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Evaluation of the virtual training softwares SeQualia and Vizendo

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BACHELOR'S THESIS
Industrial Engineering and Management
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Preface

This Bachelor thesis has been performed during 27 March to 31 May 2017 at Scania in Södertälje. The thesis is a part of the final examination of the program Industrial Engineering and Management at University West in Trollhättan. The report writing in the thesis has been divided equally by the authors and the work assignment is executed together.

The authors will firstly thank Scania for the possibility to perform the thesis in the department of Global Industrial Development and to the employees for shown interest and answering questions. Many thanks especially to our supervisors Lars Hanson at Scania and Lennart Malmsköld at University West for all the support and guidance during the study. We would also like to thank the employees at Scania Academy for the gently welcome and help in the pedal car factory. Lastly thanks to Pontus Lundin for the support and quick response to our questions in SeQualia.

Best regards,

Nathalie Augustsson Helena Löfström

BACHELOR'S THESIS

Evaluation of virtual training software SeQualia and Vizendo

Summary

The automotive industry is constantly developing and manufacturing industry is facing modernisation and need for increased efficiency which implies that the automotive industry is facing changes for assembly training. To minimise quality errors and save time computer-based training virtual training can be used to practice on product knowledge, variants and sequences. Currently in traditional training in automotive industries, the operators practice on psychical products.

The purpose of this bachelor thesis is to obtain knowledge of the effects of virtual training with cycle times longer than five minutes by evaluate the virtual training methods at Scania in Södertälje, Sweden. To achieve the purpose of the thesis the objective is to create a basis of the advantages and disadvantages. Scania is part of the Volkswagen Group and is a world leading supplier in the automotive industry which develops custom made and high-quality products with short lead times. Scania's core products are heavy trucks, buses and engines for marine and industrial applications. Scania has 46 000 employees in 100 countries. Today Scania use standardised work and Job Instructions Training tools for learning the assembling processes which could be time consuming, ineffective and resource-intensive. Therefore, Scania's vision with virtual training is to shorten the learning time on-line by implementing virtual training to practice off-line. The main objectives are to reduce the time for training simultaneously as the product quality increases.

To obtain reliable information to reach the purpose a qualitative approach has been used in the study. To obtain primary data the methods have been semi-structured interviews, observation and questionnaires that have been performed and literature studies have been used to collect secondary data to obtain a broad knowledge of the subject. Through this the bachelor thesis resulted in recommendations that will contribute to Scania's decision of future work with virtual training. The recommendations have been based on the previous accomplished studies, results and obtained comments which together were connected in the discussion and by the recommendations the authors believe that Scania can use virtual training with success.

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Nomenclature

Andon	System to notify problems occurred in production
AviX	Production Technical Software
DELMIA	Digital Enterprise Lean Manufacturing Interactive Application
DFX	Design For Excellence
FMEA	Failure Mode Effect Analysis
JIT	Job Instruction Training
MONA	A broadsheet specific for each vehicle including article numbers and important information
MSEK	Million Swedish crowns
NASA	National Aeronautics and Space Administration
NEVS	National Electric Vehicle Sweden AB
Nm	Newton meter
PDCA	Plan, Do, Check and Act
SAAB	Saab Automobile AB
SMED	Single Minutes Exchange of Dies
Takt	Determines the speed of a flow
TQM	Total Quality Management
TWI	Training Within Industry

1 Introduction

The automotive industry technology is constantly developing and the manufacturing industries are facing modernisation and need for increased efficiency (Borsci et al 2016). To be competitive it requires the ability to manufacture customised products with short lead times and to manage rapid changes in volume and product type (Malmsköld et al 2007). Due to advances in technology, the automotive industry is facing changes since traditional training methods require physical prototypes. Gaining experience of learning by doing is not always the most cost-effective solution since the physical prototypes might not exist. This might be a safety risk for inexperienced operators and the method is time-consuming (Borsci et al. 2016). It is possible to train operators to cope with rapid changes in the process through computer-based techniques, while the product quality is maintained for both internal and external customers (Malmsköld et al. 2007). Within virtual training, computer-based training has received increased attention in manufacturing. It has shown to be an effective method for training with short cycle times which is defined as less than two minutes. Cycle time is the time to complete one or several operations.

Virtual training is a training method that allows companies to provide computer-based and resource-efficient training and previous studies have shown positive effects such as faster and better cognitive learning compared to the traditional method of training mounting processes (Malmsköld et al. 2007). The automotive industries have high percentages of manual work and often try to increase the quality and efficiency in their products and processes. This requires higher qualification among the operators (Muller et al. 2016). Therefore, Muller et al. (2016, p.353) claims "*Training for operators becomes a crucial task in this process*". Currently, in traditional training in automotive industries, the operators practice on product knowledge, variants and sequences on-line. Instead, all these tasks could be practiced in virtual training off-line, it would save time and minimise quality errors. The traditional on-line training also includes craftsmanship, speed and timing as well as work in physical environment and strain (Olofsson & Waker, 2014).

Scania uses standardised work and Job Instructions Training (JIT) tools for learning the assembly process. JIT is founded from the method TWI, Training Within Industry and can be a resource intensive process since it requires one person responsible to teach each operator during learning (Liker & Meier, 2006). Menn & Seliger (2016) describes that each operator obtains different knowledge since the teaching is performed by operators with different experiences. The current training process at Scania is divided into two parts, Basic skills and on-line training. Scania's on-line training includes product knowledge, variant- and sequence training as well as training with focus on speed, timing, psychical environment and strain. The basic skills training is performed in Scania academy's division of technical training. Scania's vision with virtual training is to shorten the learning time on-line by implementing virtual training for product knowledge, variants and sequences off-line. The main objectives are to reduce the time for training simultaneously as the product quality increases. The quality is defined by defects that arise during assembly.

1.1 Scania AB

Scania is part of the Volkswagen Group and is a world leading supplier in the automotive industry which develops custom made and high-quality products with short lead times. Scania was founded in 1891 in Södertälje (Scania, 2017) and their vision is "*to drive the shift towards a sustainable transport system, creating a world of mobility that is better for business, society and the environment*" (Scania, 2016, p. 10). Their core products are heavy trucks, buses and engines for marine and industrial applications. In addition to physical products, Scania has built a great activity for maintenance of products and financial services. Today Scania has 46 000 employees in 100 countries. The activities are mainly conducted in Södertälje where the head office is located. The production is also located in Finland, France, Netherlands, Poland, Brazil and Argentina. Regional product centres are located in six emerging markets in Asia and Africa. In 2016 the net sales amounted to 103 927 MSEK (Scania, 2017).

1.2 Purpose

The purpose of this bachelor thesis is to obtain knowledge of the effects of virtual training with cycle times longer than five minutes for assembling.

1.3 Problem description

In the traditional training methods, the operators need physical prototypes to practice on. There might be safety risks in terms of occupational injuries and defects in the quality, not least if the operators are inexperienced. Training requires one person responsible to teach an operator which results in a resource intensive process.

No previous studies have been found that proves that virtual training gives positive effects on longer cycle times. Due to this, Scania does not know which of the virtual training methods are the most advantageous. As a result, current training methods could be time consuming, ineffective and resource-intensive.

1.4 Questions to be investigated

- What are the advantages and disadvantages with the virtual training software SeQualia?
- What are the advantages and disadvantages with the virtual training software Vizendo?

- What influences do SeQualia and Vizendo have on cognitive learning time for longer cycle times?

1.5 Objectives

The goal is to obtain knowledge of virtual training in the softwares SeQualia and Vizendo. The findings will support Scania's decision to introduce virtual training in the assembly process.

1.6 Project Scope

The scope of the study is delimited within Scania's education factory and inexperienced operators. The work is limited to two virtual softwares, SeQualia and Vizendo, which have been selected by Scania. All computer software and other infrastructure needed are expected to be arranged by Scania. The time span for the study is ten weeks and includes 15 credits.

2 Method

This chapter describes the methods used to achieve the objectives and purpose of the thesis. It starts by describing scientific approach and is narrowed down to description of the selected practices and credibility in the methods.

2.1 Research approaches

According to Björklund & Paulsson (2014) there are three different ways to perform a study; *analytical* approach, *system* approach and *actor* approach. The *analytical* approach strives to explain the truth objectively. It searches for cause-effect relations from a holistic perspective, where the reality is divided into smaller parts and the smaller parts together form the whole. The *system* approach views reality objectively but considers reality separated from the whole. It strives to find effects and relations between different parts to understand the underlying factors. The *actor* approach views reality as a social construction that is affected by, or affects humans. In this approach the actor is a part of the social construction (ibid). The system approach is used in this study since the reality is seen objectively and to consider all factors.

There are three different research approaches in scientific work; quantitative, qualitative and a combination (Creswell, 2014). Björklund & Paulsson (2014) claims that the approach is determined by the purpose of the study. Therefore, Creswell (2014) implies that the different approaches should not be considered as opposites, but rather more or less of the *quantitative* or the *qualitative* approach, the combined version is a mix of *quantitative* and *qualitative*. While a *quantitative* method contains numbered and measurable data, the *qualitative* approach is used to explore and increase the understanding of specific activities and conditions. In the mixed approach, the study examines both the variables' relationship and their deeper meaning. A *qualitative* study is the most suitable for observations and interviews (Björklund & Paulsson, 2014). A *qualitative* study approach has been used in this study since a *quantitative* approach is not appropriate where the statistical basis had been too small in proportion to the scope of the study.

It is common to use a case study if both observation and interview will be used (Holmblad, 2017). A case study is a strategy for research that examines a special case, where the boundaries sometimes are difficult to define. The researcher needs to identify a research question that examines, for instance, an individual, a group or an activity. Case studies have different intentions; descriptive, explicatory or exploratory. The descriptive study aims to explore and describe phenomena, while the explicatory study searches for causal links and explanations. The exploratory study aims to find a solution to an identified problem (Backman, 2016). A descriptive study has been used in this thesis where phenomenon have been explored and described.

There are three different factors which need to be considered in a scientific context. These are validity, reliability and objectivity, which together determine the study's credibility. The validity is defined in how well the study is performed to achieve the purpose, reliability defines to which extent the result of the study will be the same in a replication of the study, and objectivity in how personal values have affected the study (Björklund & Paulsson, 2014).

2.2 Data collection

The data selection methods have been used to collect primary and secondary data. The secondary data has been collected through literature studies while interviews, observations and questionnaires have been used to collected primary data. Secondary data is defined of that the information has been produced for different purposes than this study. Primary data is the information that is collected for the specific study.

2.2.1 Literature study

Björklund & Paulsson (2014) describes that all forms of written material can be collected through a literature study. The literature can be written material such as books, articles and journals. The given information is secondary data as generally has been produced for different purposes than this study. Therefore, it is important to consider that the data might be angled. Another critical aspect is the searching approach, for example the selected keywords and databases. According to Backman (2016) a literature study is often used to summarise the literature that is acknowledged, with the purpose to get an understanding of the background and of what is known within the topics. Literature studies could also be used to form problem descriptions and method approaches and see how the topic should be analysed.

Literature in forms of books, articles, PowerPoints, conference material, web pages and Scania's internal material have been collected to gather a large amount of facts within a short time. The course literature from the program Industrial Engineering and Management has been examined to evaluate the literature from the program that could be useful in this study. The literatures subjects in the study are mainly about cognitive learning, training within industry, virtual training, quality improvements and Lean Production. The Scientific articles that been used have been collected in the databases; *ScienceDirect, IEEE Xplore, SAGE Journals, Taylor & Francis Online, springer Link*. The keywords that have been used for searches in the present study are: *Virtual reality, Virtual training, Game-based training, Computer-based training, Vizendo, SeQualia, Assembly, Automotive industry, Manufacturing, Learning, Skills, VISTRA* and *Kaizen.*

2.2.2 Interviews

Interview is an established method to collect primary data. Interviews can be conducted with one person or in groups in form of; *structured, unstructured* or *semi-structured* approach. In a *structured* interview the questions are predetermined and in a certain order while an *unstructured* interview is completely open prepared to form a conversation. The *semi-structured* interview is a combination where some of the questions are predetermined and new questions are formed during the interview depending on the response (Björklund & Paulsson, 2014).

Semi-structured interviews have been carried out to provide deeper understanding of the virtual computer-based software and to get information about earlier studies with SeQualia and Vizendo. Control questions were asked to ensure that the information was perceived correctly during the interviews.

2.2.3 Observation

Observations can be performed in two different ways; in participation form or observance form. The person observed can be informed or unaware of the observation (Björklund & Paulsson, 2014). Genchi genbutsu is an observance form which means go to the place and see the actual situation to receive understanding (Liker, 2009). Liker (2009) explains the importance of examine a problem before and by this ensure a good understanding. It is unacceptable to take something for granted and just rely on reports. Tables and numbers can show results but will not show any details about the actual work. Backman (2016) emphasises that if you want to understand the reality, you need to observe it.

Observations in an observance form have been used to measure the parameters. The trainees have been informed of the observation to keep the open dialog that Scania promotes. Genchi genbutsu has been used to get an understanding of the current learning process in the pedal car factory and the assembling in the real factories.

2.2.4 Questionnaire

A questionnaire consists of several predetermined questions, traditionally with graduation or yes and no answers. The corresponding has in some cases the opportunity to give detailed answers. The questionnaires can vary depending on receiver and design. Data collection with questionnaires easily gets a large amount of primary data with small efforts. Delayed questionnaires, misinterpretations and difficulties to read the respondents' body language are all critical moments with questionnaires (Björklund & Paulsson, 2014).

Questionnaires have been used in the study to acquire information of the trainees and the Training managers' experiences of virtual training with SeQualia and Vizendo. The questions were presented with a one-to-five scale where one means *I do not* agree and five means *I agree*.

2.3 Study approach

The thesis started with project planning where the authors and the supervisors at University West and Scania formed the basis of the project, the study approach is visualised in figure 2.1. Problem description and objectives have been generated and developed through dialogues. The PDCA-method which consists of *Plan*, *Do*, *Check* and *Act* (Petersson et al. 2008) has been used continuously along the thesis. The *Plan*-phase has been used to plan the approach and to prevent eventual problems where an open communication has contributed to that problems being solved easily. The planned activities include interviews, questionnaires, set-up for training and observations. During the *Do*-phase the planned activities have been carried out. The *Check*-phase has provided the thesis with mainly learning regardless of the results by analyses. After knowledge was acquired, the recommendations have been formed to Scania's future work with virtual training. The *Act*-phase will not be included in the thesis since Scania is responsible for implementing standardisations. Throughout the thesis literature studies have been carried out.

Figure 2.1 Visualisation of the study approach

The software AviX Methods was used to ensure the quality of the data to SeQualia and the material was updated to be comparable with the worksheets which were used for training. Information from standardised worksheets from the pedal car factory was manually transferred and updated into the software. By comparing the content of Vizendo with the standardised worksheets, the data for Vizendo was quality secured.

Semi-structured interviews were carried out with managers who have experience of the softwares. The interviewed persons were a Productions Group Manager at the Chassis assembly line at Scania who had experience of Vizendo and a Process Manager at NEVS who had experience of SeQualia. The interviews lasted during approximately 30 to 60 minutes each. The earlier studies with the softwares were documented and the information have been summarised and analysed.

A current situation analysis was carried out to obtain information of the current situation in the pedal car factory. An observation through Genchi genbutsu was used to get an understanding of the assembly process. To gain information and data of the current training process in the pedal car factory a randomised reference group was used. Participants in the reference group consisted of new operators where two participants were selected by the Training managers for observation and measurements. The reference group performed Scania Academy's traditional training and the measurements were accomplished while the trainees were assembling. The set-up for the traditional training is shown in the upper part of figure 2.2. All groups practiced theoretical training in one hour where the trainees read the standardised worksheets before the performed practical training. The reference group was observed and measured during the first and fourth education day since there was no practical training on the second and third day. Before the first measurement was accomplished, the reference group performed practical training during one hour and the trainees were practicing for two hours until the second measurement was accomplished. The table used for measurements is shown in appendix A, the measured parameters were:

- **Wrong operation**: Faults where the operators chose operations in wrong sequence or miss operations.

- **Correct operation but wrong performance:** Faults where the operators' performance is wrong according to the standard worksheet or wrong articles and tools are being used.

- **Checking instructions for operation or performance:** When the operators check instructions for operation or performance, it is noted as the instructions are checked for the entire pedal car.

- **Quality defects:** Quality defects are controlled and counted for each car.

- **Cycle time:** The time to assembly the pedal car.

To obtain information of alternative assembly training in the pedal car factory two test groups were observed and measured. The test groups consisted of trainees from four education groups. The alternative training contained of practical training combined with computer-based training where Test group 1 used SeQualia and Test group 2 used Vizendo. The set-up for training is inspired by Scania's four-step method and is shown in figure 2.2 where the M1 and M2 are measurement one and two.

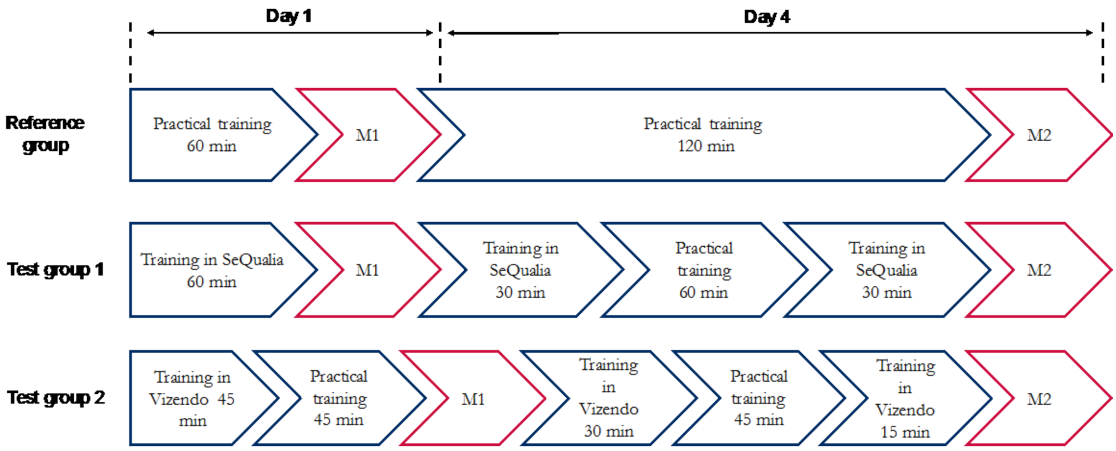

Figure 2.2 Training set-up for the Reference group & Test groups

In Test group 1, four trainees from Station 1 and six trainees from Station 2 to 4, were trained in SeQualia. The trainees were allocated in the stations available for training. Test group 1 practiced computer-based training one hour during the first education day and the measurements were accomplished after each moment with computer-based training. The measurements were carried out according to the earlier presented parameters on Station 1. At the fourth day, computer-based training was combined with practical training; 30 minutes of training in SeQualia, 60 minutes of practical training and 30 minutes of training in

SeQualia. SeQualia included one level of difficulty for all operations for red and black pedal cars.

In Test group 2, four trainees from Station 1 trained in Vizendo where one trainee trained at a time. Test group 2 trained 45 minutes in Vizendo and performed practical training for 45 minutes during the first education day. The measurements were accomplished at Station 1 in the end of the first and fourth education day. During the fourth day, computer-based training was combined with practical training; 30 minutes of training in Vizendo, 45 minutes of practical training and 15 minutes of training in Vizendo. Vizendo consisted of three difficulty levels for operation one to nine for red pedal cars, where level one and two were used to get an understanding of the software. The data in the software was not consistent with the standardised worksheets and the trainees were informed in this before the training in Vizendo started. The faults in Vizendo were at Operation 1, 2 and 3 where the assembling should have been performed at the left of the pedal car, instead of the right side and the hand grip for Operation 1 was wrong. At Operation 7, a step was missing where the user should had checked that there was a hole at the left fender. After the education weeks of training in SeQualia and Vizendo the trainees and Training managers answered a questionnaire of their experience of training with the software.

Observations through Genchi genbutsu were used to map the assembly operations in a truck assembly factory. The observation was carried out on an assembly line containing operations on Chassis at Scania. Three operators, who had different levels of experience, which were under training were observed. The time for Genchi genbutsu was three hours.

The softwares are not comparable because of their design, thereby they will not be compared. All information that been obtained in the study have been analysed and discussed to highlight the advantages and disadvantages which together formed the recommendation to Scania within virtual training with SeQualia and Vizendo.

3 Theory

In this chapter, the information from the literature study will be presented. The theory is obtained to provide an understanding of the subject and the connections between the areas. The main topics in this chapter are quality improvements, standardisation, the learning phases and training within industry. They are presented to get an understanding of the sections that will be presented in the thesis.

3.1 Quality improvements

There are several different definitions of quality. Bergman & Klefsjö (2010, p. 23) defines quality as "The quality of a product is its' ability to satisfy, and preferably exceed, the needs and expectations of the customers", while Philip Crosby claims that the definition of quality is "Conformance to requirements" (Bergman & Klefsjö, 2010, p. 22). To complete the discussion of how to define quality, Bergman & Klefsjö (2010) specify Garvin's five perspectives of quality as; transcendent, product-based, user-based, manufacturing-based and value-based. The first perspective, the transcendent, implies that quality is identified when it is experienced and is in the eye of the viewer, while in the product-based perspective quality is measurable and determined with properties and dimensions. The user-based perspective implies that quality is determined by the customer conversely to the manufacturing-based approach which is connected with achievements of requirements and tolerances from the production. The value-based perspective defines quality in relation to costs or prices. Seen from these five perspectives, quality affects both internal and external customers (ibid).

Bergman & Klefsjö (2010) consider Total Quality Management (TQM) to be an offensive quality enhancement that aims to prevent, change and improve. Continuous work with TQM will promote product and processes developing simultaneously as it supports individual progress. TQM includes five cornerstones; focus on customers, base decisions on fact, focus on processes, improve continuously and let everybody be committed. The fourth cornerstone, improve continuously, is significant in the continuously development. The product and business quality needs to improve constantly to maintain competitiveness, where the basic rule is that better products and work procedures should be achieved simultaneously as reduced resource utilisation. Therefore, there is always a way to reach better quality with a lower cost, but there might be a challenge to find actions which provides that. Within quality enhancement, a popular phrase which needs to be treated with carefulness is *to do right from the beginning*. Improvements needs to be carried out continuously to enhance quality and prevent failures to occur (ibid).

PDCA is an effective method of working with continuous improvements and standardised work. PDCA was founded by William A. Deming and aims to structure the work of improvement and is divided into four phases that illustrates in figure 3.1. The first phase *Plan* includes more than just planning, it also includes forming objectives to achieve solutions to the problems, and analysis to find the reason to the problem. A key point in this phase is communication, since all parts need continuous information and the ability to affect, to achieve desired results. In the second phase *Do,* the planned activities will be carried out and if the *plan*-phase is well prepared the process should run effortless. In the *Check*-phase, the results and the knowledge will be analysed, which not only includes analyse of the objectives but also the advantages and disadvantages with the study approach and the performed activities. In the *Act*-phase, if the study has been successful, it will be standardised to repeat the circle (Petersson et al. 2008).

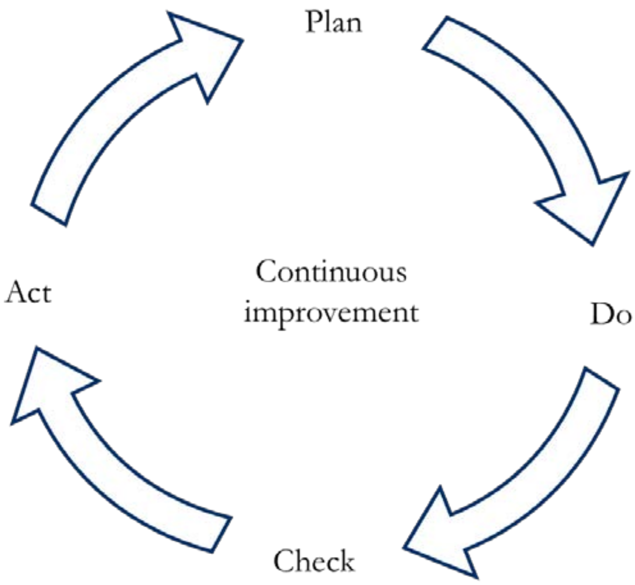

Figure 3.1 The PDCA-cycle inspired by Petersson et al. (2008)

3.1.1 Standardised work

The procedure for standardised work became a science when manual labour-production was replaced by mass-production. Standardised work does not only aim to find the scientific best way to create repetitive and effective work procedures. The underlying intention is not to enforce standards that makes the work boring instead it should be a basis that offer the operator responsibility and the possibility to generate innovations. It is important that everyone at the company practice the standardised work procedures to achieve a comprehensive view (Liker, 2009). Petersson et al. (2008) confirms that by describing that standardised work creates prerequisites to perform the work in the same way. The standardisation of work procedures should be formed together by the supervisor and the operator to get an unified understanding and mind-set within the company. The standardised work is compiled in a standardised worksheet which is a standard document for work activities. It includes information about work sequences, times, article numbers and specific safety and quality instructions (Petersson et al. 2008). Liker & Meier (2006) describes that learning cannot be achieved without standards. Standards are distinguished from documented procedures since this increases the understanding of tacit knowledge of the performance of the work. Toyota is acknowledged for their good work with standardised work and trains their operators with learning by doing and will keep the classroom-training to a minimum. The meaningful learning and understanding occurs when the employee is in the real environment (ibid). A process that has not been standardised is impossible to improve, it is likely the improving process alteration will not be used and only becomes another process variety. The process needs to be stabilised by being standardised to continuously improve (Liker, 2009).

An effective system of methods used for standardisation is AviX that is a video based software that aims to support production technology work. The software consists of six different modules; methods, resource balance, SMED (Single Minutes Exchange of Dies), FMEA (Failure Mode Effect Analysis), DFX (Design For Excellence) and ergo. All modules are used to improve companies' competitiveness in construction and production. The collection of AviX modules represent a wide toolbox for production technology in lean production work. AviX Methods can be used to standardise work material (Solme AB, 2015).

3.1.2 Continuously improvements

Kaizen is a Japanese term for continuous improvements where *kai* means change and *zen* means good. It is a methodology founded in participation, commitment and discipline by both the organisation and the operators (Salem Press Encyclopedia, 2016). According to Liker (2009) working with kaizen will achieve small and large value-increasing improvements and reduced wastage by working efficiently within the areas of problem solving, processes improvements, analysing and practice of independence within the team. Therefore, the operators will be enabled to influence the decision-making and will be offered the opportunity to identify and suggest improvements (ibid). Improvements of the organisations' standards can be obtained by letting the employees participate in kaizen, therefore kaizen can be useful to identify and solve problems. Kaizen is traditionally used as group activities with employees from different areas. The work procedure for the activities follows the PDCA cycle to create improvements that can be achieved in small steps (Salem Press Encyclopedia, 2016).

Liker (2009) consider kaizen to be a key factor to build in quality. It is well known at companies that quality cannot be guaranteed without standardised work procedures which will insure a consistent process. Toyota makes it possible for their operators to build in quality by forming the standardised work procedures by themselves.

3.2 Cognitive learning

There are three stages in the process of learning; *declarative*, *knowledge compilation* and *procedural*. In the first stage, *declarative* stage, the cognitive learning takes place and the learner gets an understanding of the task and how to perform it. The learner searches for the information that is required to execute the task (Andersson, 1982). Cognition is a physical term which includes memorising, thinking, understanding, and acquiring knowledge and insight (Illeris, 2007). According to Andersson (1982) it takes at least 100 hours of learning and practice to achieve a legitimate level of proficiency in any significant cognitive skill. The second stage is the *knowledge compilation* stage, it consists of associative learning, where the learner gradually identifies and eliminates errors by practicing the task. Within the practice, the knowledge is transformed to a procedural form where the person learning can adapt the knowledge in practical use. The last and third stage is the *procedural stage* where the learner acquire autonomous learning. The learner can perform the task automatically and constantly improve the skills. This stage only occurs after the procedural knowledge is achieved. These skill improvements involve further knowledge of the tasks and better time efficiency performing tasks resulting in the learner becoming more suitable for them. The three stages can be illustrated in a graph where the needed operation time is in relation to training cycles, see figure 3.2 (Andersson, 1982).

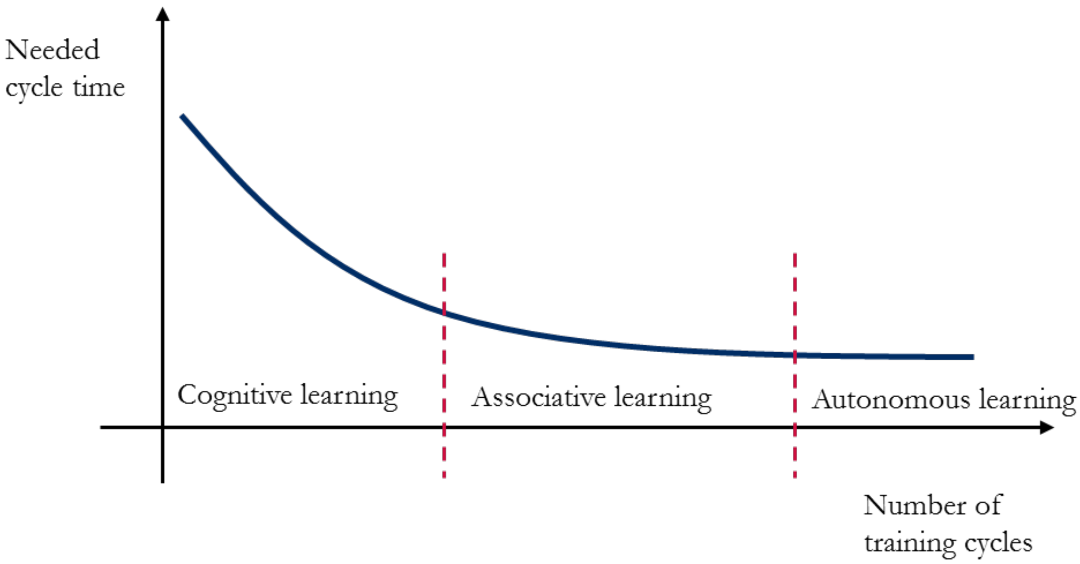

Figure 3.2 The cognitive learning graph inspired by Malmsköld (2012)

In early stages in assembly training, the cognitive learning stage dominates the learning process since the operator needs to understand and learn to follow the standardised worksheets. The operator also learns how to handle the tools and parts during assembling. The learning stages can be divided into four knowledge phases; *product*, *process*, *sequences* and *finesse* where virtual training can be used in all phases. In the *product* phase, the operators can learn different product shapes and variants etcetera. In the phase *process*, knowledge can be achieved for needed tools, placements, quality and safety demands. In the regular assembly, the *sequence* phase can be used to achieve knowledge of sequences for different variants and stations. In the last phase, *finesse*, the operator can acquire knowledge of quality and safety issues, how to avoid them and why to perform the operations in a certain order. In associative learning the operator need physical products to acquire experience and reach the stage of autonomous learning. The operator learns how to handle the product, grip position and handling tools, speed and performance with quality within the cycle time. (Malmsköld et al., 2007).

3.3 Traditional training

Traditionally, the operators assemble physical prototypes to practice in advance, which requires needed parts available. The operators practice by mounting prototypes in correct sequences. Then the prototypes need to be dismounted to be able to be rebuilt again, this method is called strip and build (Gorecky et al. 2013). Many automotive industries have training sessions shorter than two weeks which often results in a high frequency of first time failures and quality problems. In traditional training forms the training often consists of lectures and individual mentoring, where one mentor teaches one operator (Muller et al. 2016). Gorecky (2013) describes current planning and training in automotive industries as an expensive and ineffective process since it is still carried out as physical activities.

3.3.1 Training Within Industry (TWI)

Training Within Industry (TWI) was founded during World War II when the United States was in need of a rapid change within the ship production. Ships were the only transport which could transfer people around the world and The United States needed to expand the number of ships with ten times within a short time span (Dinero, 2005). There were 500 000 untrained people which had never built a ship before. The U.S. government requested a method to train all these people rapidly and asked industry trainers for help. When the mission was completed the trainers realised that they had developed an exceptional knowledge about principles to teach untrained people. The principles have been developed during several decades and have resulted in Basic Training Material which is connected with a Four-step method. The Basic Training Material includes three skills; *Job Methods*, *Job instruction* and *Job Relations*. The first skill, *Job Methods*, will develop the ability to improve operator's way to perform tasks. The aim is not to improve processes by introducing a suggestions system but to improve them by letting the operator get involved by having an open suggestion process. The second skill, *Job Instruction*, is significant according to Job Methods since changed methods to perform tasks require the operator to perform the job differently with new instructions. A clear way to really understand the meaning of the instructions is to instructing someone else. TWI requires Job Instruction training for any person responsible to teach operators since if the trainer has knowledge and skills about the job and how to instruct it, it takes less time for the employee to learn. The third skill, *Job Relations*, might seem nonessential but it is significant since people interact with each other daily. People should know how to prevent and solve problems, if when the problems have occurred. The skill of Job Relation is to handle and solve the problem in a logical and consequential way (ibid). The Four-step method was developed for each skill program and has four general steps; *Collect facts*, *Analyse them*, *Make a decision* and *Check or follow up the decision*. The steps are adapted and specified to each program, see table 3.1. The method aims to develop confidence and resourcefulness for operators and organisations in a practical way (Dinero, 2005).

Table 3.1 The TWI Four-Step method inspired by Dinero (2005)

TWI Four-Step Methods				
Steps	**Job instruction**	**Job Relations**	**Job Methods**	**Program Development**
1	Preparation	Get the facts	Break down the job	Spot a production problem
2	Presentation	Weigh and decide	Question every detail	Develop a specific plan
3	Try-out Performance	Take actions	Develop the new method	Get plan into action
4	Follow up	Check results	Apply the method	Check results

Job Instruction Training (JIT)

Job Instruction Training (JIT) is a structured method to train new operators. The method is founded from the TWI Four-Step Methods and has been advanced by Toyota who has added a few minor things. JIT can be used to train both new and experienced operators. The training is led by a trainer with skills and experience within the subject. JIT is divided into a four-step method. The first step is to *break down the job* where the job is analysed, divided into important steps and inserted in a job breakdown sheet. The new operators are evaluating the ability to learn during training and it will be adapted to each trainee's learning style. New operators are determining the key points from each step of the training together with experienced trainers. A key-point explains the basis of certain performances connected to safety, quality, costs and techniques. The trainees need to consider the key-points to perform the work correctly. The second step is to *present the operation* where there are three phases in the individual training; what, how and reason. What explains what is performed in the steps, how explains how it is performed referred to the key-points and reason explains why it is performed in that way. The trainers should teach new operators by telling, showing and illustrating the steps and the key-points, and repeat that again. The third step of the JIT method is to *try out performance* and the operators get to try to perform the work by themselves. The trainer is still present but is not supposed to meddle, they need to have a balance between coaching and non-interference, because if the operators get free hands they might develop incorrect methods to perform the work. The trainers should give questions about the steps in different levels of difficulty and repeat the levels. The new operators' ability to perform the work correct should be the clarifying factor to know how much support the operator needs. The fourth and last step is *follow up* where the operator is put in the workspace performing their actual work tasks, although their training is not finished and they still need to be provided support. The new employee is not finished with the training and still need some support. New operators only have the ability to perform parts of the work while the rest will be performed by the trainer. As the new operator's skill level increases the tasks will become more comprehensive. The operators should always be supported if it is necessary and should never be left alone (Liker & Meier, 2006).

3.4 Virtual training

It is expensive and time-consuming to build and recreate an environment for training similar to the actual work environment. The environment can instead be simulated in a virtual reality. Training within virtual reality systems can create improved methods for training as it trains human to perform tasks in simulated environments (Kozak et al, 1993). The users can experience exercises in an artificial world replicating the reality with real objects, tools and actions. Training in virtual reality systems can be used for several applications within different fields (Borsci et al. 2016). Borsci et al. (2016) describes virtual training as a powerful tool useful to operators, specialists and managers in training for driving, flying, assembling and surgery. Gorecky et al. (2013) distinguish two forms of virtual reality; high instrumented virtual reality and computer-based. The high instrumented virtual reality uses haptic feedback, complex interaction concept and head mounted displays and give the user an immersive experience. The computer-based concept uses traditional interactions as joystick, mouse and keyboard and are normally not immersive.

Flight simulators are used to train pilots to operate modern aircraft and as support during the design process. NASA (National Aeronautics and Space Administration) used training in virtual environments to train crews before a repair mission at a Telescope. The National Guard and The U.S. Military are using virtual training to practice and prepare for complex scenarios in combat operations (Adams et al. 2001). The use of virtual training in automotive assembly production aims to prepare large amounts of operators for rapid changes (Malmsköld et al. 2007). Several factors need to be considered to assemble a part in the right place. The operator need to reach, grasp and move to find the correct position and insert the parts, each which require a different guidance (Bound et al. 1999). By using virtual training companies reduce training costs and time educating the operators (Borsci et al., 2016). Tools as increases the visualisation for operators contributes with better knowledge and perception in complex processes (Stork, et al. 2012). This will prepare the operators to handle new situations together using less physical prototypes and in less time (Malmsköld et al. 2007). Virtual training can be adapted to operators' needs and imitate specific conditions which can increase the motivation to improve by forming the training with the operators' learning style. The training systems can collect data about operators' performance which is an efficient way to adjust the training process in order to work with continuous improvement (Borsci et al. 2016). Virtual training can shorten the cognitive learning time, reduce costs and eliminate risks with learning by doing in (Muller, et. al. 2016).

3.4.1 Game based training

According to Muller et al. (2016) gamification in virtual training in forms of simulation games has been a successful method to increase learning. It gave positive responses from the operators where the effect was higher motivation to learn through games than in lectures, documents and other methods in traditional training. The games are an imitation of the real world over time using specific rules and often have a reward system to motivate. Through game-based training experienced operators can easily learn new tasks in the operations and new operators can easily learn the operation standard (ibid). The game based training should encourage a learning experience which is fun, interesting and challenging. By having a serious purpose, the games' credibility will increase to the user and a significant part to keep the operator motivated is to have levels with increasing difficulty (Gorecky et al. 2013).

People have different opinions about the term *game* depending on their relation to video and computer games. A gap between generations brings different point of views since people who have grown up in the last thirty years have played games during their entire childhood (Zyda, 2005). To perform a game-based training the user type need to be defined since different types have different needs of playing and learning. There are seven user types according to Muller et. al (2016). Enjoyers, farmers, self-seekers, networkers, achievers, goal seekers and socialisers. The tutorial should be designed for manual work and should be able to be used by both experienced and inexperienced operators, it also needs to consider that a user can change type during the game. The tasks are often categorised in three categories where the first is to recognise the tools and components that are mounted on the workplace. The second is to know where to position and how to handle components and fixtures. The third stage is to use the right tools and how to apply them correctly. The stages should be applied in correlation with the operators' competence (Muller et al. 2016). Game-based training in virtual reality is usually developed in relation to the technological aspects and forgets to adapt it to the user. Gorecky et al. (2013) proposed a user-centre design, of the game to achieve the user's needs. It is significant to consider the user's background, level of knowledge and attitude to computer games during development of the game.

SeQualia

SeQualia is a software aimed to train operators by self-study training. It is structured as the ordinary worksheets which includes both illustrations, what to do, how and why. The application is designed as a game where the operator trains in the application by practice on assembly information. It is flexible so the operators can choose parameters to practice on by themselves. The selectable parameters are work station, vehicle model and model variant (Malmsköld, 2012). The software can be designed and adapted to companies' worksheets.

The version of SeQualia is adapted to Scania's pedal car factory, screenshots are shown in figure 3.3.

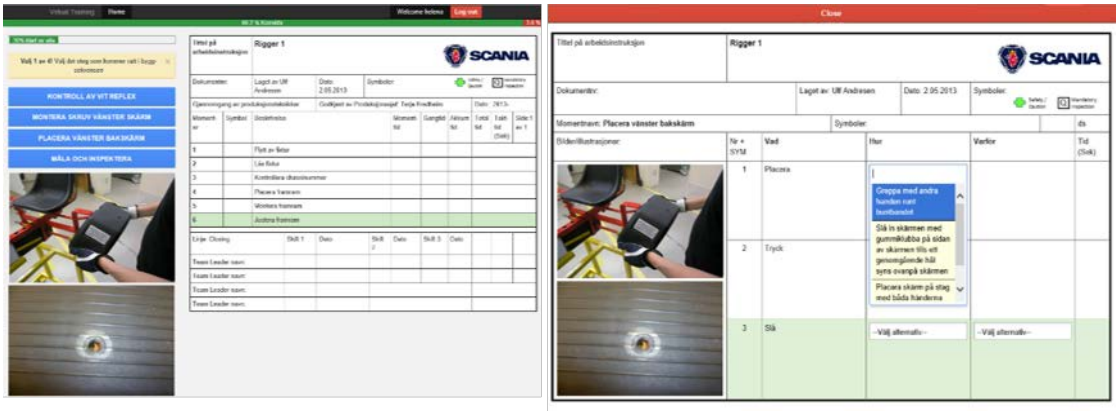

Figure 3.3 Screenshots of SeQualia

The operator chooses one of the four available workstations to practice on and a vehicle model; red or black. The blue squares in the upper left corner shows four alternatives of elements, of which one is correct. A new window opens when the operator chooses the correct operation. The operator needs to choose the correct alternatives for how to perform the operation and why it should be performed in that way for each operation. The software saves data about each operator's training in SeQualia which is presented after the game is completed.

Vizendo

Vizendo is a software aimed to train operators virtually in digital environments in manufacturing industries. The technology is comprehensive and should receive efficient training and a deeper knowledge about the products. The software has three different applications, Vizendo Trainer, Vizendo Repair and Vizendo Creator. Vizendo Trainer is an application aimed to train operators in the final assembly (Vizendo, n.d.). The operator chooses which sequence of the process to practice on. The training is divided into four different difficulty levels. The first level is the easiest and shows the sequence graphically by showing the places where parts should be assembled. The operator needs to press at the selected surfaces to confirm. At this level all necessary information is available for the user. For the remaining levels, second, third and fourth, the necessary information is gradually reduced each level. At the fourth level the user does not has any helpful information and need to complete the level themselves. The software saves each user's training data as a log file which shows the progress of the operator's assembly experience (Malmsköld, 2007).

Figure 3.4 Screenshots of Vizendo

Figure 3.4 shows two operations at Station 1 in the pedal car factory in Scania. The first level of difficulty provides the user with information of the articles, tools and positions. The second level only gives information of articles and tools and in the third level, the user needs to manage the game by themselves.

4 Previous accomplished studies within Virtual Training

The chapter describes previous studies that have been performed with SeQualia and Vizendo. The focus is to gain an understanding of the operators' experience of virtual training and to map the set-up for the training. The predetermined questions asked during the interviews are shown in appendix B.

4.1 SeQualia

The process manager (1) at NEVS (previous SAAB) explains that the traditional training started with basic skill training where the operators practiced at using the right tools and screw techniques. The operators had five different elements to perform and the operators were assigned a station. The operators watched an experienced operator who was mounting simultaneously as they read the instructions. The operators practiced the standardised worksheets and when they had sufficient knowledge they changed positions. The new operators assembled approximately one third of the operations and the experienced operator performed the remaining operations in a slow takt. Initially the goal is to deliver quality but at a shorter takt time, as the new operator gain experience the takt time was reduced. During Job Instruction Training the operators used a flexible chart as a matrix that showed an overview of the skills for respective operator and workstation. Afterwards the competence was transferred from the results of basic skills into the matrix. The operators performed strip and build-training on critical operations where the focus was to correctly assembly according to the *how* and *why* from the standardised worksheets. The Process Manager (1) explains that SAAB used SeQualia to train both new and experienced operators for new variants and operations. The cycle time that was used was 123 seconds, which is considered a short cycle time. The set-up used for training was a mixture of computer-based training in SeQualia and practical assembly training. Saab built an institutional computer room where the operators trained individually in SeQualia.

(1) Process manager NEVS, interview 20 April 2017

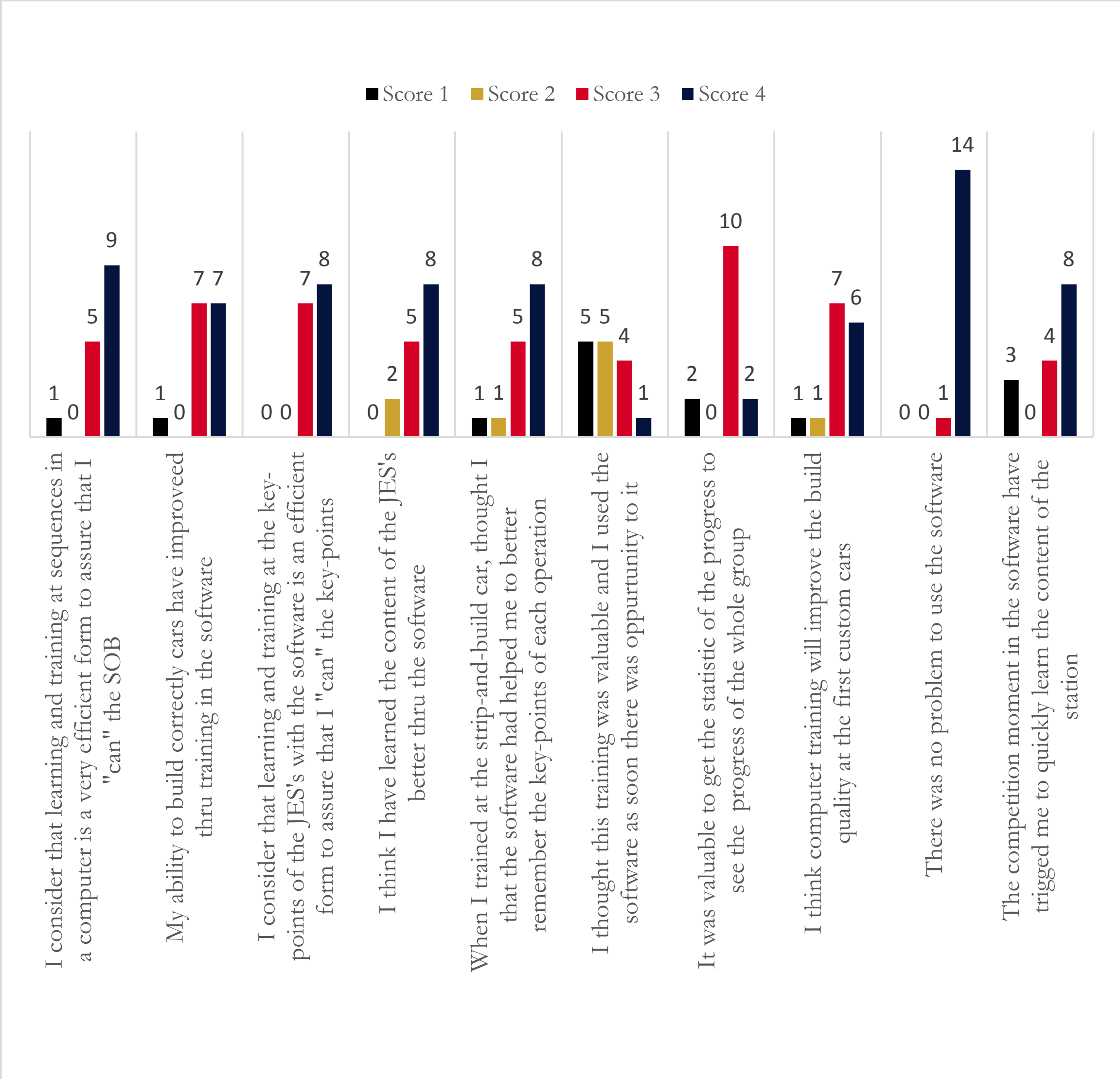

Figure 4.1 Opinions of SeQualia from recent accomplished studies

The operators answered a questionnaire about their experience of training with SeQualia, see figure 4.1 for compilation of the answers. The questionnaire consisted of ten questions with a scale of one to four and at the end there was a possibility to leave comments. Answers from fifteen randomly chosen questionnaires were used to compare with the previous study. The main part of the group was positive to the training with SeQualia. Approximately a third of the group thought it was efficient for sequence training. The main part of the group also considered their ability to build correctly have improved and that they have learned the key-points better. Almost every operator thought there was no problem using the software and thought it was valuable to receive statistic from the game.

According to the Process Manager (1), the training with SeQualia was among most of the operators positive and the operators who had a negative attitude towards the software had reading difficulties. Since the training in SeQualia was time limited, the operators which had reading difficulties did not have enough time to complete the task. Another positive aspect was that the operators were more focused to perform the job correctly in their regular work, which resulted in that the operators were more involved and influenced in the work. The operators became more successful in less time which implied that the learning time was reduced. When the operators trained in SeQualia they were "forced" to perform the work accord to the standard. The operators usually performed the work in their own way since they were not controlled to work according the standard. That became very clear when the operators trained in SeQualia since the supervisor saw the result of the tests. Even though the results were not directly visible for everyone, many operators did not want to show a wrong result to the supervisor. The process manager concludes the interview by explaining the significant benefit with SeQualia or computer-based training, to have the possibility to a combination of reading, learning, writing and practical work.

4.2 Vizendo

A previous study of operators receiving virtual training in Vizendo has been performed at Scania and was aimed to investigate the software's effect and influence on attitudes. The Production Manager (2) explains that the expectations of the project were to have the possibility to start the assembly training in an early state, reduce the physical training time and reduce quality defects when introducing new products. The study consisted of experienced operators who were in the process of learning how to assemble a new truck using Vizendo. The assembly training in Vizendo was used within three areas; pre-assembling, assembling of APS and battery box assembling. Vizendo needed to be prepared before it was ready to use, where digital files containing the information were sent to Vizendo and some files were insufficient and missed information about details such as screws. Therefore, Vizendo had to create screws which were similar to the ones that Scania had, which resulted in the screws being different from the physical screws. This became a disadvantage since these issues complicated the process of setting up and working with Vizendo. The set-up for the training included reading, computer-based training and lastly practical training. The operators started by going through and reading the sequence of work sheets that were in DELMIA, Digital Enterprise Lean Manufacturing Interactive Application. DELMIA is a software that Scania uses as support to modelling and planning of manufacturing. The second phase in the set-up was training in Vizendo and last was physical mounting. According to the Production Group Manager the advantages with using Vizendo were that it was a good tool for the project manager to quickly learn the assembly process and that the majority of the operators found it fun and easy to perform. A disadvantage was that the training was used for a new product, therefore all information was not complete. The Production Group Manager (2) explains that the older generation of operators thought it was unnecessary and difficult to train in Vizendo, probably due to the

(2) Production Group Manager, interview 5 April 2017

operators' lack of experience in using computer-based programs. Young operators usually have a digital learning style different from the elderly who have a practical learning style.

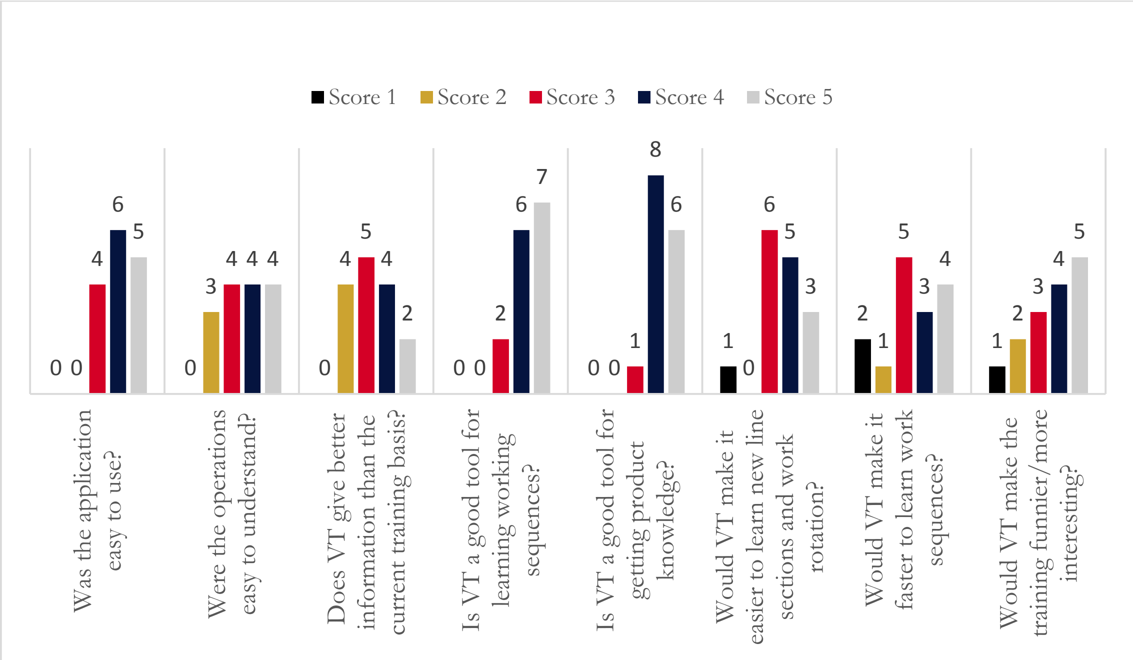

Figure 4.2 Opinions of Vizendo from recent accomplished studies

The operators answered a questionnaire about their experience of Vizendo. There were eight questions with a scale between one and five and also a place to leave comments. The scores of the questions are shown in figure 4.2. The majority of the operators had a positive experience of the software and thought it was easy to use and understand also that it was a good tool to learn sequences, to introduce new operators, products and to practise new areas before training on physical products. Many operators mentioned that the program would be a great tool for people with reading difficulties. A disadvantage was that it was hard to train without the MONA which is a broadsheet with article numbers and important information, since the article numbers were executed in the software. Another disadvantage was that there was no scoring system which would made the training more fun and interesting. The managers thought it was a good tool during introduction, training and deviation training and that it would be great to use on the line, since the learning process will be faster when the operators can practice individually without a truck. The managers estimate that virtual training could reduce the learning time of new projects with 20-30 percent and 40-50 percent of new operators (Olofsson & Waker, 2014).

5 Scania as a Learning organisation

Scania's leadership is founded in the principles of Lean Production as a learning organisation. It encourages an open climate where employees and management improve operations together. Scania believes in a strong team where all employees have the opportunity to influence the work, which will create a strong organisation with a secure future (Scania, 2017). This chapter describes a part of Scania's work with continuous improvements, the training process in the technical division Delivery & Industrial (XACC) and lastly the concerned process for the study.

5.1 Scania Academy

Scania has an institution for skill-development training as a support to the learning organisation. Scania Academy is divided into six departments that provides Scania with courses and training for all activities (Scania, 2017). The six departments are Regional Operations, Leadership & Organisation Development, Technical Training, Commercial Training, Learning Development & Support and Employer Branding. The departments are divided into smaller division which are shown in figure 5.1. The trainees get an understanding of how Scania works and how the operations are formed through this training. The division, Delivery & Industrial is in the department of Technical Training which is located in Södertälje and has a training factory where the trainees can perform practical training within assembly, logistic and quality control.

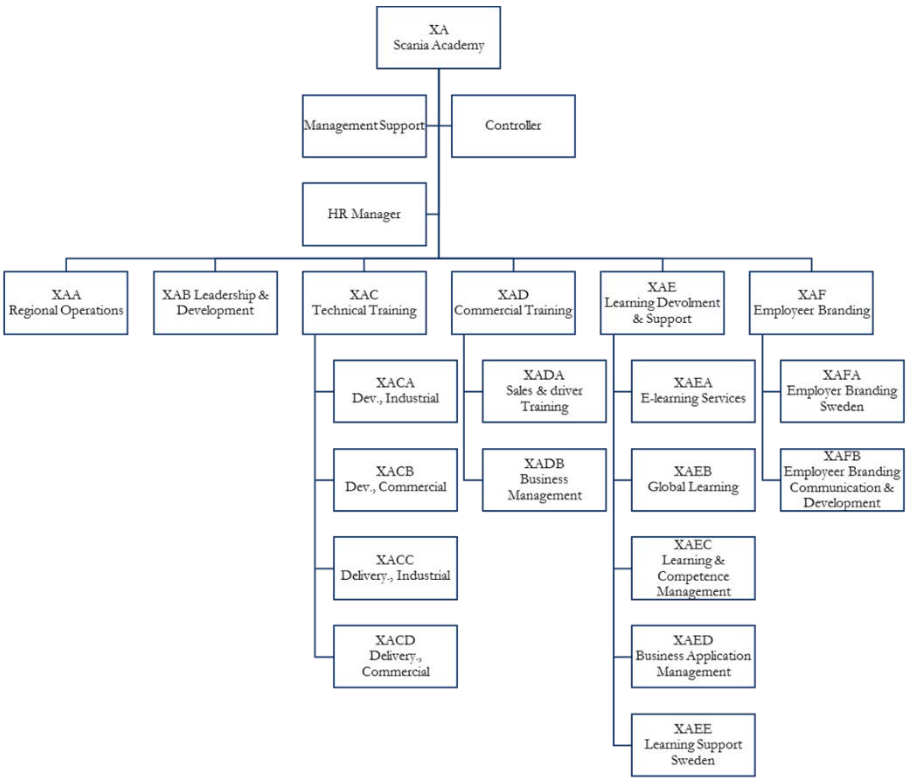

Figure 5.1 Organisation map of Scania Academy

5.2 Training in Pedal Car Factory

The pedal car factory is used for education and development within several sections. The education for new employees consists of both theoretical and practical training as proceeds during a week. The trainees have practical work in the pedal car factory during two times a week and the remaining time is theoretical education. There are traditionally two groups during an education week with approximately 12 to 15 trainees in each group.

The practical education starts with an introduction of the pedal car factory where the trainees are divided into pairs and are working together at same station during the assembling. The practical work consists of different activities; mounting, quality control, dismounting and logistic. There is an andon system that the trainees can use in need of help and if the trainees are doing something wrong the Training managers will explain. The trainees should be able to work independently in the end of the introduction week with the degrees of difficulty increasing during the week since the takt time is shortening. There are four different practical tasks in the pedal car factory. The first is assembling where the operators assemble the pedal car following Scania's standardised worksheets where the first trainee instruct the second trainee by reading while assembling the pedal car. After performed operations, the pedal car is moved to the next station and the trainees on each station are changing tasks. There is a quality control station after the fourth assembling station where the trainee is controlling that the pedal car achieves desired level of quality through following the standardised worksheets. Chassis number, components and functions are controlled. The last pedal car station is disassembling where trainees are disassembling the pedal cars in order from a standardised worksheet and places the components back in the storage so the components can be used again. There is a logistic department providing the assembling stations with components by a logistic system called two-bin. The assembling stations have two types of flags; yellow shows that parts need to be refilled but there are enough to complete the next car and the red flag shows that parts needs to be refilled immediately. The trainees practicing in the logistical department are picking components from the store and load them onto at a trolley which symbolises a truck. The logistic worker drives the trolley within marked paths and deliver the parts to the mounting stations.

During the theoretical education the Training managers gives information about Scania and rules during the education. The trainees also receive information about ergonomics, basic skills, Personal Protective Equipment, fire protection, mindfulness, safety and labour unions. The Training managers shows different tightening techniques, lifting safety and 5S work in the pedal car factory.

5.3 Parketten – The Pedal Car Line

The assembling process in the pedal car factory is named Parketten which is a line with four assembling stations. The layout is shown in Figure 5.2 below, it starts at Station 1 and are proceeding to Station 2, Station 3 and lastly Station 4. The process consists of assembly of two variants; red and black pedal car. When a new takt starts, the trainee at the next station are bringing the pedal from the previous station. The chassi for the pedal car arrives on a fixture where it stays during assembling at all remaining stations. All assembling stations have two shelves each that stores the parts for assembly where every part have a marked place with an article number and the parts are continuously refilled by a logistic worker. There are pegboards with marked names and silhouettes for the tools needed for the operations and worksheets are easily available in a cover next to the shelves. Two trainees are working together at each station and are assembling two different variants of pedal cars; red and black. The operations should be performed in order of the standardised worksheets. The goal cycle time for the process is approximately 360 seconds.

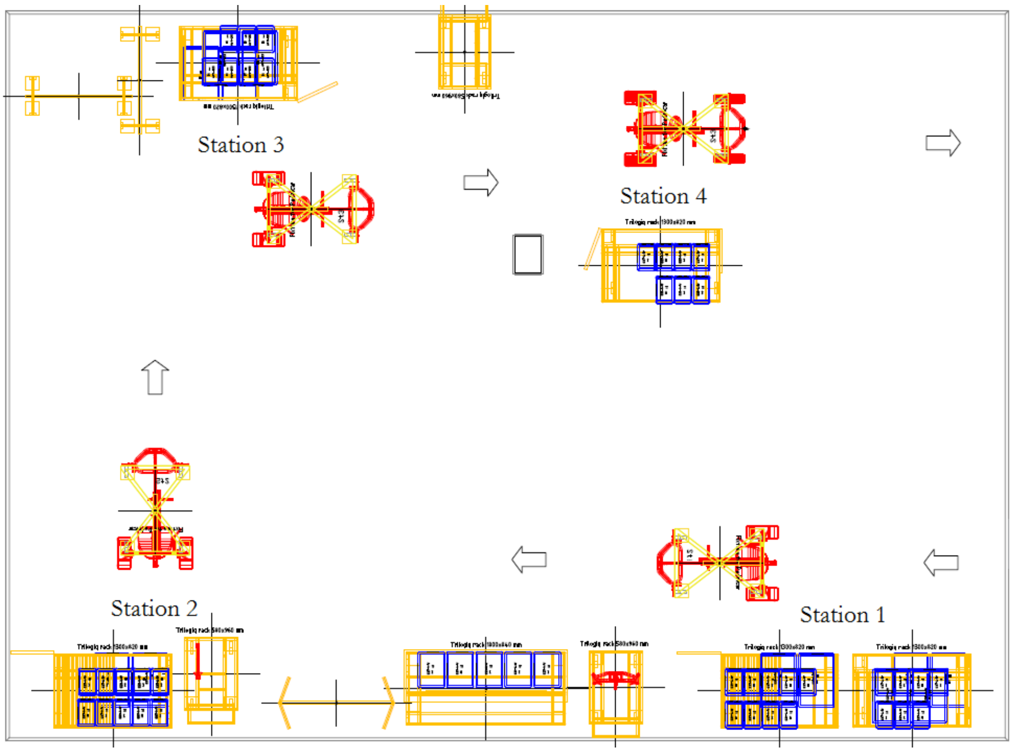

Figure 5.2 Layout of Parketten

The study has been focusing on the assembly work at Station 1 where the front frames, rear fenders and handbrake are assembled. The operations are shown in the appendix C where a cross indicates which operation belongs to each variant. The tools that are needed for Station 1 are torque wrench, rubber mallet, spanner, allen-key, circuit breakers and a pencil. At Station 2 the right pedal, control stick and chair seat assembled. Station 3 includes assembly of steering link for control stick and steering wheel. At Station 4 the left pedal, tires and hubcap are assembled.

5.4 Scania's Four Step Method

Scania's four step method consists of; *Prepare, Show & Instruct, Practice* and *Continuous training* and is a standardised work procedure used to train both new and experienced operators. After the introduction at Scania Academy, the new operator fills in a checklist to obtain the lowest level for the introduction. The operators can try and practice at some of the regular off-line training during the introduction such as training in the pedal car factory, test the equipment and use AviX Movies to learn the correct operation performance. Step one to three is used to train new operators and step four is used in continuous training with experienced operators (Anjou & Eriksson, 2016).

The first step, *Prepare the operator*, the preparation is done off-line and determines the level of knowledge of the new operator which includes what the operator has learned during the introduction. After the level of knowledge is determined, the place and use of the tools and articles for the operations are described as well as the flow and the role of the station, supplier and customer. The seconds step, *Show and instruct* the operator, starts with an introduction of the operations which will be performed on the station where the operations are shown and explained. The new operator should read the position standard and standardised worksheets and when the mentor explains the operations it is important to mention the safety risks and how to avoid them by following the standards. It is also important to ensure that the operator has understood and is encouraged to ask questions, the questions which cannot be answered by the trainer should be delegated. The third step, *Practice* give experience, the operator gives the opportunity to practice on-line where the new operator is working together with an experienced operator. The new operator gets a few varying operations to perform during a takt while the experienced operator is supporting and the new operator starts to work more independently with more responsibility. The training starts by practicing on one component which intensifies by practicing at a takt and lastly training on the entire process. During the training the experienced operators should correct eventual errors and give feedback to avoid that the new operator deviates from the standards. The knowledge is secured in the end of the third step where the trainer asks control questions to ensure that the operator has understood the key elements; What, How and Why. It takes approximately one to two weeks to train a new operator and two to three days for an experienced operator. The fourth step, *Continuous training*, is used for continuous training where the earlier steps have created the basis of knowledge (Anjou & Eriksson, 2016).

6 Performed case studies & results

The results of the performed case studies will be presented in this chapter. The results of the current process for assembly training are presented from the Reference group and the training with SeQualia are presented from Test group 1 and Vizendo from Test group 2. The chapter is divided in order of the measured parameters which consists of; *Wrong operation*, *Correct operation but wrong performance*, *Checking instructions for operation and performance*, *Quality defects* and *Cycle time*. The measurements are only carried out with trainees at Station 1 for all groups. This chapter will also present the score from SeQualia and Vizendo where the SeQualia score has been collected from the entire Test group 1 and the Vizendo score has been collected from Station 1. Comments and opinions about the softwares will also be presented in the end of the results from Test group 1 and Test group 2.

6.1 Reference group

Measurements of the current process for assembly training was accomplished using a reference group. The reference group consisted of two trainees with no experience of assembly work. They were 21 and 24 years old and performed operations at Station 1. The operators were assembling four pedal cars during the first day and nine at the second day, the results of the measured parameters are described in this chapter. The takt time decreased after each pedal car assembled.

6.1.1 Operation & performance faults

To be able to compare the result with the results of Test group 2, the results of Operation 1 to 9 will be presented separately. Figure 6.1 shows a bar chart with the total average value of choosing wrong operation and choosing correct operation but wrong performance of the total number of takts. During the first day of assembly, the total average value of choosing wrong operation in a takt was 1.25 times with a standard deviation of 1.50. During the second day of assembly, the total average value of choosing wrong operation increased to 1.89 times where the standard deviation decreased to 1.17. The average value of choosing wrong operation in Operation 1 to 9 was 1.25 with a standard deviation of 1.50 on the first day and decreased to 1.56 with a standard deviation of 1.53 on the second day of assembly. Frequently missed operations were Operation 6 and 9 which are tightening of the screws on the right and left rear fenders. The trainees had difficulties to place the fenders in the correct sequence where the right fender is placed before the left. One situation that occurred was that Operation 4 was correctly selected but made with the wrong performance since the trainee mounted a fender with the wrong article number. Due to this, Operation 5 was performed twice, once with the wrong article and once with the right article.

The bar chart in figure 6.1 shows the average value of choosing correct operation but wrong performance of total number of takts. During the first day of assembly, the total average value was 1.00 with a standard deviation of 0.82. During the second day, the total average value increased to 1.33 times with a standard deviation of 1.12. The average value of choosing correct operation but wrong performance in Operation 1 to 9 was 0.75 with a standard deviation of 0.96 on the first day and increased to 1.00 with a standard deviation of 0.73 on the second day of assembly. The trainees had issues with placing their hands correctly and assembling the front frame which are Operation 1 and 2. During assembly of the rear fenders a common fault was that the trainees hit the fender with the hand instead of using the rubber mallet. Another common fault during assembly of the fenders was that the trainees did not lay the washers on the nut before placing it on the screw. In both Operation 13 and 14 the trainees placed the torque wrench first instead of the allen-key.

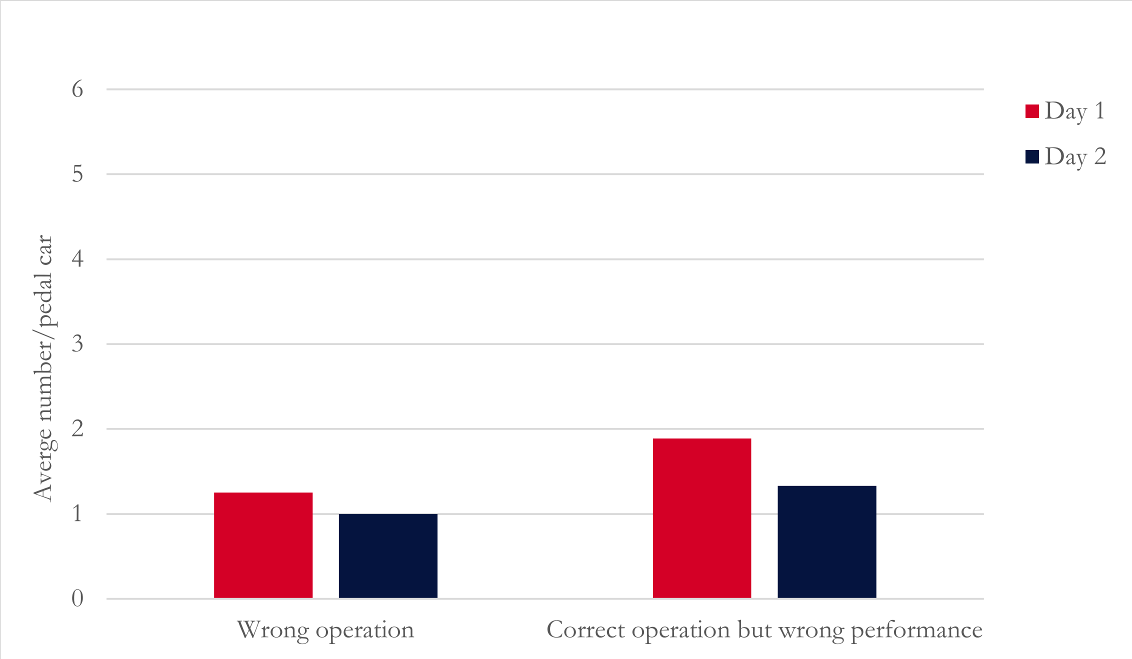

Figure 6.1 Average of Wrong operation and Correct operation but wrong performance (Reference group)

6.1.2 Checking instructions for operation & performance

Figure 6.2 and 6.3 shows pie charts with the percental number of times where the trainees checked the instructions for operation and performance in the total number of takts. During the first day of assembly, the percental number of times where the trainees checked the instructions for chosen operation was 100 percent and decreased to 78 percent on the second day of assembly. The percental number of times where the trainees checked the instructions for performance was 100 percent on the first day of assembly and decreased to 22 percent the second day. The pie charts visualise that the instructions were checked on operations and performances on all pedal cars during the first day which decreased for both during the second day.

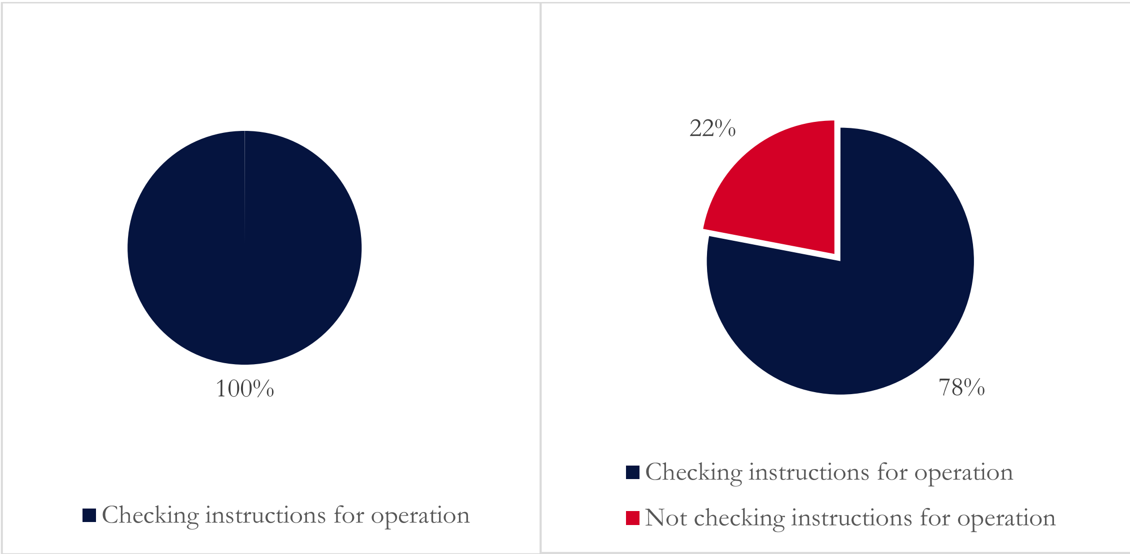

Figure 6.2 Number of Checking instructions for operation (Reference group)

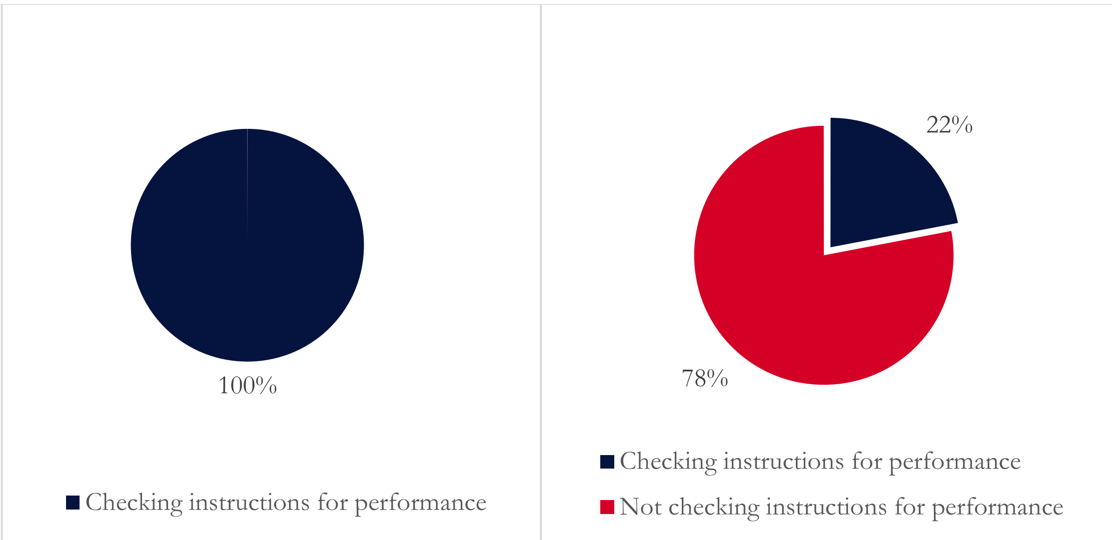

Figure 6.3 Number of Checking instructions for performance (Reference group)

6.1.3 Quality defects

Figure 6.4 shows a line chart with the number of quality defects on a pedal car. The chart shows that the number of quality defects slowly decreases. Frequently existing defects were that screws on the left and right fenders were not tightened, which makes it an assembly issue since these operations have been missed to be performed. The defects could result in the fenders of the pedal car falls off. Another quality defect was that the wrong handbrake was assembled which results in that the function of the handbrake does not meet the requirements, the performance of the assembling of the handbrake was correct but the wrong articles were used which makes it an article number issue.

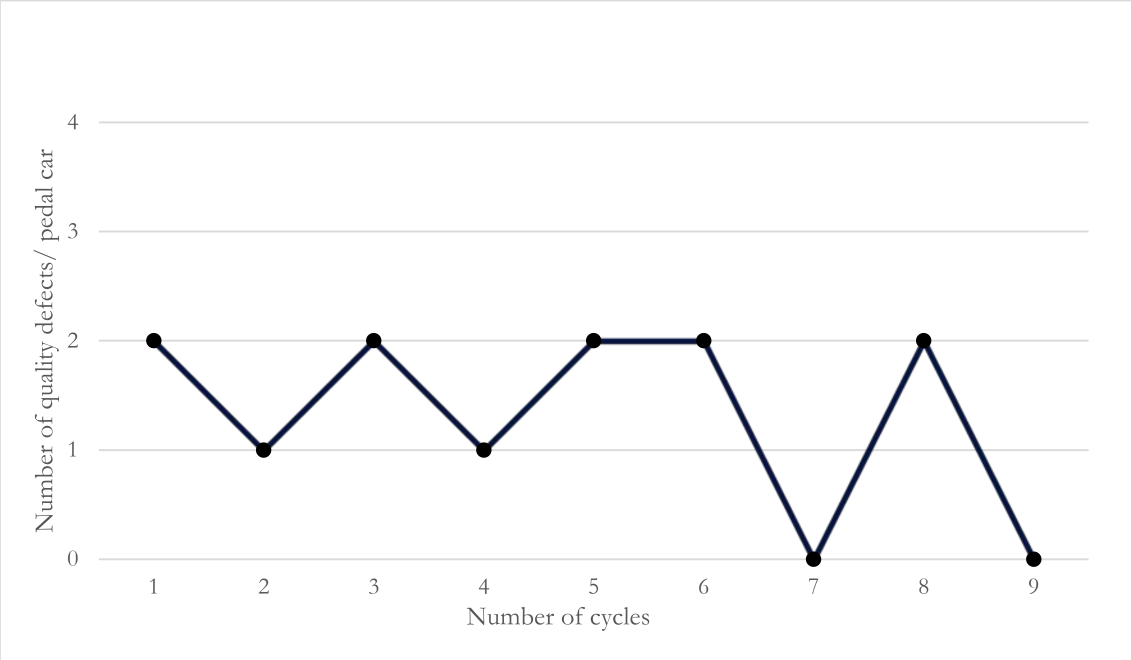

Figure 6.4 The number of Quality defects (Reference group)

6.1.4 Cycle time to assemble the pedal car

Figure 6.5 shows a line chart with two lines representing the time progress for red and black pedal cars. The chart shows that the time to assemble decreases for each pedal car completed. The first red pedal car was assembled in 1241 seconds and the time decreases quickly and by the third car the time is reduced to 540 seconds. The time then becomes steadier and is continued in an approximately equal pattern where the last assembled cars cycle time was 391 seconds. The seventh red pedal car had an issue where the front frame was not assembled since it was hackneyed and therefore it was assembled the same time as operation, place the front frame. As mentioned earlier, the operations to tighten the screws on the left and right fenders were not performed and the time was therefore lower than it would had been if all operations were performed.

The first black pedal car was assembled in 1000 seconds where the time decreases afterwards. The handbrake was already assembled at the second black car which implied that those operations were not performed and that resulted in a misleading cycle time of total 528 seconds. The last black pedal car was assembled in 281 seconds and had the same issue with the front frame as the last red pedal car.

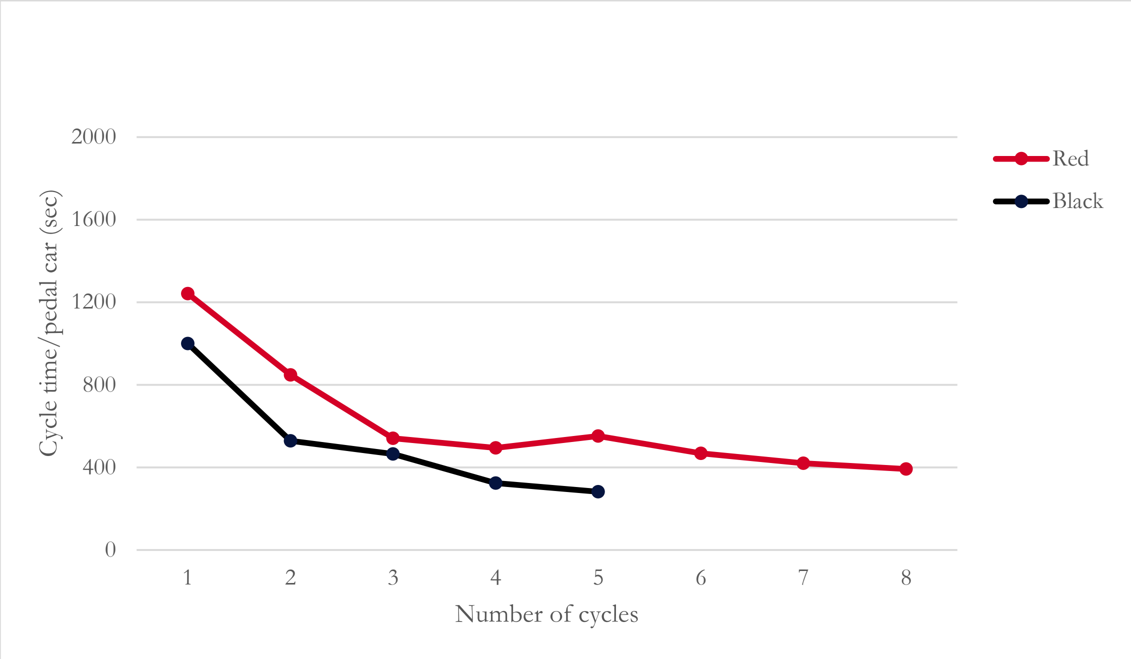

Figure 6.5 The Cycle times (Reference group)

6.2 Test group 1

The total test group consisted of total ten trainees with an age span between 20 and 47 whence four trainees at Station 1 in the age between 20 to 23 years old. The trainees were performing computer-based training in SeQualia. All results are measured during assembling at Station 1 except from the SeQualia score which consists of the results from all trainees in Test group 1. The assembling performed by the trainees from Station 1 did not lead to any quality defects, thereby will that parameter not be presented. The takt time decreases during each assembled pedal car and Test group 1 assembled totally 14 red pedal cars and 11 black pedal cars during the measurements.

6.2.1 Operation & performance faults

Figure 6.6 shows a bar chart with the total average value of choosing wrong operation and choosing correct operation but wrong performance of the total number of takts. During the first day of assembly, the total average value of choosing wrong operation in a takt was 0.33 times with a standard deviation of 0.58. During the second day of assembly, the total average value of choosing wrong operation increased to 0.63 and the standard deviation to 1.21. Frequently wrong chosen operations were Operation 5 where the trainee assembled the right fender directly after the left, and Operation 10 and 11 on the black pedal car where the trainee changed the order and performed Operation 11 before 10. The trainees missed to perform Operations 14 to 16 at one pedal car. See appendix C for all operation on Station 1.

During the first day of assembly, the average value of correct operation but wrong performance in a takt was 5.33 times with a standard deviation of 4.04. The average value decreased on the second assembly day to 3.84 with a standard deviation of 2.27. The trainees' general issues were that they picked the wrong articles and tools and picked articles to several operations at the same time. This resulted in that the tools and articles were placed on the pedal car, in the trainees' pockets or hands during performing current operation. Two trainees were cooperated during performing the operations and therefore the operations were wrong performed. Other specific wrong performance for correct operation was wrong placement of the hands in Operation 1 and 2. The trainees hit the fender with the hand instead of using the rubber mallet during the fender assembly. The trainee was placing the washer directly on the screw instead of placing it on the nut first at Operation 5 and 8. The trainees watched the wrong instructions for Operation 4 and read instead the instructions for Operation 10 and therefore placed the wrong articles but the trainee rectified that afterwards with the correct articles. The tools were placed in the wrong order at Operation 6 and 8 by placing the torque-key before the allen-key. At one pedal car during Operation 12, the trainee who was assembling performed the operation correctly until the reading trainee said that the trainee was doing it incorrectly and changed it so it became wrong performance. At Operation 15 the control of the handbrake was performed incorrectly and afterwards the control of the handbrake was left in the wrong position.

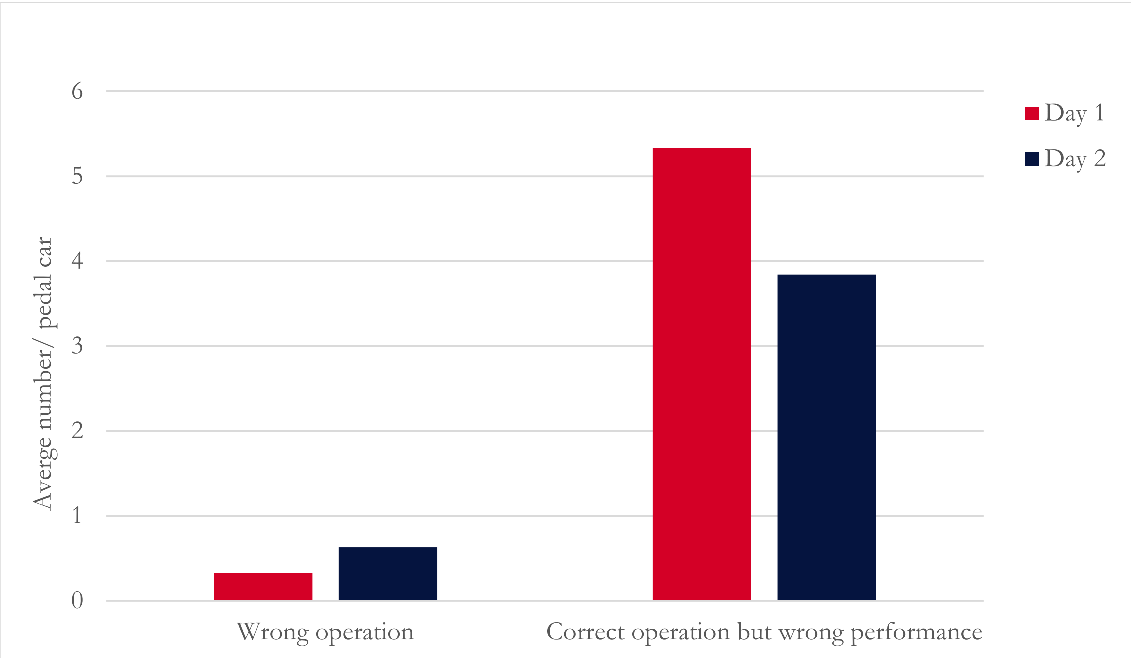

Figure 6.6 Average of Wrong operation and Correct operation but wrong performance (Test group 1)

6.2.2 Checking instructions for operation & performance

Figure 6.7 and 6.8 shows pie charts with the percental number of times where the trainees checked instructions for operation and performance of total number of takts. During the first day of assembly, the percental number of times where the trainees checked the instructions for chosen operation was 75 percent and decreased to 52 percent on the second day of assembly. The percental number of times where the trainees checked the instructions for performance was 75 percent on the first day of assembly and decreased to 62 percent the second day. The pie charts show that the need of checking the instructions has decreased for both operation and performance.

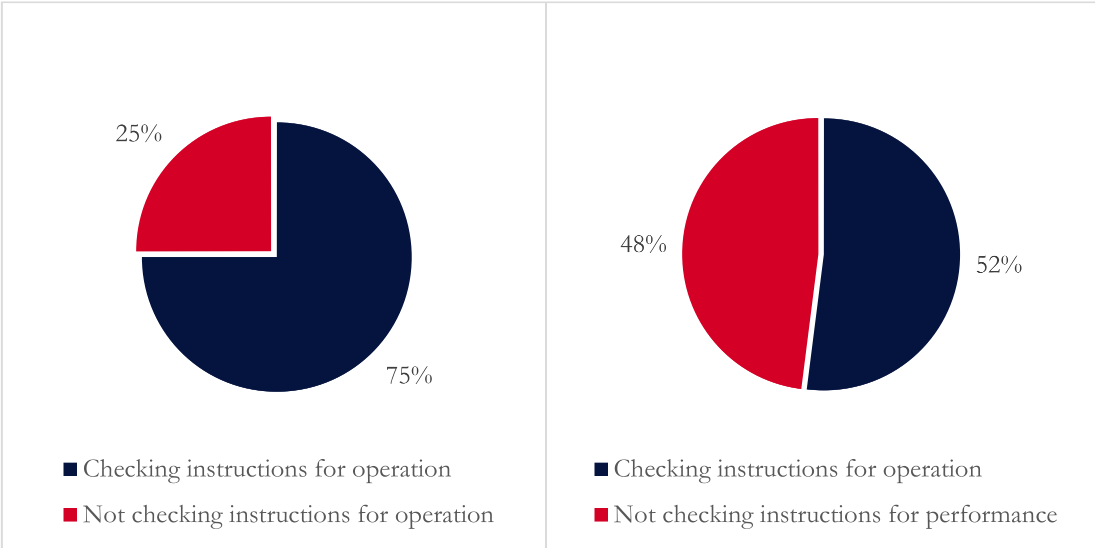

Figure 6.7 Number of Checking instructions for operation (Test group 1)

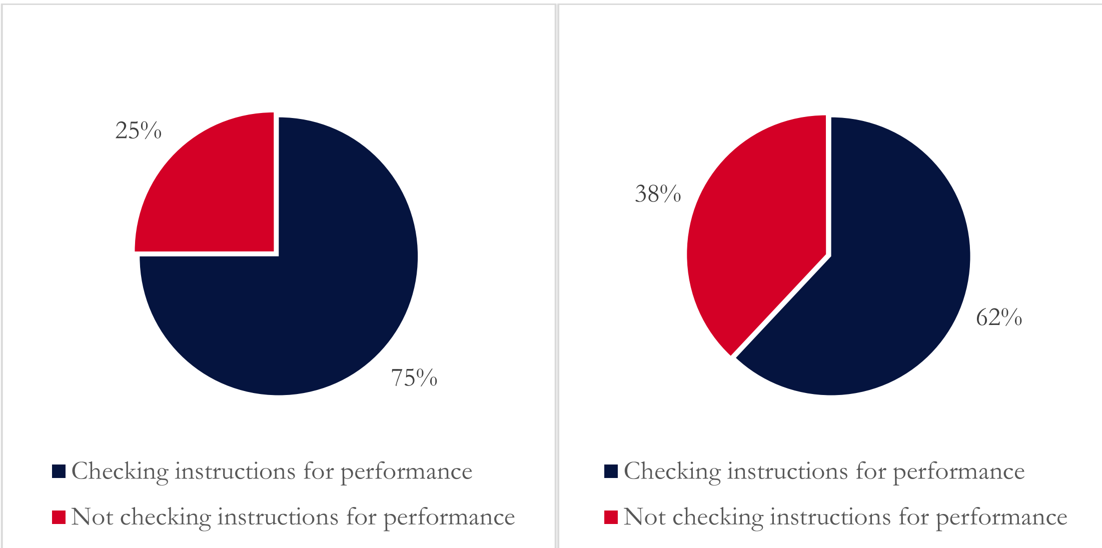

Figure 6.8 Number of Checking instructions for performance (Test group 1)

6.2.3 Cycle time to assemble the pedal car

Figure 6.9 shows a line chart with two lines that represent the time progress for red and black pedal cars. The vertical lines in the diagram represent the moments of training in SeQualia, thereby the training was performed after the second and fourth red and black car. The trainees assembled four pedal cars before the first training moment, then assembled four cars again after which they had another training moment and lastly assembled the remaining pedal cars. The first red pedal car was assembled in 2086 seconds and the time decreases quickly afterwards. The third red pedal car was assembled in 862 seconds but the trainee missed to perform operations 14, 15 and 16 therefore the cycle time is misleading. Andon was used in the assembly of the fourth pedal car to perform operation 12-15, the time to assemble the car was 1056 seconds. The cycle times until the seventh red pedal car are unsteady. The eight red pedal car's cycle time of 492 seconds is misleading since the andon operator assembled Operation 6 to 9 and 12 to 15. The last cars cycle times decreases slowly and by the thirteenth car the cycle time was 371 seconds. On the last pedal car, the trainees had issues with that the right fenders were out of store which implied that the andon-operator performed Operation 8 and 9. The time for waiting for the right fenders was 70 seconds and was subtracted from the total cycle time, the cycle time amounted to 432 seconds. The first black pedal car was assembled in 1275 seconds, though the correct fenders were missing and the waiting time was 240 seconds and was subtracted from the total cycle time. Operation 2 was missed and andon performed Operation 14 and 15 and time to assemble ended on 1035 seconds. The second assembled black car was assembled in 969 seconds, after the second car the cycle time decreases for each assembled pedal car and the last black pedal car was assembled in 309 seconds.

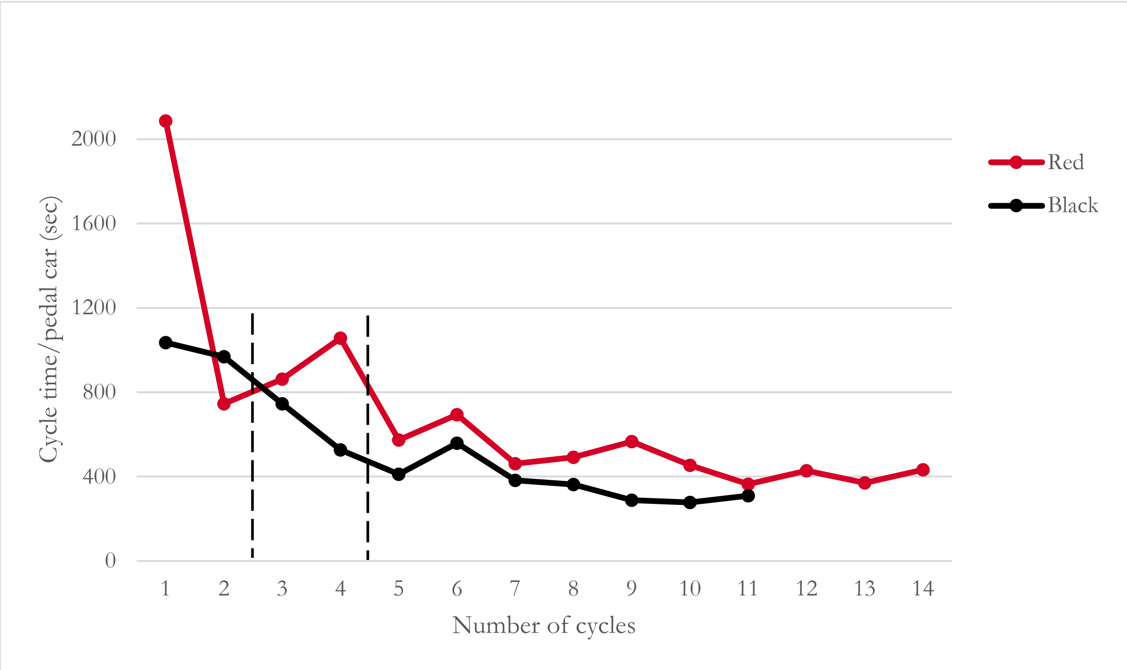

Figure 6.9 The Cycle times (Test group 1)

6.2.4 SeQualia score

The score from SeQualia consists of results from games performed by trainees in Test group 1. The scores from trainees at Station 1 are presented below in Figure 6.10, the scores from the remaining trainees are presented in appendix D. The scores are based on performing of Operation 1 to 16 for red and black pedal cars. The number of played cycles varies between 9 to 14 cars. While playing SeQualia, the trainees alternated playing a red and a black car. The main part of trainees score starts within 60 to 80 percent and increases afterwards, the average number in score starts at 78 percent and increases to 98 percent. The results from Trainee 2 stands out from the other trainees since the trainee performed a higher result than the other trainees. There was a technical problem during a training moment with SeQualia which resulted in that some scores were not saved.

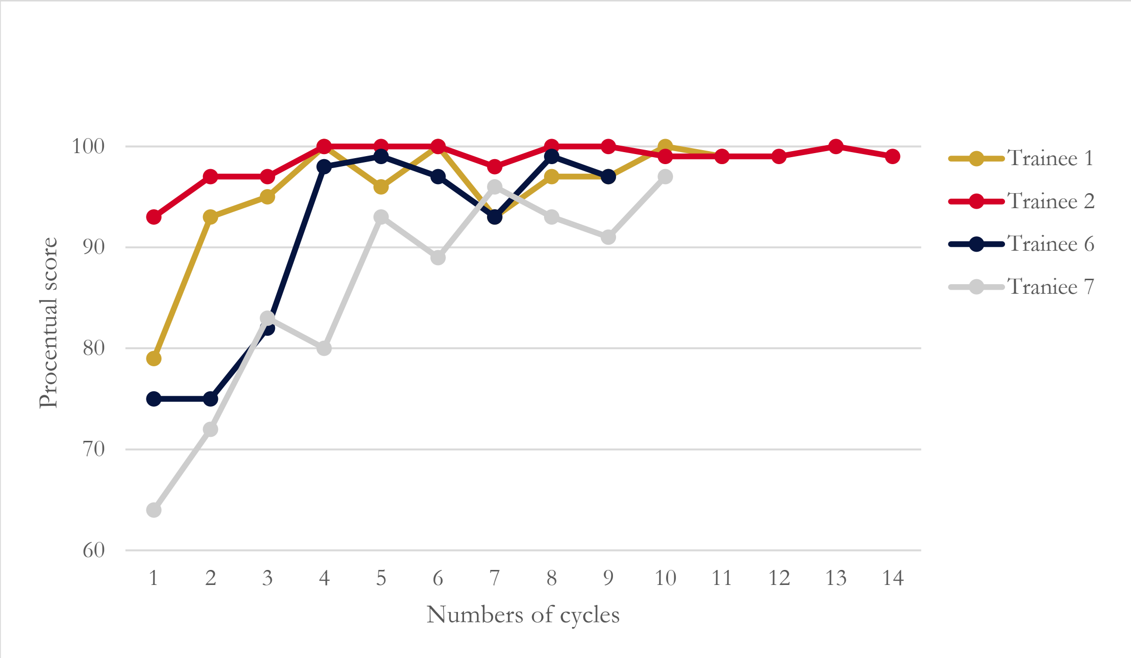

Figure 6.10 SeQualia score for trainees on Station 1 (Test group 1)

6.2.5 Opinions of SeQualia

Comments about the software have been obtained from four Training managers and ten trainees from Test group 1. The answers have been collected from the questionnaires and other opinions have been gathered during the observations and training moments. The questionnaire for the Training managers shows in appendix E and the questionnaire for the trainees is shown in appendix F.

6.2.5.1 Training managers

The answers from the Training managers were scattered and are shown in figure 6.11. There were different opinions about if training in SeQualia is a better method than reading the standardised worksheets. Two Training managers thought it is a better method and two did not agree. The main part of the Training managers answered that the trainees' ability to build a pedal car has not been changed through training in SeQualia. Some of the Training managers thought that were easy and fun to train in SeQualia. Thoughts obtained from the Training managers were that it was a great software but it could be better. It is hard during the first training moments since the trainees cannot ask someone about for example which parts should be assembled and what the differences are between the two variants red and black car. Training through SeQualia might be better suited for experienced operators to learn new variants and operations. There was a lot of text to read before getting the right sequence. A personal opinion from the Training managers was that they preferred to read standardised worksheets and practical training but the understanding of learning and repeating have been obtained. A suggestion was to train in SeQualia to handle deviations. One opinion was that the technology for SeQualia is available and should be used.

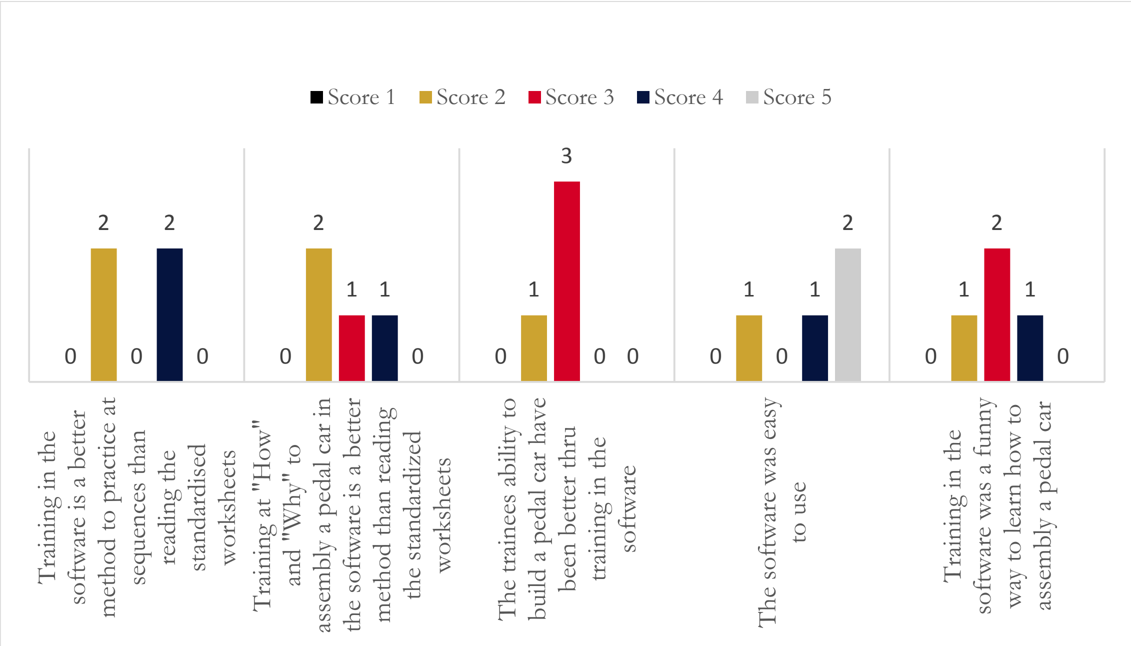

Figure 6.11 Opinions of SeQualia from the Training managers

6.2.5.2 Trainees

The answers are scattered within the one-to-five scale are shown in Figure 6.12. The mainly part of the group thought training in SeQualia is a better method to practice on sequences and what and how assemble the pedal car than reading the standardised worksheets. All trainees thought that the ability to build the pedal car has been improved through training with SeQualia. The main part of the group considered the software easy to use, but two people thought it was a little difficult. The last question answered was if the trainees thought that training in SeQualia was fun and the result became scattered in the scale between two and five.

Obtained comment was that it was a great software to practice the standardised worksheets. Some of the trainees understood the main purpose with the computer-based training, to learn the standards faster and more accurate. Some of the trainees would like to have more practical training before the computer-based training to obtain the knowledge of the physical part since the trainees are new employees. Some trainees had a negative approach to use computers and were not motivated to train in SeQualia. Another opinion from the trainees was that it was boring to train on the computer and would have preferred only practical training. Some of the trainees thought it was hard to handle computers and the trainees who had reading difficulties thought it was difficult to play the game.

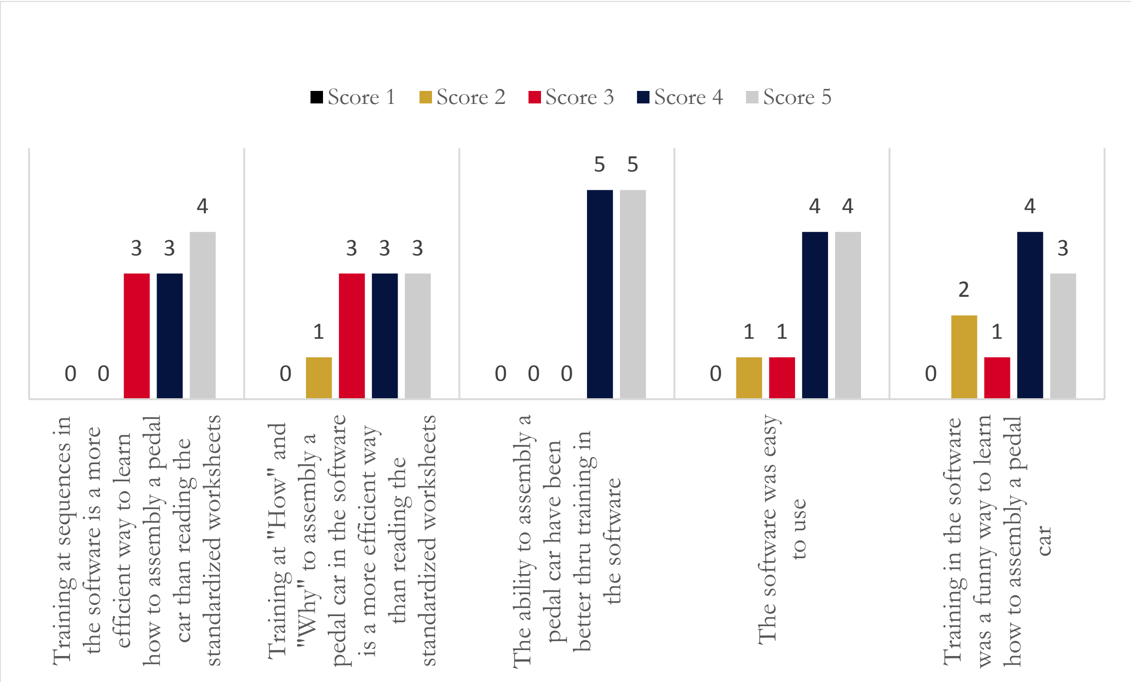

Figure 6.12 Opinions of SeQualia from the trainees (Test group 1)

6.2.5.3 External comments

Group managers at Chassis at Scania thought that SeQualia seemed to be a great software. There might be a problem when the standardised worksheets have been updated since there is no system for synchronise the software and the standardised worksheets. Chassis at Scania has thousands of element sheets with extensive "How"-instructions. The group managers consider that training in SeQualia would be a good tool for a theoretical test since the training at Chassis only check the operators' practical ability. SeQualia could be used for individual training but it is not necessary to report the result to someone else to show progress. Training in SeQualia could work today at the line since there is a lot of young operators that are very comfortable working with computers.

6.3 Test group 2

The test group consisted of four trainees assembling at Station 1 where the age span was between 24 and 38 years. The trainees performed computer-based training in Vizendo. All results were measured during assembling at Station 1. The results of the performed operations only consisted of results from Operation 1 to 9 since the trainees have not trained the remaining operations in Vizendo. The takt time decreases during each assembled pedal car and Test group 2 assembled 16 red pedal cars and 11 black pedal cars during the measurements.

6.3.1 Operation & performance faults

Figure 6.13 shows a bar chart with the total average value of choosing wrong operation and choosing correct operation but wrong performance of the total number of takts. During the first day of assembly, the average value of choosing wrong operation in a takt was 0.20 times with a standard deviation of 0.45. During the second day, the average value and standard deviation of choosing wrong operation increased to 0.36 and 0.50. Both on the first and second day of assembly, the only wrong chosen operation was Operation 5 where the trainee assembled the right fender before the left, which is Operation 6. One trainee missed to perform Operation 1 to 3 at a pedal car which implied that the front frame was missing.

During the first day of assembly, the average value of correct operation but wrong performance in a takt was 2.20 and the standard deviation was 0.84. The average value decreased to the second day to 1.23 and standard deviation increased to 1.47. Issues that the trainees had with wrong performance were generally choosing the wrong articles and placing the tools in the wrong order. The torque-key was often placed before the allen-key during Operation 6 and 9. A situation that occurred was when one trainee performed Operation 1 and 2 at the same time, another trainee placed the front frame upside down and the trainees are often placing their hands incorrectly. At one pedal car, the trainee hit the fender with the hand in Operation 4 and 7 which might lead to hand injuries. Some other issues were in Operation 5 and 8 where the trainee placed the washer on the screw instead of placing it on the fender. Since the software of Vizendo was incorrect, the performance which was wrong according to the standardised worksheets but correct in the software was expected from the results.

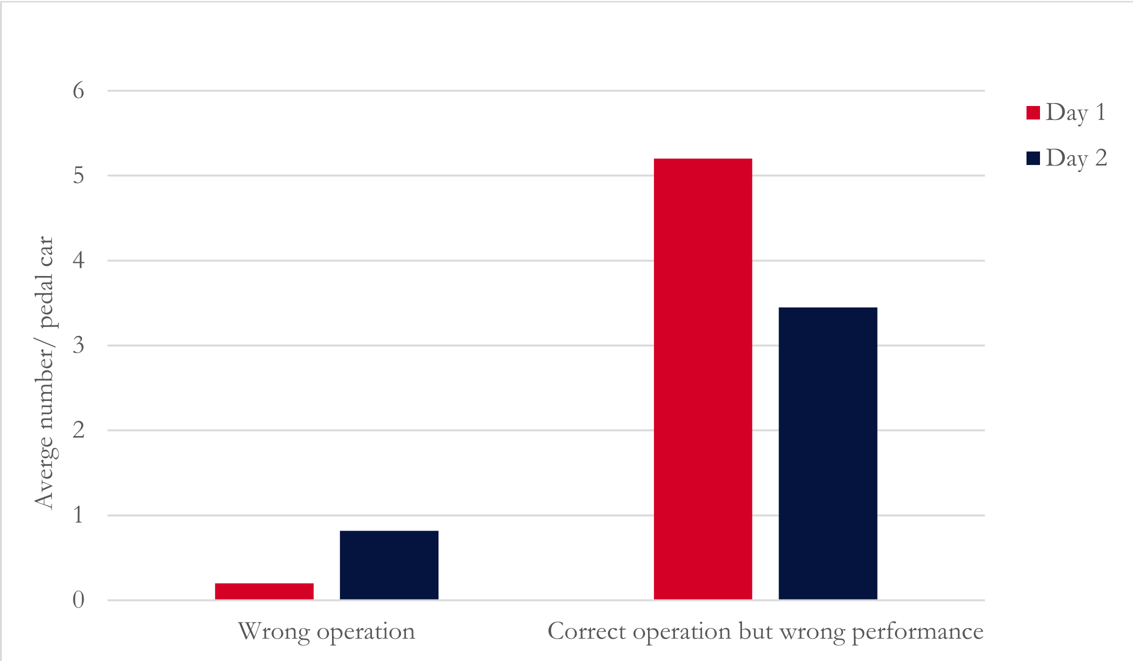

Figure 6.13 Average of Wrong operation and Correct operation but wrong performance (Test group 2)

6.3.2 Checking instructions for operation & performance

Figure 6.14 and 6.15 shows pie charts with the percental number of times where the trainees checked the instructions for operation and performance in the total number of takts. During the first day of assembly, the percental number of times where the trainees checked the instructions for chosen operation was 100 percent and decreased to 35 percent on the second day of assembly. The percental number of times where the trainees checked the instructions for performance was 100 percent on the first day of assembly and decreased to 35 percent the second day. The pie charts show that the need of checking the instructions has decreased for both operation and performance.

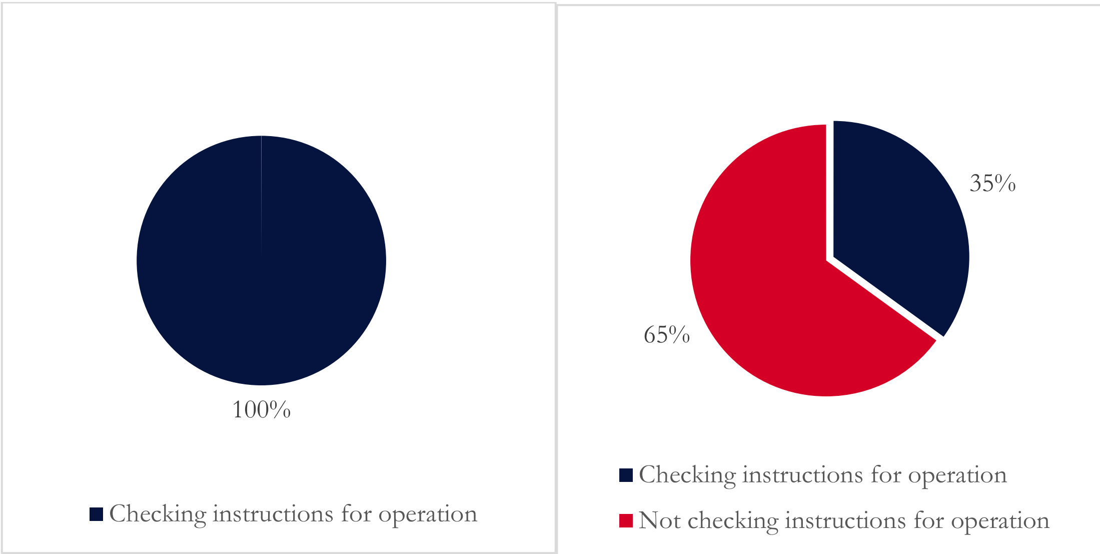

Figure 6.14 Number of Checking instructions for operation (Test group 2).

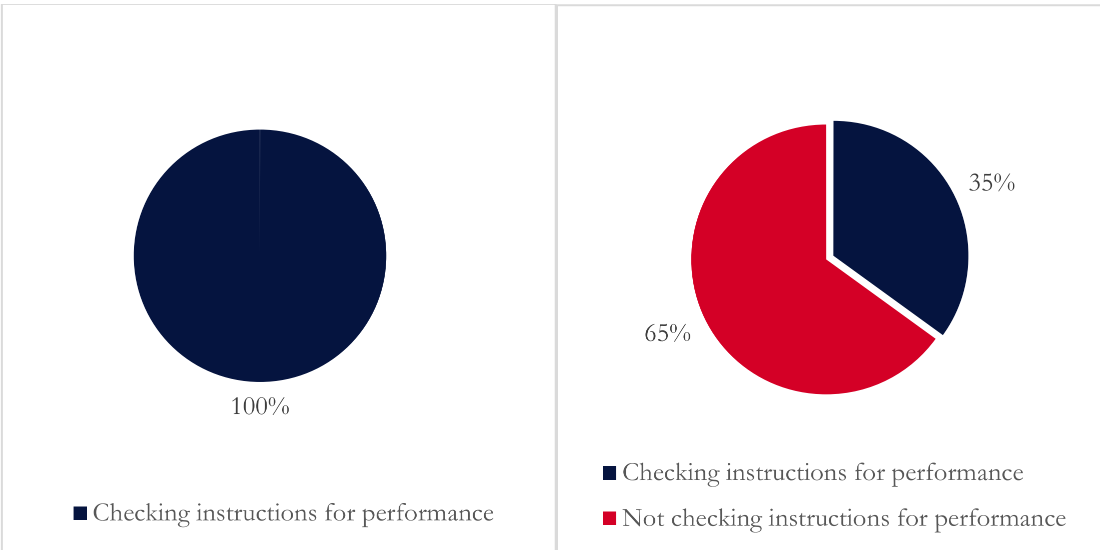

Figure 6.15 Number of Checking instructions for performance (Test group 2)

6.3.3 Quality defects

Figure 6.16 shows a line chart with the number of quality defects on a pedal car. The chart shows that the number of quality defects is relatively few. The quality defects consisted of that one trainee had assembled the wrong articles for the rear fenders, this fault is more of an article number issue than an assembly issue. At one pedal car the trainee had not signed off on that the handbrake was controlled which makes it unclear if the function of the handbrake work correctly, these issues have occurred during operations which the trainees did not train in in Vizendo. One critical failure which the trainee practiced in Vizendo and missed during a measurement was to assemble the front frame on one car.

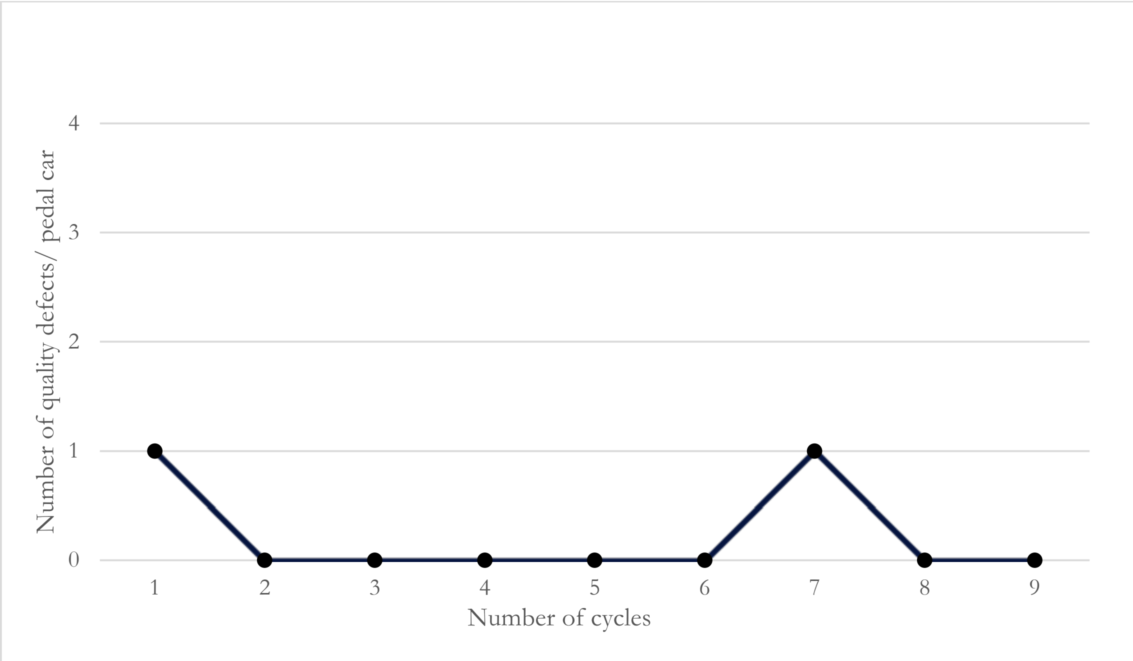

Figure 6.16 The number of Quality defects (Test group 2)

6.3.4 Cycle time to assemble the pedal car

Figure 6.17 shows a line chart with a line that represent the time progress for red pedal cars. The cycle time is unsteady and it turns up and down for approximately all red cars. The first red pedal car's cycle time was 1137 seconds. The fourth red pedal car's cycle time was 982 seconds, though the rear fenders were out of store which implied that the trainee waited for 154 seconds until new fenders came in and andon performed Operations 7 to 9. The 154 seconds were subtracted from 982 seconds and the new cycle time amounted to 828 seconds. By the sixth red pedal car the cycle time has decreased to 736 seconds, though the left fenders were out of stock. Therefore, the trainee assembled the handbrake so no time to assemble was lost. The tenth pedal car's cycle time was 613 seconds, after this pedal car the cycle time decreases more continuous where the last car's cycle time was 311 seconds.

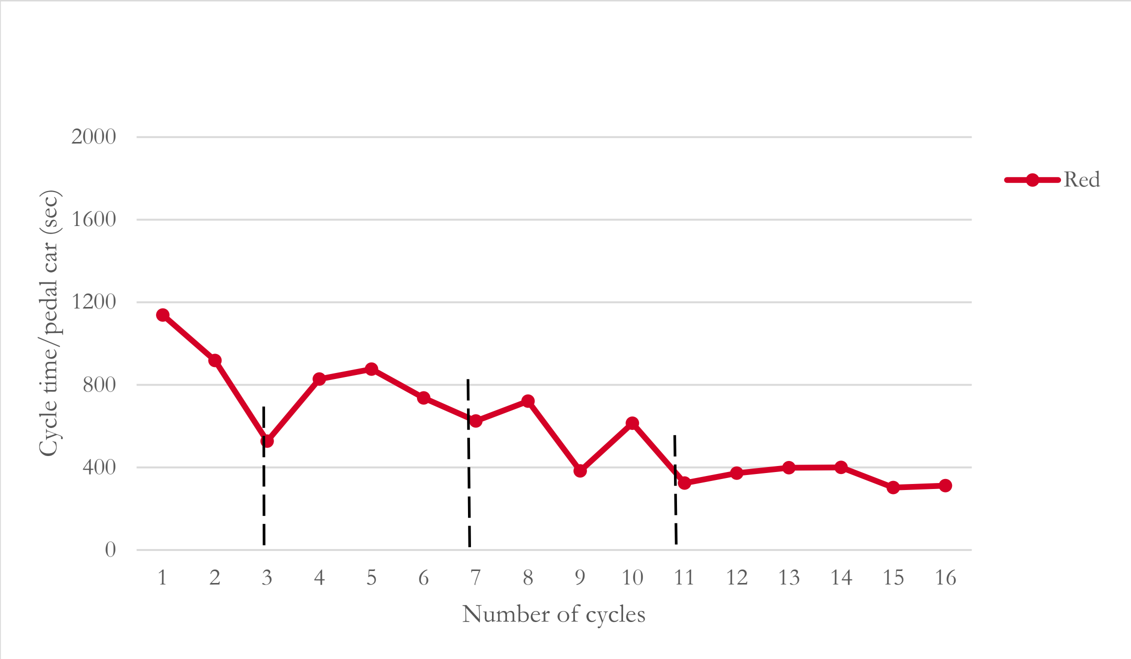

Figure 6.17 The Cycle times (Test group 2)

6.3.5 Vizendo score

The score from Vizendo consists of the result from games performed by trainees in Test group 2. The score from Vizendo consists of results from the third level in the software. The scores are performed by trainee 11, 12, 13 and 14 which assembled at Station 1. The scores are based on assembly of operation 1 to 9 for the red pedal car and the scores are presented in figure 6.18 below. The number of played cycles varies between the trainees, from ten to eighteen cars. The average number of the score starts at 96.5 percent and increases to 99.8 percent. The result from trainee 11 is distinguished from the other trainees during the first seven played games and became steady after the eighth assembled car.

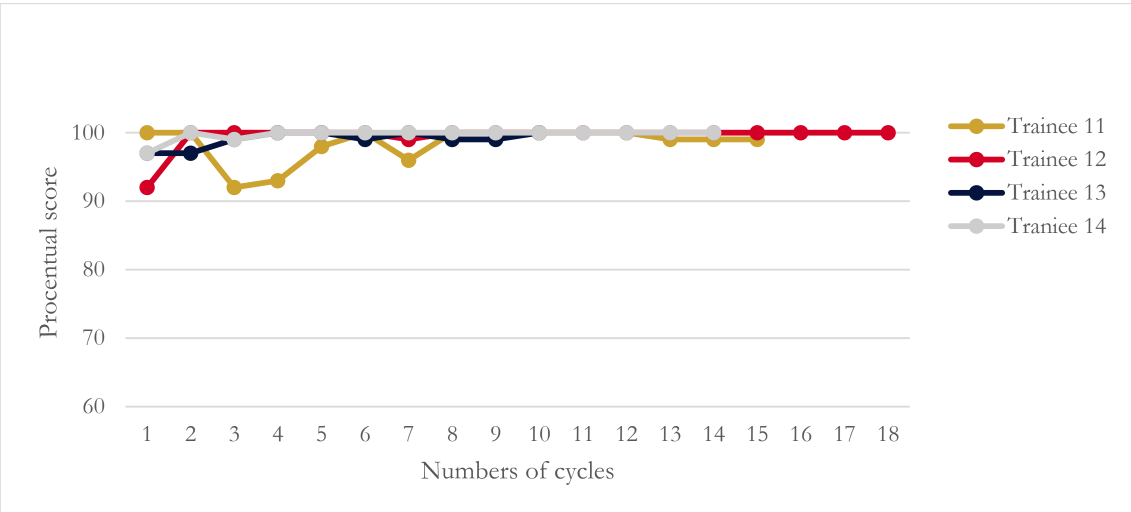

Figure 6.18 Vizendo score for trainees on Station 1 (Test group 2)

6.4 Opinions of Vizendo

Comments about Vizendo have been obtained from four trainees from Test group 2, the comments from the Training managers could not be obtained. The answers have been collected from the questionnaires and other opinions have been gathered during observations and training moments. The questionnaire for the trainees shows in appendix F.

6.4.1 Trainees

The answers are scattered within the one-to-five scale as shown in Figure 6.19. The main part of the group was neutral to the first and second question except from one trainee who thought training in Vizendo was an efficient method to learn sequences. 50 percent of the trainees thought the ability to assemble the pedal car had been better through training in Vizendo. All trainees considered the software easy to use and the main part thought it was fun. Some of the trainees thought the software was difficult since it did not match the standardised worksheet completely, therefore the trainees considered lower scores at the questions.

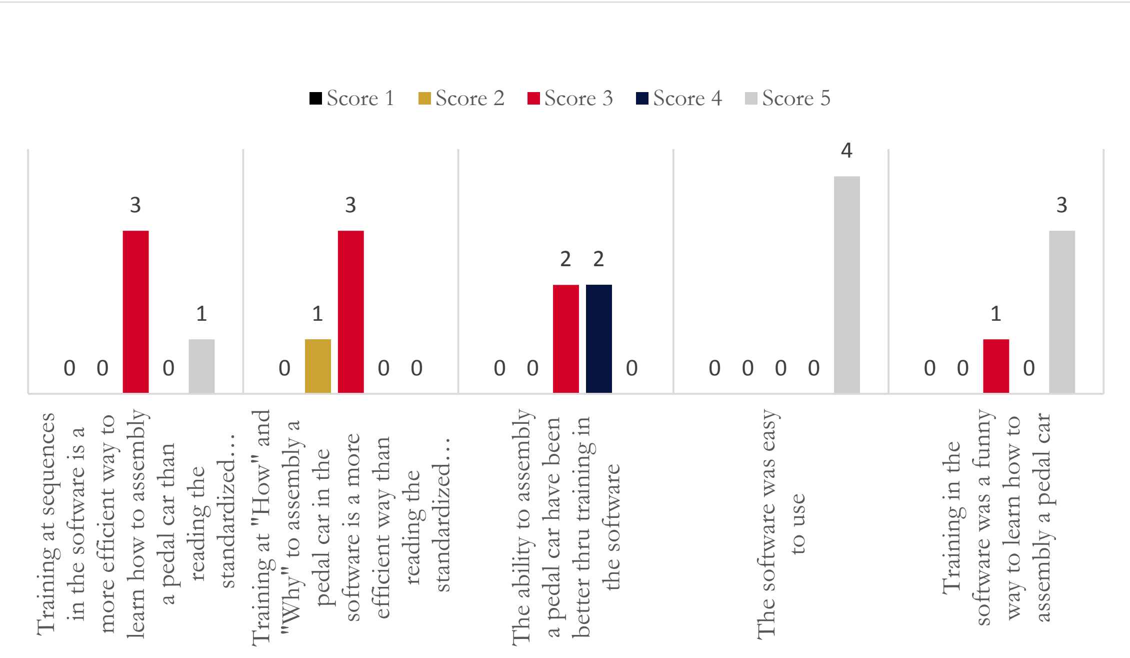

Figure 6.19 Opinions of Vizendo from the trainees (Test group 2)

7 Result analysis

This chapter will present the analysis of the obtained results. The analysis will follow the structure of the result chapter and will therefore be presented in order of the parameters; *Wrong operation*, *Correct operation but wrong performance*, *Checking instructions for operation and performance*, *Quality defects* and *Cycle time.*

The number of choosing wrong operations and wrong performance are calculated in average values of an operation. A summarisation of the comparison of the results of *wrong operation* and *wrong performance* between the Reference group, Test group and Test group 2, are shown in table 7.1. The results of Test group 1 training with SeQualia shows a negative progress of choosing correct sequences of operations but the Test group 1's value is lower. The average number of choosing wrong operation during the first day was 1.25 for the reference group and 0.33 for Test group 1. Until the next day, the average number of choosing wrong operation increases for both the reference group and Test group 1 but the average number for Test group 1 is still lower at 0.63. The average number of wrong performance for Test group 1 in the first day is significantly higher than the reference group's. Until next day, the average number for Test group 1 is decreasing while the reference group's average number is increasing. As earlier mentioned, Vizendo was not consistent with the standardised worksheets, therefore only the results from Operation 1 to 9 for the red pedal car will be presented and compared. The results of Test group 2's training with Vizendo shows a negative progress of choosing the correct sequences of operations, but the values are lower for Test group 2. The average number of choosing wrong operation during the first day was 1.25 for the reference group and 0.2 for Test group 2. Until the second day, the average number of choosing wrong operation is increasing for both the reference group and Test group 2 but the average value for Test group 2 is still lower at 0.36. The average number of wrong performance is higher for Test group 2 than the reference group at the first day. Until the next day, the average number for Test group 2 is decreasing with 44.09 percent while the reference group's average is increasing with 108 percent.

Table 7.1 Summarisation of the comparison of the result of wrong operation and wrong performance

	Reference group			Test group 1		
	Day 1	Day 2		Day 1	Day 2	
Wrong operation	1.25	1.89	51.20%	0.33	0.63	90.91%
Correct operation but wrong performance	1.00	1.33	33.00%	5.33	3.84	-27.95%
	Reference group			Test group 2		
	Day 1	Day 2		Day 1	Day 2	
Wrong operation	1.25	1.56	24.80%	0.20	0.36	80.00%
Correct operation but wrong performance	0.75	1.56	108.00%	2.20	1.23	44.09%

The times of checking the instructions for operation and performance is calculated in percental number of pedal cars where the instructions were checked. A summarisation of the comparison of the results of *checking instructions for operation and performance* between the reference group, Test group and Test group 2 are shown in table 7.2. Generally, the trainees checked the instructions even though they actually knew what operation to choose and how to perform it but did not trust their ability. In some cases, the trainees checked the instructions when they were stressed which implied that they did not read them clearly and the operations were chosen or performed wrong anyway. The total need for checking the instructions for Test group 1 shows a positive progress. The percental number of checking the instructions for choosing operations decreased to 0.52 and for performance 0.62 where the reference group had a lower value for checking the instructions for performance than Test group 1. The total need for checking the instructions for Test group 2 also shows a positive progress. The percental number of checking the instructions for choosing operations decreased to 0.35 and for performance 0.35 where the reference group's value was lower for checking the instructions for performance than Test group 2.

Table 7.2 Summarisation of the comparison of Checking instructions

	Reference group			Test group 1			Test group 2		
	Day 1	Day 2		Day 1	Day 2		Day 1	Day 2	
Operation	1	0.78	-22.00%	0.75	0.52	-30.67%	1.00	0.35	-65.00%
Performance	1	0.22	-78.00%	0.75	0.62	-17.33%	1.00	0.35	-65.00%

By training in SeQualia the *quality defects* were eliminated and by training in Vizendo the quality defects decreased to two defects, which is a reduction with 87.5 percent.

The *cycle times* assembling the red pedal car are presented from all groups. A summarisation of the comparison of the result of *cycle times* between the reference group, Test group 1 and Test group 2 for the red pedal car is shown in Figure 7.1. The comparison of the results for the black pedal car is shown in Figure 7.2, where the results from Test group 2 are not included. The reference group consisted two trainees which implied a steadier curve but with fewer pedal cars assembled. The figure shows that the cycle times decreases quickly after the first pedal car assembled and evens out after the second assembled car for all groups. The first red pedal car assembled by Test group 1 assembled after training in SeQualia had a cycle time that was significantly longer than the first red pedal car assembled by reference group.

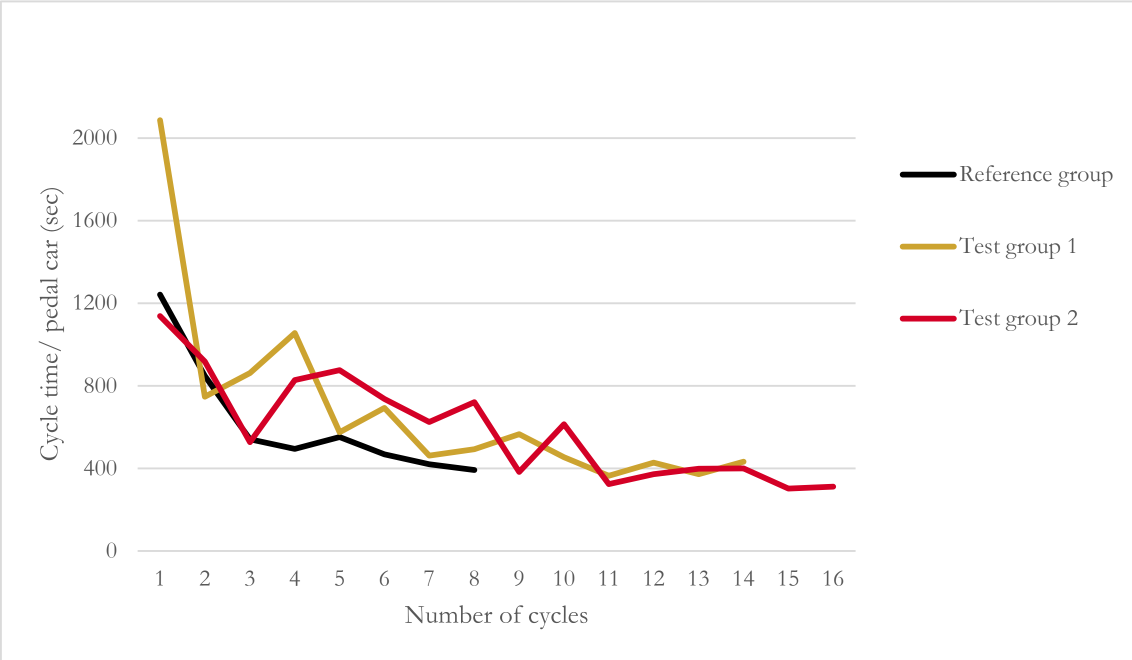

Figure 7.1 Summarisation of the comparison of the cycle times for the red pedal car

Figure 7.1 shows that the *cycle time* for Test group 2 is unstable and turns up and down simultaneously as it decreases slowly. Since the trainees could not practice assembling the black car in Vizendo these results cannot be analysed. A critical aspect is that the trainees only practiced Operation 1 to 9 on the red pedal car, therefore the cycle time is difficult to analyse against the reference groups. When assembling the black pedal car, the cycle times are declared in figure 7.2. The curves for the reference group and Test group 1 decreases equally but the reference group decreases a bit faster.

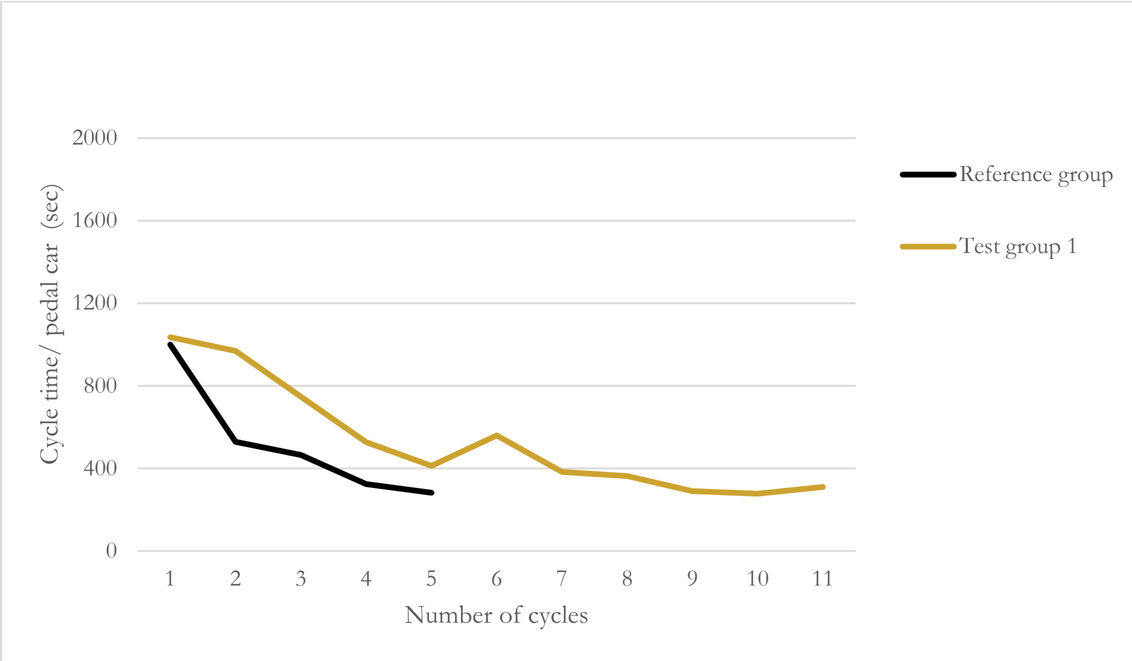

Figure 7.2 Summarisation of the comparison of the cycle times for the black pedal car

Earlier presented line chart showed that the scores from games played in SeQualia were scattered between the trainees. The trainees started their scores at different levels and the lines increase quickly in the beginning and arises slowly afterwards. One trainee was distinguished from the other trainees having a result significantly higher from the beginning. The score from Vizendo showed a steadier progress for all trainees. At first, there was a result distinguished from the other where the progress was unsteady and later became steady and in line with the other trainees. After the eight played game in Vizendo almost all trainees achieved the highest score and continued on the same level.

8 Discussion

A large amount of measurable and immeasurable data has been collected in the study. To respond to the questions which needed to be investigated this chapter will discuss the results with consideration of significant factors and relevant literature. The chapter aims to find strengths and weaknesses to support future recommendations to Scania.

8.1 Credibility in methods

By working with the acknowledged method PDCA for continuous improvements, reliability has been achieved. The scientific articles that been used in the study are published in peer reviewed journals and are available in full text to be able to see the entirety in the articles. The literature has been critically examined to make clear that it is secondary data. Only books in the latest versions have been reviewed. Some of the keywords and scientific articles have been recommended by the supervisor at University West who has knowledge and experience of the subject.

To increase the validity in the study several methods of data collection have been used; interviews, observations and surveys. The interviews have been formed in a semi-structure way with control questions that were asked during the interviews to increase the credibility. Notes were taken during the interviews and were compiled directly after to ensure that no information was forgotten. There was no time-limit in the interviews to avoid stress and loss of important information. The interviews have been executed with peoples who have experience of Vizendo and SeQualia to obtain knowledge of previous studies with the softwares. Genchi genbutsu was used to obtain an objective and reliable view of the current situation analysis and the assembling in the real factories. Although that was time-consuming, it was valuable to a get good understanding of the training processes. During the measurements the trainees were informed that they were observed and measured. This decision was taken together with the Training managers relating to Scania academy's approach, since they are used to having open dialogues with the trainees. The authors did not tell the trainees what were correctly and incorrectly performed, and did not assist them during the assembling, to not affect the results.

The survey with questionnaires for the trainees were performed after the last training moment in the pedal car factory, the questionnaires were manually collected from all trainees to ensure that the information was obtained. The scale on the questionnaires were one to five on to obtain credibility in the information. The respondents were anonymous to keep it objective. The test groups have practiced computer-based training combined with practical training during equal time as the traditional training for the reference group. Since the test groups training was performed during regular education weeks, the external errors in the training process were clocked and noted so that they would not affect the result.

Validity, reliability and objectivity have been achieved through the approaches mentioned above. The insurance of the study's credibility is achieved by connecting these three factors together.

8.2 Previous accomplished studies within Virtual training

The interviews with the experienced users of SeQualia and Vizendo were performed according to Björklund & Paulsson's (2014) description of a semi-structured interview. A few predetermined questions were prepared before the interview which meant that the interviewed persons could lead the interview by them self. The interviewed persons had the opportunity to talk freely about their experiences of the softwares and new questions were formed to get a deeper understanding of the topics during the interviews. The interviews have implied that reliable data has been obtained which was useable to see training with the softwares in a holistic perspective.

Factors that could have affected the result of the interviews are presented in this section. Before the interviews were carried out documented information about the results of the studies were already obtained which might have affected the forming of the predetermined questions. The interviews were carried out at two different moments in the study. The interview with the user of Vizendo was performed in the start while the interview with the user of SeQualia was in the middle of the study. Thereby, more knowledge was obtained before the second interview. Even though the same questions were asked during both interviews, more detailed questions to follow-up the subject could have been asked in the second interview which created more comprehensive discussions. The result of the interview with the SeQualia-user has not affected the study's result since the set-up for training was already determined before the interview and was not changed afterwards. The training in SeQualia was not carried out before the interview with the user of SeQualia, thereby the interview was not affected by the user's own experiences with SeQualia.

Several conditions for the earlier studies were not the same as the thesis's which needed to be considered. The operators who were trained in SeQualia at SAAB consisted of both new and experienced operators and the operators who trained in Vizendo at Scania were also experienced. Therefore, the experienced operators were used to working with standards. The set-up for training in SeQualia was the same as in the thesis but the operators trained at the regular processes which gives a more serious impression of the training. SAAB built a separate room for computer training where the operators could train without being disturbed by any external factors. The operators who trained in SeQualia were more focused to doing correct performances which implies they have an increased involvement in their work. This indicates that involvement from SAAB has increased the operators' understanding of computer-based training which have led to improved results. A significant factor to consider is the takt-time, at SAAB was it 123 seconds which is approximately a third of the takt time in the thesis.

The operators' experience of using Vizendo was in general positive where an advantage was that they thought it was easy to use. A disadvantage was that the operators from the older generation did not understand the purpose to train in Vizendo and believed it to be unnecessary. This is probably founded in that the younger generation is more experienced of using computer-based software and therefore have a more positive attitude. The incoming generation is more digitalised and therefore the training process can be in need of modernisation. This confirms Zyda's (2005) statement that there is a gap between the generations today which brings different point of views at digital training. It is hard to please everyone, but the new generation is the future and by that there are good possibilities for development in the traditional training methods. With training in SeQualia the operators had a generally positive experience of the program as well. An advantage with the training in SeQualia was that the operators who have reading difficulties can be identified and receive extra help to learn the standardised worksheets both easier and faster.

8.3 Results of the study

This chapter will discuss methods for data collection, external factors, why the results were acquired and what that could have been performed in a different approach.

8.3.1 Study approach

The training in SeQualia and Vizendo needed to be adaptable to the regular schedule of education at Scania Academy. Thereby, the set-up for training was formed in discussions with the Training managers at Scania Academy to find an appropriate solution. The set-up for the training was inspired from the Four-Step Method in Training Within Industry that Dinero (2005) describes in the book *Training Within Industry: The Foundation of Lean*. The trainees in this study were preparing themselves by reading the standardised worksheets. A short presentation of the software was carried out where the trainees got a preview of some operations and performances. But a practical presentation of operations and performance was missing. The trainees performed computer-based and practical training which were followed up with measurements of the assembling on the pedal cars. It was not considered to be necessary to give back the results of the measurements to the trainees since it was education and the trainees were not supposed to assemble more pedal cars. The set-up for training is connected with Scania's four step method described by Anjou & Eriksson (2016) where step one, two and three are the same and the fourth step is used during the later continuous training. It was hard to determine the time for the training and find an appropriate level of practical training needed for the computer-based training. Seen in the hindsight of the set-up for training with SeQualia in this study, the set-up was not suitable for all operators since SeQualia is a knowledge-based software and the ability to use the tools is not trained in the software, which is a disadvantage. A set-up with more practical training before the first moment of computer-based training would probably had been more successful. The result from SeQualia is still considered to be reliable since the trainees actual progress is shown in the fourth education day when they have received more practical training. The set-up for training in Vizendo was successful and since the trainees trained one at a time their focus was better in both computer-based and practical training. In some training moments, the takt time in the process was long towards the cycle time in Station 1 which resulted in that the trainees were only assembling one car and the rest of the time they were waiting. This might have led to a confusing and boring training set-up. When the selected trainees were practicing computer-based training, the Training managers needed to replace them and assemble pedal cars at the line so the trainees at the remaining stations still could be able to perform the traditional training. Therefore, it was not possible to use as many trainees in the study as were desired which resulted in a less statistical basis.

The observations were performed according to one of Björklund & Paulsson's (2014) approaches. The observations were in an observance form where the trainees were informed of being observed. The obtained data from the observations is considered to be reliable since both the authors were observing at the same to avoid that something was missed. An advantage with being two observers is when issues have occurred they have been discussed directly after the moment. To ensure the performance of the operations the standardised worksheets have always been available. There might be some occasional operations where the authors have perceived a performance wrong since some operations were assembled in small areas and the observer did not want to be in the way and some few specific faults might have been judged differently. These few factors which have affected the observations partly have not affected the final result and the result is still considered to be reliable. The observers' ability to observe might have increased during the study so there might be that faults which were not recognised during the first measurements have been noted in the later measurements. This is not advantageous for the computer-based training and this effect needs to be considered in the recommendations and conclusions. In some cases, it was hard to measure faults that were unclear according to the parameters and the judgement in the measurements might have been too harsh. When the trainees chose the wrong operations to perform, but the performance was correct, it was considered to be wrong operation since they were not following the sequences in the standardised worksheets. The parameter for checking instructions were measured so when the trainees were checking the instructions for one operation in a takt it was noted as checking the instructions for the entire pedal car. It might had been better to note which operations the trainees were checking instructions for, to perhaps see a clearer pattern.

A significant factor which need to be considered is the takt-time. In the first education day the trainees were working without time pressure while on the fourth day the takt-time starts. A takt-clock was used set with the assembly time, which then was shortened as the training proceeded, this affected the trainees negative because they started to stress. But the takt-time is a significant factor in the real assembling processes where there always is a takt-clock that controls the flow and thereby it is a factor that needs to be considered. In some cases, the takt-time in the pedal car training process might had been scaled down too fast in proportion to the trainees' learning progress. Since the study's training set-ups are adapted to the regular education, external errors have occurred and have been hard to control. The Parketten is provided with articles from the logistic department in the pedal car factory and since the logistic workers also are trainees it is common that articles are out of store or are wrongly picked. This have affected several cycles during assembling and need to be considered in the thesis. To cope with this the external factors have been controlled by clocking, this was an effective method and reliable cycle time could be measured. During a training moment in SeQualia there was a problem with the internet connection, which might be seen as a disadvantage. This resulted in that the statistics from SeQualia were lost and the trainees thought that were tiring and hard to start over multiple times.

8.3.2 Results of measurements

The results of *wrong operation* and *correct operation but wrong performance* were compiled and calculated as average value to be comparable since the groups did not consist of equal number of trainees and were not assembling equal numbers of pedal cars. The result of the test groups will not be compared with each other, just each group's progress against the reference group.

The fact that the data in Vizendo was not consistent with the standardised worksheets was a disadvantage since all geometry needs to be available to get a functioning usage of the software. This situation could not be affected by the authors since Scania was responsible to provide the infrastructure. The decision to use Vizendo was taken with Scania since it was considered to give a reliable result despite the circumstances. In the training with Vizendo the trainees could only train at a small part of the operations from Station 1. Thereby, a negative effect was that the trainees did not get a serious impression of the training and it was difficult to know how to perform the operations since some operations were not consistent with the standardised worksheets. This affected the results of the trainees' experience of the software. To cope with this the operations that were correctly performed during measurements according to Vizendo but wrong according to the standardised worksheets were not noted as wrong performance. Only the operations that were consistent will be compared with the reference group to acquire a fair result for Test group 2.

The phenomena which occurred in the result analysis that the average of *wrong performance* increased for the Reference group and decreased for the test groups, but the average value was higher for the test groups. Is there more advantageous with a higher starting position that decreases or a lower starting position that increases? The authors considered it being more important that the trainees learn the standardised worksheets than having a great starting position. This is founded in Kaizen since according to Liker (2009), small and large value-increasing improvements and reduced wastage are achieved by working efficiently within the areas of problem solving, processes improvements, analysing and practice of independence within the team.

The trainees who expressed that they have understood the purpose of learning the standardised worksheets in the software, performed good results during the training in the software and the measurements of the trainees who did not understand the purpose and had no motivation to train in the software performed weaker results. The trainees in the study had different learning styles just like Muller et. al (2016) states, all personalities have different styles to motivation. This resulted in that the personalities in the study have different motivation to learn the standardised worksheet and play the game. This is good to emphasise on since real assembly includes different learning styles and personalities that exists in the real factories. There is no learning style that works the best for all individuals but the aim is to find a way of learning that is suitable for most individuals according to Muller et. al. (2016). There is an uncertainty in the results of Vizendo since the data was not consistent where some performance was not correct. Therefore, it was hard for the trainees to learn how to assemble the pedal car.

According to Muller et. al. (2016), virtual training can eliminate risks that occurs by learning by doing is strengthened by this study. The training in SeQualia and Vizendo resulted in positive effect on the number of the quality defects, which is advantageous for both softwares. A check that could not be performed in the quality control in the process was how hard the trainees had torqued the screw where the approved level was five Nm. The screws could be destroyed if the torque was drawn to hard.

The results of the cycle time did not show any difference between the learning time for the traditional training with the reference group and the computer-based training with SeQualia and Vizendo. A possible reason for this is that during training in SeQualia and Vizendo the trainees does not practice reading article numbers and using tools, which have been seen as a disadvantage. Therefore, the trainees needed more practical training before the computer-based training. The time processes for SeQualia and Vizendo are thereby mainly equal with the time process of training practically. Since the cycle time for the reference group is lower, an estimation is that if the trainees practice at all operations in Vizendo the cycle time would had been more stable. It is difficult to connect the time results of virtual training since many of the trainees taking part in the education have no experience and have never handled a tool, leading to a lot of time being consumed finding the correct articles, tools and use of the tools. Both Borsci et. al. (2016) and Muller et. al. (2016) states that virtual training is an efficient method to shorten the cognitive learning process. This study does not strengthen this declarative. On the other hand, it does not disprove the declarative either since it has earlier been proved within training with experienced operators and on shorter cycle times. The factor that the trainees were inexperienced is believed to be the main reason of the results, rather than the longer cycle times, also that the education week was intensive which might have caused that the importance of learning standards decreased simultaneously as the time pressure affected them.

8.3.3 Opinions of the softwares

The obtained comments and opinions about SeQualia and Vizendo were scattered which shows that there are different opinions about the softwares. Before the training in the softwares the trainees were only informed about the purpose of the computer-based training, to learn the standard worksheets faster and more accurate, and how the software worked. The trainees were not informed about the underlying purpose to reduce the training time on-line. If the purpose would had been described it could had changed several opinions of training with the software since the trainees did not understand why parts of the practical training were replaced by computer-based training. When the test groups and the Training managers were informed about the softwares some information might have been unclear which implied that they did not understand. The trainees had different experience using computers and some had reading difficulties which made it harder to perform the training, which is a disadvantage which might have affected some results. An obtained comment from the Training managers about SeQualia was that there was no one to ask questions to during the game. The conditions were not same for the Training managers as for the trainees with the training in SeQualia. The Training managers got an email with a link to the software as they were responsible to try and evaluate since there was no time to set-up a training session for them. The comments that were negative towards training in the software came from two trainees that belonged to the elderly generation. As mentioned earlier in the discussion, this issue confirms Zyda's (2005) statement that the gap in the generations affect the attitude of digital training.

9 Recommendations

This chapter present the suggested recommendations that hopefully will contribute to Scania's decision of future work with virtual training. The findings are based on previous studies, results and obtained comments which were connected in the discussion.

9.1 SeQualia

Since training in SeQualia is not proven on longer cycle times, the authors' suggestion is to accurately evaluate all recommendations for SeQualia before implementation in assembling to acquire knowledge of the effects with experienced operators and longer cycle times.

Training with SeQualia should be used when the operators have gained basic knowledge and experience. A suggestion is to practice training in SeQualia when the operators is in the stage between the second and third step in Scania's four step method, where the operators have been instructed and will start the process with practical training. The training in SeQualia should increase gradually in step with the practical assembly training and thereby, the practical training will be used to practice the performance instead of what to do.

Training with SeQualia can be used as a complement to the practical test in the final phase of the assembly training. SeQualia can be formed as a theoretical test where the operator and team leader can be ensured of sufficient knowledge being obtained to perform the work according to the standardised worksheets.

Training with SeQualia could be used with experienced operators to practice at new variants and updated standards. It could also be used to follow up the memory of the regular standards by letting the operators train in SeQualia at regular intervals.

9.2 Vizendo

Training with Vizendo has been proven in previous projects at Scania with experienced operators. The studies in this thesis with inexperienced operators did not achieve sufficient basis to be ensured that it was successful. The authors' suggestion is to evaluate and try the recommendations before implementation in assembling to acquire knowledge of the effects with inexperienced operators.

Training with Vizendo could be used for new and inexperienced operators in the stage between the first and seconds step in Scania's four step method, where the operators have been prepared off-line and will be instructed by the mentor. Thereby, the operator had gain knowledge and sufficient experience to acquire a basic understanding of the sequences and performance of the operations before the practical training.

Training in Vizendo could be used for inexperienced and experienced operators and project managers when a new product has been developed to get a pre review of the product and to get an understanding of the geometry before the product exists.

A prerequisite is that the geometries are complete and consistent with the standardised worksheets if Vizendo will be used as a tool for virtual training.

10 Conclusion

The purpose of this bachelor thesis was to obtain knowledge of the effects of virtual training with longer cycle times and the objective was to obtain knowledge of virtual training in the softwares SeQualia and Vizendo where the findings will support Scania's decision to introduce virtual training in the assembly process. Through the study, the question formulation has partially been answered, the questions to be investigated were:

- What are the advantages and disadvantages with the virtual training software SeQualia?
- What are the advantages and disadvantages with the virtual training software Vizendo?
- What influences do SeQualia and Vizendo have on cognitive learning time for longer cycle times?

Reliable results have been obtained by exploring previous accomplished studies within virtual training, by performing observations of the pedal car factory and the chassis assembly, interviews and studies including practicing and measurements of the mentioned parameters. The results have been discussed to acquire the advantages and disadvantages of training with SeQualia and Vizendo. By presenting the advantages and disadvantages the first two questions that were investigated have been answered and the purpose could be achieved.

In the end of the study, it became clear that the main part of the operators was not responsive and motivated to learning standards. The education week was intensive and the trainees had much to process which might have caused that the importance of learning standards decreased simultaneously as the time pressure affected them. The training with the softwares had neither a positive or negative effect on the cognitive learning process in this study. This is believed to have more to do with the operators' inexperience and mentioned factors, than the longer cycle times at Scania. Therefore, the last question investigated has not been able to be answered.

Even if the results in this study did not result in any greater improvements, the authors believes that through the findings and recommendations Scania can use virtual training in their training process with success.

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A: Table for measurements

Date:				Group:		Measurements:		
Nr.	Variant	Correct operation & performance	Wrong operation	Correct operation, wrong performance	Checking instructions		Cycle time	Comments
					Operation	Performance		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

B: Interview questions for earlier studies with SeQualia & Vizendo (Swedish version)

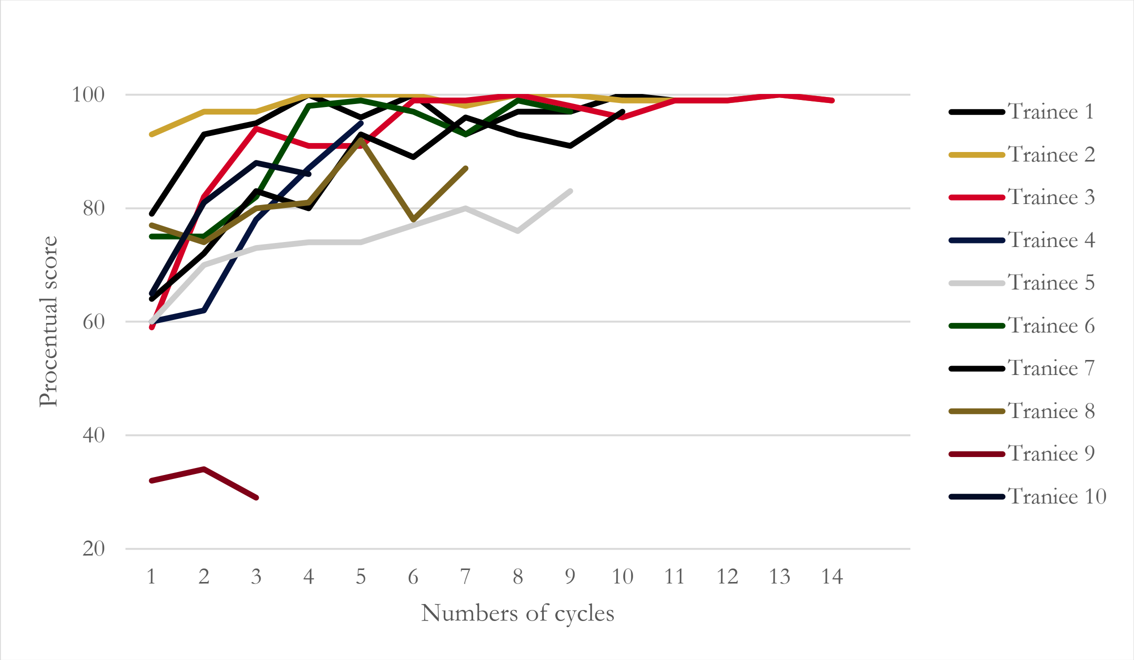
- Vad för operationer utförde operatörerna?
- Hur tränades operatörerna med Vizendo/SeQualia?
  - Hur lades träningen upp?
  - Varvades träning med praktiskt arbete?
  - Fick operatörerna någon förkunskap innan de började träna i Vizendo/SeQualia?
  - Ungefär hur länge tränades operatörerna?
- Vilka var för- och nackdelarna med träningsupplägget och Vizendo/SeQualia?
- Hade operatörerna någon tidigare erfarenhet av montering?
- Ungefär hur långa var cykeltiderna?
- Uppstod det några problem vid träning med Vizendo/SeQualia?
  - Vad skulle kunna förbättras? I så fall hur?
- Upplevde operatörerna att programmet var svårt att förstå och hantera?
- Nåddes en "maximal" kunskapsnivå där operatören inte fick ut mer av träningen?
- Vad resulterade träningen i Vizendo?
  - Jämfördes det med någon annan metod?
  - Vilka parametrar studerades?
  - Hur förändrades operatörernas utförande?
- Vad kan skillnad i resultatet bero på?
  - Skiljde sig resultaten om operatörerna om de hade tidigare erfarenhet av arbetsuppgiften?
  - Skulle skillnaden i resultatet kunna bero på operatörernas datorvana?
- Vad är relevant att titta på i en träningsutvärdering, vad finns ett intresse för?

C: Operations at Station 1

Element nr.	**Operation**	**Black car**	**Red car**
1	Place front frame	X	X
2	Mount front frame	X	X
3	Adjust front frame	X	X
4	Place rear left fender		X
5	Mount screw left fender		X
6	Torque left fender		X
7	Place right fender		X
8	Mount screw right fender		X
9	Torque right fender		X
10	Place rear left fender	X	
11	Place right fender	X	
12	Place handbrake	X	X
13	Torque handbrake	X	X
14	Discharge handbrake	X	X
15	Check handbrake lever	X	X
16	Check white reflex		X

X= Shows which operation that is included for the black pedal car and the red pedal car

D: SeQualia score for the entire Test Group 1



E: Questionnaire - Training managers (Swedish version)

Datorbaserad träning

Operatörerna har använt datorprogrammet för träning och uppföljning av teoretiska kunskaper av elementbladen för trampbilen. För att få en bättre bild av hur ni upplevde programmet ges några uppföljande frågor.

*Obligatorisk

1.

1. Jag anser att datorbaserad träning med programmet är en bättre metod för att träna på ordningsföljd av standarden än att läsa i standardpärmen *

Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

2.

2. Jag anser att datorbaserad träning med programmet är en bättre metod för att träna på "Hur" och "Varför" vid montering av trampbilen än att läsa i standardpärmen *

Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

3.

3. Jag tror att operatörernas förmåga att bygga trampbilen har blivit bättre genom datorbaserad träning med programmet *

Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

4.

4. Jag anser att datorprogrammet var lätt att använda *

Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

5.

5. Jag anser att datorbaserad träning i programmet var ett roligt sätt att lära mig att montera trampbilen på *

Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

6.

Övriga kommentarer och feedback

Tack för ditt svar!

F: Questionnaire – trainees (Swedish version)

Datorbaserad träning

Du har använt datorprogrammet för träning och uppföljning av teoretiska kunskaper av elementbladen för trampbilen. För att få en bättre bild av hur du upplevde programmet ges några uppföljande frågor.

*Obligatorisk

1. **Namn (Valfritt)**

   ____

2. **Ålder** *

   ____

3. **Monteringserfarenhet (antal år)** *

   ____

4. **Vilken station är du på?** *

   ____

Frågor

Svara på följande påståenden och kryssa i hur väl påståendet stämmer utifrån skalan 1 till 5.
1 = Stämmer inte alls
2 =
3 =
4 =
5 = Stämmer mycket väl

5. **1. Jag anser att träna på ordningsföljd av standarden i datorprogrammet är ett effektivare sätt att lära sig att montera en trampbil på än att läsa i standardpärmen** *

   Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	◯	◯	◯	◯	◯	Stämmer mycket väl

6.
2. Jag anser att träna på "Hur" och "Varför" man ska montera trampbilen med datorprogrammet är ett effektivare sätt att lära än att läsa i standardpärmen *
Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	⬭	⬭	⬭	⬭	⬭	Stämmer mycket väl

7.
3. Jag anser att min förmåga att bygga trampbilen har blivit bättre genom datorbaserad träning *
Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	⬭	⬭	⬭	⬭	⬭	Stämmer mycket väl

8.
4. Jag anser att datorprogrammet var lätt att använda *
Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	⬭	⬭	⬭	⬭	⬭	Stämmer mycket väl

9.
5. Jag anser att träning i datorprogrammet var ett roligt sätt att lära mig att montera trampbilen på *
Markera endast en oval.

	1	2	3	4	5	
Stämmer inte alls	⬭	⬭	⬭	⬭	⬭	Stämmer mycket väl

10.
Övriga kommentarer och feedback

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Tack för ditt svar och lycka till med nya jobbet!