1997). This fit our goal of creating a more personalized and cooperative learning environment perfectly.

Within the social constructivist framework we settled on using project-based learning for our training, as it is a very hands-on and student-centered form of learning. It allows for cooperation between students with the teacher playing a facilitating role. We also included micro-learning, as the technical field is very hands-on and practical, which fits well with micro-learning.

Based on this framework we designed our first prototype of the course through the use of design-based research because it provided us with a structured and complete way to create our teaching and learning sequence.

To test the internal coherence of our teaching and learning sequence prototype we organized a focus group with 6 educational experts. Through this focus group we obtained and implemented various improvements to our final prototype.

The participants of the focus group suggested that students' misconceptions and misunderstandings should be addressed in the teaching learning sequence. The first prototype had various points where students were asked to individually study a concept through the tools provided to them. However, the first prototype included no moment where it was made sure that the knowledge students obtained through this self-directed learning was actually correct. To make sure this would not lead to misconceptions about certain concepts, we added an interactive session at the beginning of the next class in which students discussed the topic they individually studied among themselves with the teacher as a facilitator to make sure no misconceptions were created.

It was also suggested that safety precautions should be more specifically addressed in the teaching and learning sequence. The example project in the prototype only includes very simple electrical work. Even so, it is important to take safety precautions wherever possible, so we included safety instructions wherever necessary in the final prototype. Given that the actual projects used might include more difficult and dangerous electrical work, it is important for teachers using the teaching and learning sequence to evaluate if safety precautions are sufficient themselves. It should be noted that the use of VR to practice electrical work before conducting the work in the real world does add to the safety of the students, but it cannot replace proper safety precautions.

Another suggestion to come out of the focus group was the addition of specific indications of time for each activity. These were added to the final prototype to allow for a more structured way of instruction using the teaching and learning sequence.

It was also suggested that the client should be more involved in the project. To facilitate this, two moments were added to the final prototype in which the client would be present in class. These being the sixth week after the students have learned about their final piece of content and at the very end to listen to the students' presentation on the project.

The participants also suggested that the teacher has too prominent a role in the teaching and learning sequence for project-based learning, and that the instruction at the start of each week was more in line with the traditional education of the old trainings. To avoid this the instructions at the start of each class were changed to interactive sessions in which the students explain what they think a certain concept is and eventually arrive at the correct explanation of the concept through back and forth with the teacher. Rather than the teacher simply explaining the concept to the students.

Finally, it was suggested that there is a mismatch between the scientific inquiry cycle used in the teaching and learning sequence and the field of engineering. This mismatch was likely the consequence of the tension between science and engineering design. According to Pedersen (2015) it is the task of engineering design to assist in the realization of complex systems in their concrete real life context. On the other hand, it is the task of science to find and justify new knowledge about the universal working of nature. Often, scientific theories are far away from the concrete contexts that engineering design is about. Which leads to a certain tension or mismatch.

This tension is a complicated topic that could be the subject of an entire paper on its own. It was outside the scope of this project due to our limited available time and resources, but this tension would be an interesting venue for future research.

This study, as it was conducted, has several limitations. Our knowledge about engineering content is limited. To alleviate this we had originally planned a focus group with technical workers to obtain their insight in what should be taught in the course, but this focus group unfortunately ended up being impossible to arrange. As a result, we were forced to use very simple electrical procedures as the basis of our course, which might lead to difficulties when trying to apply the course to more difficult material.

The timeframe for this project was also relatively short, which meant that we were only able to go through one prototype of our teaching and learning sequence before arriving at our final version, ideally we would have been able to go through multiple prototypes before arriving at our final version.

As briefly mentioned before it would be interesting to delve into the tension between science and engineering in future research. Specifically on the tension between science and engineering when it comes to education. This could allow for a teaching cycle that is completely aligned with engineering which could lead to an improved teaching and learning sequence.

Further, it would be interesting to get the input of technical workers in future research. As mentioned before, one of the limitations of the current study was our inability to talk to technical workers about what content they think is required in an in-service training course. With the input of technical workers the content of the teaching and learning sequence can be more closely aligned to what they require, leading to a better teaching and learning sequence.

References

Adams, P. (2006). Exploring Social Constructivism: Theories and Practicalities. *Education 3-13*, *34*(3), 243–257. https://doi.org/10.1080/03004270600898893

Ahmad, S. F., Rahmat, M. K., Mubarik, M. S., Alam, M. M., & Hyder, S. I. (2021). Artificial intelligence and its role in education. *Sustainability*, *13*(22), 12902. https://doi.org/10.3390/su132212902

Cakmakci, G., Aydeniz, M., Brown, A., & Makokha, J. (2020). Situated Cognition and Cognitive Apprenticeship learning. In *Springer texts in education* (pp. 293–310). https://doi.org/10.1007/978-3-030-43620-9_20

De Carvalho, G. L., Fulgêncio, V. A., & Iannicelli, A. C. P. (2021). A comparison between analogic and digital media in Engineering teaching. *Acta Scientiarum. Education*, *43*, e51075. https://doi.org/10.4025/actascieduc.v43i1.51075

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of Project-based learning in Higher Education: Student Outcomes and Measures. *International Journal of Educational Research*, *102*, 101586. https://doi.org/10.1016/j.ijer.2020.101586

Handrianto, C., & Rahman, M. A. (2018). Project Based Learning: A Review of Literature on its Outcomes and Implementation Issues. *LET: Linguistics, Literature and English Teaching Journal*, *8*(2), 110–129.

Heyma, A., van Kesteren, J., Bakens, J., Gerards, R., Klinker, I., & Graus, E. (2022). Arbeidsmarktkrapte technici ontwikkelingen, verklaringen en handelingsperspectieven. In *Rijksoverheid*. SEO economish onderzoek. https://www.rijksoverheid.nl/documenten/rapporten/2022/09/15/rapport-arbeidsmarktkrapte-technici

Hmelo‐Silver, C. E. (2004). Problem-Based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/b:edpr.0000034022.16470.f3

Ito, T., Tanaka, M., Shin, M., & Miyazaki, K. (2021). THE ONLINE PBL (PROJECT-BASED LEARNING) EDUCATION SYSTEM USING AI (ARTIFICIAL INTELLIGENCE). *International conference on engineering and product design education*. https://doi.org/10.35199/epde.2021.19

Jalinus, N., Nabawi, R. A., & Mardin, A. (2017). The Seven Steps of Project Based Learning Model to Enhance Productive Competences of Vocational Students. *Advances in Social Science, Education and Humanities Research*, *102*. https://doi.org/10.2991/ictvt-17.2017.43

Jorba, J., & Puig, N. S. I. (1996). Enseñar, aprender y evaluar, un proceso de regulación continua : propuestas didácticas para las áreas de Ciencias de la Naturaleza y Matemáticas. https://dialnet.unirioja.es/servlet/libro?codigo=186191

Krajcik, J., & Shin, N. (2014). Project-Based learning. In *Cambridge University Press eBooks* (pp. 275–297). https://doi.org/10.1017/cbo9781139519526.018

Larmer, J., Mergendoller, J. R., & Boss, S. (2015). *Setting the standard for project based learning: a proven approach to rigorous classroom instruction*. https://www.amazon.com/Setting-Standard-Project-Based-Learning/dp/1416620338

Lu, J., Bridges, S., & Hmelo‐Silver, C. E. (2014). Problem-Based learning. In *Cambridge University Press eBooks* (pp. 298–318). https://doi.org/10.1017/cbo9781139519526.019

Mcmahon, M. (1997). Social Constructivism and the World Wide Web-A paradigm for learning. *ResearchGate*. https://www.researchgate.net/publication/243618245_Social_Constructivism_and_the_World_Wide_Web-A_Paradigm_for_Learning

Nieveen, N., & Folmer, E. (2013). Formative Evaluation in Educational Design Research. In *Educational Design research: An Introduction* (pp. 152–169). SLO.

Pedersen, S. A. (2015). The tension between science and engineering design. In *Philosophy of engineering and technology* (pp. 179–198). https://doi.org/10.1007/978-3-319-16172-3_10

Plomp, T. (2013). Educational Design Research: An Introduction. In *Educational Design research: An Introduction* (pp. 10–51). SLO.

Rannikmäe, M., Holbrook, J., & Soobard, R. (2020). Social Constructivism—Jerome Bruner. In *Springer texts in education* (pp. 259–275). https://doi.org/10.1007/978-3-030-43620-9_18

Rijksoverheid. (2020). Nationaal Techniekpact 2020. In *Rijksoverheid*. https://www.rijksoverheid.nl/documenten/convenanten/2013/05/13/nationaal-techniekpact-2020

Tapalova, O., & Zhiyenbayeva, N. (2022). Artificial Intelligence in Education: AIED for Personalised Learning Pathways. *Electronic Journal of e-Learning*, *20*(5), 639–653. https://doi.org/10.34190/ejel.20.5.2597

Taylor, A., & Hung, W. (2022). The Effects of Microlearning: A scoping review. *Educational Technology Research and Development*, *70*(2), 363–395. https://doi.org/10.1007/s11423-022-10084-1

Van Den Akker, J. (2013). Curricular Development Research as a Specimen of Educational Design Research. In *Educational Design research: An Introduction* (pp. 52–71). SLO.

Vygotsky, L. S. (1962). *Thought and language*. http://ci.nii.ac.jp/ncid/BA07207011

Windelband, L. (2023). Artificial intelligence and assistance Systems for technical vocational education and training – Opportunities and risks. In *Springer eBooks* (pp. 195–213). https://doi.org/10.1007/978-3-031-26490-0_12

Zhang, J., & West, R. E. (2019). Designing microlearning instruction for ProfessionalDevelopment through a competency based approach. *TechTrends*, *64*(2), 310–318. https://doi.org/10.1007/s11528-019-00449-4

Appendix A Focus group template

Task for participants

In the coming hour, we would like you to analyze the prototype for the teaching and learning sequence we have designed. We would like you to focus on the internal coherence of the teaching and learning sequence, which means we want to know if the teaching and learning sequence aligns with our teaching approach and learning objectives detailed below. We would like to receive comments on what all of you think can be improved upon in the final version of the teaching and learning sequence.

We would like you to answer the following questions:

Does the teaching and learning sequence generally align with the project-based learning and microlearning approach?

What improvements do you think should be made in the TLS to make it align even better with our PBL and microlearning approach?

Does the teaching and learning sequence generally align with the learning objectives?

What improvements do you think should be made in the TLS to make it align even better with our learning objectives?

Is it clear what is expected from the students and the teachers in the TLS?

Is there anything else you think we should improve in the TLS towards the final version?

Teaching approach

We use a combination of project-based learning and microlearning in our teaching and learning sequence. Below you will find a quick description of the steps of project-based learning we follow and microlearning.

Project-based learning steps

PBL is a student-centered form of teaching. It engages learners in knowledge construction by having them accomplish meaningful projects and develop real-world products (Guo et al., 2020). In project-based learning, students are allowed to investigate questions, propose hypotheses and explanations, argue for their ideas, challenge other ideas and try out new ideas, with instructors playing a supporting role to assist in the learner's learning process. We follow the following seven steps of PBL in our teaching and learning sequence:

1. Formulate a driving question or problem to be solved
2. Identify facts and formulate hypotheses
3. Identify gaps in current knowledge

4. Engage in self-directed learning as well as skills training
5. Apply newly obtained knowledge/skills to the problem
6. Evaluate
7. Reflect

Figure 1. The seven steps of project-based learning

2.1.1 Formulate a driving question or problem to be solved

An interesting and sufficiently complicated problem is necessary for good project-based learning. After all, it is the problems that make the learning process meaningful, learners are learning not just to obtain knowledge and skills and remember these, but to actually use this knowledge and these skills. By channeling learning through a project, learners not only obtain new knowledge and skills but also immediately learn where this knowledge and these skills can be used (Larmer et al., 2015).

Learners should ideally be supplied with minimal information about the problem to allow them to gather most of the facts themselves (Hmelo-Silver, 2004).

2.1.2 Identify facts and formulate hypotheses

In this step, learners should gather information and identify facts about the problem they've been presented with. This information can be obtained through questioning the one who supplied the problem, whether that be the teacher or a third party. Simple questions that can help learners in coming up with targeted questions are for example: ‘What do we know about the problem?’ and ‘What do we need to know to formulate a hypothesis?’. Based on the information obtained during this step, learners can come up with one or several hypotheses about the problem. (Hmelo-Silver, 2004; Larmer et al., 2015).

2.1.3 Identify gaps in current knowledge

When learners have gathered the relevant facts to the problem at hand, they should broaden the scope of the questions they previously asked to identify what knowledge and/or skills they are missing to solve the problem. Example questions would be: ‘What do we need to know to solve the problem?’ and ‘What knowledge/skills are we missing to solve the problem?’.

2.1.4 Engage in self-directed learning as well as skills training

When it is clear what knowledge/skills the learners are missing they should engage in self-directed learning (SDL) and skills training independently, at the end of this step the learners should regroup and share their new insight with one another, there is also an opportunity here for learners to reconsider their hypothesis or formulate an entirely new one based on their new learning (Hmelo-Silver, 2004).

Self-directed learning is an important feature of project-based learning, it is initiated through discussions in the previous steps. Learners have discussed the problem based on their initial knowledge and have assessed gaps in their knowledge and/or skills. With those gaps clear, learners can guide their own research and actively evaluate if their learning matches their learning goals (Lu et al., 2014).

However, given the more practical nature of the technical projects that would likely be supplied in the training courses we are discussing, it might not always be sufficient to have learners engage in theoretical research. Oftentimes, learners might need certain practical skills to solve the problem supplied. In this case, skills training should be provided to allow learners to obtain the skills necessary for solving the problem (Jalinus et al., 2017).

2.1.5 Apply newly obtained knowledge/skills to the problem

When learners have obtained the knowledge and skills necessary to solve the problem provided, they should apply this knowledge and these skills to actually solve the problem. The result should be a tangible product as a solution to the problem (Krajcik & Shin, 2014).

2.1.6 Evaluate

As learners finalize their project they should be able to evaluate whether or not their goals have been attained and whether or not the project was a success. On top of thinking about this individually and in their project group it can be beneficial to have learners present their project in front of the class. This allows for discussion between the project group and the other learners as well as the teacher (Hmelo-silver, 2004; Jalinus et al., 2017).

2.1.7 Reflect

Finally, reflection is an important part of the PBL approach. Reflection helps learners to relate their newly obtained knowledge to their prior knowledge, mindfully abstract knowledge and understand how their learning and problem-solving strategies might be applied again in the future (Hmelo-silver, 2004). Learners already reflect on their process a few times before this step, such as at the self-directed learning step, but in this step they should reflect on the project as a whole.

Microlearning

Microlearning has been gaining popularity over the past several years. Social media has changed people's information-seeking and consuming behaviors. Shifting their preference to single, discrete topics that are presented in a short duration to meet their moment of learning need (Taylor & Hung, 2022). Generally, microlearning can be described as a form of e-learning delivered in small chunks, focused on delivering skill-based and just-in-time knowledge (Zhang & West, 2020). Just-in-time knowledge can be defined as delivering the right knowledge at the right time (Taylor & Hung, 2022).

Microlearning can be delivered in the form of videos, documents and other varieties of learning created by learning professionals. Or, it can be developed by peers as user-generated content. The type of instruction varies in format and instructional purpose, but microlearning always provides bite-sized amounts of information that are easily and quickly consumed, learner-driven, and on-demand in nature (Taylor & Hung, 2022).

This makes it perfect for skills training in step 4 of the PBL approach in technical worker education. If learners have access to a catalog of content created by professionals in the field explaining and demonstrating the desired and required skills this could cut down on the need for instructors to be present for skills training drastically.

VR in microlearning

There are, however, limits to instruction through a video. After all, learners are still only observing how to perform certain tasks, rather than practicing performing these tasks themselves. Virtual reality can help make this learning more engaging.

VR can be used to simulate virtual work environments in which learners can practice practical skills through quick bite-sized lessons without the risk of damaging equipment or any of the danger that can come with working with unfamiliar equipment. In the meantime, instructions can be shown on the side in video, textual or other visual formats (Windelband, 2023). This allows learners to practice their skills in safe virtual environments that prepare them for work in the real world. Learners can take their time without risking potentially dangerous situations.

Aim of the TLS

The goal of the training course is to supply learners with the theoretical knowledge and practical skills they require to work in the technical field at a MBO level. The course should not only just provide the learners with the knowledge necessary, but should also provide them with ways to learn how to apply this knowledge in a practical setting. On top of that the course should provide learners with various skills they can use in the field.

Content of TLS

Throughout the course learners will obtain the knowledge and skills required to complete various projects in the technical field. On top of that, learners will learn how to complete projects working together in a team and what to expect from clients/employers when working on such projects. More specifically, this prototype is based on a set of specific content that needs to be taught during the course. This content consists of simple electrotechnical operations, more specifically, the course includes the following content: Creating a lighting system using a technical drawing, to do this learners will be taught about voltage, electricity, resistance and capacity, DC and AC voltage and 1 and 3-phase networks. Next they will be taught how to bend PVC-pipes, attach pipes, install distribution boxes, pull wires and weld them, install and wire electrical outlets, install and wire light switches and lamps, and provide the installation with electricity. On top of that, learners will be taught about a few different types of circuits, these being the series connection, hotel switch and the cross connection.

Content of the course	
Theoretical Knowledge	Practical Skills
Understanding voltage, electricity, resistance and capacity	Bending PVC-pipes
Understanding DC and AC voltage	Attaching pipes
Understanding 1 and 3-phase networks	Installing distribution boxes
Understanding how series, hotel and cross connections work	Pulling wires
	Welding wires
	Installing and wiring electrical outlets

	Installing and wiring light switches & lamps
	Providing an installation with electricity
	Creating a series, hotel and cross connection

Prototype of TLS

WEEKS	ACTIVITIES	OBJECTIVE	CONTENT	MATERIALS
1	**Teacher -** The beginning of the course is dedicated to setting the foundation for the project-based learning approach. The teacher begins by explaining the philosophy and expectations of PBL, emphasizing the importance of self-directed learning. To give learners a sense of the practical skills they'll develop in the course, the teacher provides a brief overview of the essential electrotechnical skills involved. This overview acts as a preview, establishing context for the projects that will follow	Providing learners with an overview of the course so they know what to expect.		Projector and screen
	Teacher - Ideally, clients or employers present the available projects to the learners. Having this real-world connection brings a sense of authenticity and motivates learner engagement. The careful selection of projects ensures they align with the skills and content of the course while giving learners a sense of choice and ownership over their learning journey. In the case of this prototype, only one project is available. The project is outlined above in section 6.2.2.3.	Introducing learners to the projects available to work on in the course to allow them to make an informed decision on what they want to work on.		Projector and screen
	Students - A1. Form	Forming the group		

	groups of 4 and decide which project you want to work on. When you have decided as a group, share your decision with the rest of the class.	you will be working with for the duration of the project and picking the project you will be working on.		
	Students - A2. Discuss with your group what you think the driving question of your project should be. Driving questions are likely to be along the lines of: What sort of electrical installation needs to be created to fulfill the needs of the client?	Formulating the driving question of your chosen project.		
	Teacher - To conclude the first class the teacher should instruct the groups to think about the knowledge and skills they still require to successfully work on the project. They should do this individually between now and the next class. Examples of the knowledge and skills learners are likely to come up with are knowledge about voltage, electricity, resistances and connections. As well as the ability to design, wire and install electrical circuits.	Getting learners to think about the knowledge and skills they want to learn about during the course.		
2	**Students -** A3. Talk with your group about the knowledge and skills you came up with that you think are necessary to complete the project.	Coming to an agreement on the skills and knowledge you want to obtain through the course with your group.		
	Teacher - The teacher	Making sure all		

	should engage the groups in discussion while they are discussing among themselves and guide them in the right direction through simple questions if necessary.	groups arrive at the right knowledge and skills required to successfully complete the course.		
	Students - A4. Together with your group, formulate a hypothesis about the project based on the knowledge and skills you came up with. A likely hypothesis would be something along the following lines: To fulfill the needs of the client we need an electrical installation that includes a series, hotel and cross connection.	Coming up with an hypothesis about the project.		
	Teacher - To facilitate self-directed learning, an AI chatbot program and micro-learning environment are used. It is important for the teacher to introduce both of these to the class as a whole and show them the basic functions of both programs.	Introducing learners to two of the learning tools used in the course so they can successfully engage with these when they need to.	.	Projector and screen
	Students - A5. As an individual, decide on one piece of knowledge you thought you were lacking that came up during your group discussion (it is best to start simple. e.g. Voltage) and use the AI chatbot program and micro-learning environment to delve into that topic. The AI chatbot program	Getting familiar with the learning tools introduced before while studying a simple topic such as Voltage.	Voltage	Computer, laptop or phone

	and micro-learning environment are discussed in more detail further up in section 6.2.2.6			
	Teacher - To conclude the second class the teacher should instruct the class to individually study the basic concepts (voltage, electricity, resistance and capacity) using the self-directed learning tools provided. To this end they will have to engage with the AI chatbot program and answer questions about the topics in the micro-learning environment.	Getting learners to engage with the learning tools introduced earlier to obtain basic knowledge they will need in the course.	Voltage, electricity, resistance and capacity	Computer, laptop or phone
3	**Teacher -** During this class, the learners are going to create a simple light installation. The teacher should start the class with an explanation of the VR program meant for skills training. The VR program is discussed in more detail further ur in section 6.2.2.6	Introducing learners to the VR program tool used in the course so they can successfully engage with it when they need to.		VR headsets
	Students - A6. Individually, use the VR program to walk through the following lessons: Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity. The lesson on installing	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets,	VR headset

	and wiring electrical outlets for example would show learners a video on how to properly execute the task before simulating the components and allowing the learners to try it for themselves in virtual reality.		installing and wiring light switches & lamps and providing an installation with electricity.	
	Students - A7. As a group, use the knowledge you obtained through the VR program to create a simple light installation based on a simple technical drawing. The installation should include 1 lamp that can be controlled with a switch from a fixed point.	Using the knowledge and skills obtained through the VR program to create a simple light installation that can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps and providing an installation with electricity.	Electrical components, technical drawing of the installation
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the	Evaluating the work of the learners.		

	groups of learners. In this case it should be evaluated if the lamp can be turned on and off using the switch of the installation.			
	Teacher - To conclude the third class the teacher should instruct the class to individually study AC and DC voltage as well as 1 and 3-phase networks using the self-directed learning tools.	Getting learners to engage with the learning tools introduced earlier to obtain more knowledge they will need in the course.	AC/DC voltage, 1 and 3-phase networks	Computer, laptop or phone
4	**Teacher -** During this class, learners are going to create a light installation with a series connection. The teacher should start the class with a basic explanation of a series connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Series connection	Projector and screen
	Students - A8. Individually, use the VR program to walk through the lesson about series connections. Again, learners would be shown a video on how to properly create a series connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Series connection	VR Headset
	Students - A9. As a group, use the knowledge you obtained through the VR program to create a series connection light installation based on a simple drawing. The installation should have 2	Using the knowledge and skills obtained through the VR program to create a series connection light installation that can be	Series connection	Electrical components

	lamps that need to be controlled from 1 place, both lamps are supposed to be able to turn on and off in turn.	evaluated by the teacher.		
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the 2 lamps in the installation can be controlled by the switch and can be turned on and off in turn.	Evaluating the work of the learners.		
5	**Teacher -** During this class, learners are going to create a light installation with a hotel connection. The teacher should start the class with a basic explanation of a hotel connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Hotel connection	Projector and screen
	Students - A10. Individually, use the VR program to walk through the lessons about hotel connections. Again, learners would be shown a video on how to properly create a hotel connection after which the components they need to create the connection will be simulated and they will be allowed to create it	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Hotel connection	VR Headset

	themselves in virtual reality.			
	Students - A11. As a group, use the knowledge you obtained through the VR program to create a hotel connection light installation based on a simple drawing. The installation should have 1 lamp that can be controlled by 2 switches in different locations.	Using the knowledge and skills obtained through the VR program to create a hotel connection light installation that can be evaluated by the teacher.	Hotel connection	Electrical components
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be controlled individually by the 2 different switches.	Evaluating the work of the learners.		
6	**Teacher -** During this class, learners are going to create a light installation with a cross connection. The teacher should start the class with a basic explanation of a cross connection.	Introducing learners to the concept that will be at the center of today's class so they know what to expect.	Cross connection	Projector and screen
	Students - A12. Individually, use the VR program to walk through the lessons about cross connections.	Engaging with the VR program tool to get familiar with the skills that will be required for today's class.	Cross connection	VR Headset

	Again, learners would be shown a video on how to properly create a cross connection after which the components they need to create the connection will be simulated and they will be allowed to create it themselves in virtual reality.			
	Students - A13. As a group, use the knowledge you obtained through the VR program to create a cross connection light installation based on a simple drawing. The installation should have 1 lamp that can be controlled by 3 switches in different locations.	Using the knowledge and skills obtained through the VR program to create a cross connection light installation that can be evaluated by the teacher.	Cross connection	Electrical components
	Teacher - The teacher should be available to support the groups during the process in case things go wrong, but ideally the groups would be able to figure out the installation themselves.	Assisting learners should things go wrong or if learners can't figure something out. The installation is simple enough that things won't get dangerous.		
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the lamp in the installation can be turned on and off by the 3 different switches in the installation.	Evaluating the work of the learners.		
7	**Teacher -** During this class, learners will work in their group to use the knowledge and skills they have obtained to create a light installation that fits	Introducing learners to the assignment they will work on during this class so they know what to	Bending PVC-pipes, attaching pipes, installing distribution	

	the requirements of the project. This means the light installation has to include a series, hotel and cross connection. The teacher should start with an explanation of what is expected.	expect.	boxes, pulling wires, welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Students - A14. As a group, reflect on your hypothesis and driving question. Using the knowledge and skill you have obtained during the course, evaluate if the hypothesis is still accurate or needs to be revised.	Evaluating if the hypothesis your group came up with is accurate or if it needs revision.		
	Students - A15. As a group, create a light installation with all the elements to satisfy your driving question.	Using the knowledge and skills obtained throughout the entire course to create a light installation that satisfies your driving question and can be evaluated by the teacher.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires, welding wires, installing and wiring electrical	Electrical components

			outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the installation contains all three of the different connections that it should (series, hotel and cross) and if the installation works as it should.	Evaluating the work of the learners.		
	Teacher - When the groups are finished, the teacher should introduce a malfunction into the system while the groups are on break.	Testing learners' understanding of the workings of the installation they created by introducing a malfunction for them to find and solve.		
	Students - A16. As a group, figure out what is wrong with your system and repair the malfunction to restore the system back to normal.	Putting your knowledge to work in solving a malfunction in your system and restoring it to normal.	Bending PVC-pipes, attaching pipes, installing distribution boxes, pulling wires,	

			welding wires, installing and wiring electrical outlets, installing and wiring light switches & lamps, providing an installation with electricity, series connection, hotel connection, cross connection.	
	Teacher - The teacher should evaluate the installation made by the groups of learners. In this case it should be evaluated if the learners found the malfunction and repaired it properly, restoring the installation back to proper function.	Evaluating the work of the learners.		
	Teacher - To conclude the class, the teacher should instruct the groups to create a presentation about their project before the next session.	Getting learners to think about what they want to discuss about their project with the rest of the class.		
8	**Teacher -** During this class, the groups will present their projects one by one. The teacher should decide on an order of presentation.	Creating an order of presentations so learners know when they are supposed to present.		Projector and screen
	Students - A17. As a group, present your	Discussing together with the		Projector and screen

	project. Discuss with the teacher and rest of the class about what went well and what could have gone better.	teacher and other groups what could have been done to make the project easier to complete.		
	Students - A18. As a group, discuss the project among yourselves. Focus the process of the project and reflect on what you would use this knowledge for in the future.	Discussing together with your group about what you have learned and what you can use this knowledge for in the future.		

Appendix B Focus group results

Answers to questions

1. Does the teaching and learning sequence generally align with the project-based learning and microlearning approach?

    - The TLS generally aligns with the PBL and microlearning approach. It focuses heavily on the microlearning and use of VR by breaking down the parts by different installations with different switches and components.

    - Overall the structure is aligned with PBL at least at my level of understanding. However, I have difficulty understanding how the inquiry cycle within the PBL cycle is going to be facilitated. I miss students' misconceptions and prior knowledge. How is that going to be addressed?

    - After the problem definition, you say that the students have to identify the knowledge and skills they need to solve this problem. This is an amazing strategy! But what is the plan to support the students if they miss something during their investigation? How is feedback going to be provided to them?

    - The selected structure of PBL is based on an inquiry process (with hypothesis, research, etc.). The aim to develop technical knowledge is not aligned with a scientific inquiry. Therefore, the project should be guided for technological driving questions. ‘How can different available technologies help me to address this client issue?’

2. What improvements do you think should be made in the TLS to make it align even better with our PBL and microlearning approach?

    - The clients should be more involved with the project, not only the teacher. Maybe every few weeks the client can come and see how the project is going and give advice about the project to the students.

    - Collect students ‘ prior knowledge and misconceptions so you can be sure they collect the correct information.

    - Based on the literature about misconceptions and challenges, prepare a plan for inputs that can facilitate their building of understanding the knowledge and skills they need to implement in order to solve the problem.

    - PBL is aligned with constructivist perspectives, so how is the project ensuring that no misconceptions around electricity arise?

    - Preparing microlearning activities should be considered in the design. Very open projects cannot be compatible with a guided instruction towards certain skills and knowledge. Anticipation of the issues that every problem involves and how they are linked to different pedagogical choices (VR, chabots, etc) should be better described.

3. Does the teaching and learning sequence generally align with the learning objectives?

    - Yes, it teaches the students the skills to create a lighting system. Students are taught about the different components through self-learning or micro learning, this might however allow them to be selective in their learning and to not go through all the aspects but only those needed for their chosen project.

4. What improvements do you think should be made in the TLS to make it align even better with our learning objectives?

    - It is unclear whether it also teaches them to create a technical drawing, or whether these are provided to them.

5. Is it clear what is expected from the students and the teachers in the TLS?

    - Yes, it is. Teachers explain the philosophy of PBL in the first week. Teachers should supervise the student’s project progress every week.

6. Is there anything else you think we should improve in the TLS towards the final version?

- When the students are asked to learn individually about the concepts, the teacher needs to make sure they understand the concepts correctly and misconceptions do not exist.

- Before students work on the project, the teacher needs to explain how long it takes to finish it.

- For now, it is still a bit vague to see whether students can be selective in their micro learning environment because the projects they can choose are not provided. If the projects were provided, it would be clearer to see what components students would need for their lighting system and whether all components are within this lighting system.

- Safety regulations are not clear, you are working with voltage and power here, these should be clearer than “the installation is simple enough that things won't get dangerous”.

- AI chatbots functions should be better explicated to the students (what are their options and uses.

- More logistical aspects about project time limitations should be mentioned.

- Sentences as the teacher should start with a basic explanation of hotel connection conveys a traditional idea of learning not aligned with PBL.

Open discussion

Participant 1

For me it was interesting because the learning objectives are mainly focused on small concepts and then very specific skills, but then project-based learning kind of goes for a more complex situation. I can imagine a technology expert doesn't just have to fix a plug or a pipe. So it's kind of a more complex situation. So I think there's a gap there, we are focusing very much on the small skills, but we are not taking advantage of using a project-based approach.

At least for me it is not super clear how the different driving questions tackle this.

Participant 3

Would that be because you missed the project provided, or just because there's a different path?

Participant 1

I don't know. It's not explicit what the projects are, so maybe the project is really taking advantage of these methodologies.

Participant 3

Yeah, that's why.

Participant 2

Also, I think we care that it missed the strategy of how the small inquiries within this cycle will be aligned to the big problems, this connection.

Participant 1

Yeah. And also, it said: let's talk about resistance. Why is it important to know about resistance? So for me linking the skills with the concept and seeing what the use is of knowing how. How it plays a role I think, yeah. Learning objectives can be improved in that direction.

And I don't see any opportunity to transfer knowledge like, yeah, we do the project and yeah, we did reflect about our different projects, but how do I know that this person is competent in using these skills and knowledge in a different situation?

Participant 4

Is your suggestion to let the students design the installation for a whole house, for instance, to make it more complicated and more a project?

Participant 5

Maybe not a whole house. Maybe one or two rooms.

Participant 3

Or the entire group could do like the entire class could do a system for an entire house. And yeah, different groups and they could work on different rooms.

Participant 2

Yeah, I don't know. The way that I understood the process is that something like that will be assigned to them. A client, hypothetical or real, will come and say I want to develop the electrical facilities for my house and then during the course this task will be broken into sub tasks and small inquiry cycles within the project until the students will end up with the big project. So I think this already exists.

What I think I miss is the role of the teacher as a facilitator during these small inquiries. The chat bot will probably be programmed to facilitate this. But I missed the explanation of how, for example, they do the problem definition at the beginning and it's very nice that they have to identify for themselves the knowledge and the skills that they have to apply to solve this problem. But do we have a plan if they don't find the suitable knowledge and skills that are needed? How we will address this gap if they don't.

I think this part should be first as a way to collect their misconceptions and then build on that with different pathways for each group. Or for each one of them somehow, to help them reach finally the proper knowledge and skills that they need to acquire to to solve the problem.

Another thing that I felt I miss is the structure of a worksheet during the experiments. Because it's very nice that they will experiment with themselves to, for example, make a circuit and see in the end if the lamp lights up or not.

But during this we have to somehow help them structure their reasoning to start from having a hypothesis on how the circuit will be, to testing the hypothesis, to measuring the results in this case through an observation. And interpret the results and conduct conclusions and then generalize in order to be able to transfer the knowledge to another situation. For us it's very for granted, but I'm not sure if it is for MBO students. And we have to help them structure their way of thinking somehow.

Participant 1

Yeah, I don't know if I completely agree with everything because we're thinking about it from a very scientific perspective maybe so we're thinking ohh they need to explore the misconceptions and then from that developed scientific ideas. But here we are talking about more engineering skills.

Participant 2

Yes, I know. I'm not an engineer, so I cannot think that way.

Participant 1

They should test differently so opportunities to develop like this engineering practices should be part of the project and here the structure, the model that you use for project based learning. It's kind of you getting engaged in a scientific inquiry rather than having an engineering problem and a design process.

Participant 2

Probably he could use an engineering design cycle instead.

Participant 1

Yeah, a design thinking type of structure, which is also compatible with project-based learning.

Participant 2

Yes, because basically I think that's why also I lost in the inquiries more than the design.

Participant 3

Not necessarily even prototypes, I think, because here I understood it like they need to create a lighting system using a technical drawing, but I never see that they draw a technical drawing themselves. So I'm missing a practical skill here in the skill set because you're giving a project that could be anything we don't know if it's variable, you need to be able to make the technical drawing yourself and play with that. This might be a form of design right on a lower basis.

Participant 1

It's quite demanding designing the technical drawing.

Participant 3

No, but they've been given technical drawings and then they need to use them.

Participant 1

Yeah, but one thing is understanding it and another knowing all the nuances about it. Maybe they have just to interpret it.

Participant 4

They practice, they have a technical drawing and then they make the installation.

Participant 2

Yeah

Participant 5

What makes me interested is what kind of VR can change the role of the teacher, what kind of VR is used. For example VR 360 is just a video.

Participant 1

I was imagining more a kind of thing that you can test things in.

Participant 5

So I have designed an electrical circuit and then I try it in VR and then the simulation is working, so we can start on the real things.

Participant 2

But sometimes it's also important to not start with the real things and compare the simulation with the real things, because it's also an interesting lesson to see that maybe your design, your hypothesis, can be perfect in that perfect world of simulation, but in real life there are things other complex things that you have to take into consideration.

Participant 5

We are talking about the electrical thing, so I am from engineering of course. And before we do real things, I mean the real thing we have to buy like a lamp. If we are wrong, we will waste the lamp. So to avoid that we make some simulations first and we test it in the simulation. So I think it doesn't have to be VR if we have the simulation software.

Also, the teachers supervise but maybe it can be more of a real world problem if the client also comes a few times, not only in the first time to supervise and explain.

Participant 3

Yeah, or not even explaining, but also more elaborating, if you're going to test it with materials and it's going to break down, it's going to cost us this much money.

Participant 4

Well, I think well, you made a lot of useful remarks about the project. Well, first, the examples I know of project-based learning are more well students work rather independently and I think here the teacher has a very prominent role in explanation in instruction, so I would say it is not my idea of project-based learning.

Participant 4

Also, the theoretical component here, I think it's very difficult to connect the theoretical component with the practical component.

I think you should also be aware of misconceptions. Although these students are well to some extent familiar with the concepts because, well, they come from a technical field and they know the concepts of resistance, voltage and current. But there is a lot of literature about possible misconceptions about these concepts.

And I read somewhere: start simple with voltage. So, what do you mean by that? Start simple with voltage. I think it's not a simple concept and you can also see that in literature that it's well, it's less simple than we think.

Also, I liked the malfunction example which was included in your teaching learning sequence. It might be a good illustration to the students.

What I missed was, but I didn't read it very carefully because there was not sufficient time for that, but about safety because that's very important when you work with electricity, safety regulations are very strict here.

Participant 1

That's also an added value from virtual reality. Like you can try things without being unsafe.