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Designing an Automation Course

An Application of the ADDIE Model

Master’s thesis in Learning and Leadership

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Department of Applied Information Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

Industry 4.0 is the fourth era of industry. It changes how products are produced which also changes the expectations on the industrial workers. Everything in the production should now be automated and connected via IT (Informational Technology). So how does this change the work and the knowledge requirements of the industrial workers? And how will they reach these requirements?

The purpose with this thesis was to increase the level of knowledge for SKF employees towards the company's needs and desires. The purpose was also to help the course participants reach the learning objectives by using scientific learning methods and theories. In addition, the created course would not only apply to automation courses at SKF (Aktiebolaget Svenska Kullagerfabriken), but to other courses in the industry as well.

This thesis describes how to design an automation course by using the ADDIE model. The ADDIE model is an instructional design method which divides a project in the five following steps: analysis, design, development, implementation and evaluation. This thesis focused on the analysis step to create a framework and a content that can be used to design automation courses in different industries.

A thorough analysis about previous knowledge and important knowledge for the future participants, what motivates the future participants and the company, assessment and learning theories and methods has been conducted. Learning objectives, assessment and activities were created from the result of the analysis. The results from the analysis can also be used to create other courses in the future. Data have been collected with observations, questionnaires and interviews. The questionnaires have been conducted by SKF personnel and the answers have been visualized with bar charts. The interviewees were also SKF personnel and the results were analyzed using coding to create categories of important material. Brainstorming was used to produce learning objectives and to design the course.

The results in this thesis show, for example, that skill development is getting more and more important in the industry. It becomes crucial for all industrial workers to have understanding of the automation cells and its components. It also shows the importance of an industrial worker being able to troubleshoot the automation cell when something goes wrong. It is important that they receive training, to help them develop their skills in these areas. This thesis shows that it is important for them to get practical education with similar equipment as they use in their everyday work and that they get to see many examples of what can go wrong and how to fix it.

This thesis shows that assessment is an important area to analyze. The managers, the teacher and the course participants can all benefit from assessment. Assessment can increase learning, help the teacher to evaluate the course and give managers a receipt on the participants' knowledge.

There are many different learning methods and theories to take into account when an automation course for operators is created. One important thing is to motivate the course participants and to keep them motivated throughout the course. To do this, we have used research about adult learning, cooperative learning, the 5E model and motivation strategies. Practical education, which has support from for example John Dewey and the 5E model, has been a big part of the course.

A course was designed based on the results from the analysis step. Activities and assessment were developed to meet the course objectives and the course was implemented as a pilot course at SKF Competence Center. The pilot course was evaluated with a questionnaire which showed that the participants wanted to keep all of the content and that they gained a good overview knowledge. The evaluation also showed that the time was not sufficient and that IT and PLC (Programmable Logic Controller) were difficult areas.

This thesis can be used in two different ways. The first way is to use the created course as presented in this thesis. The second way is to use results from the analysis to design similar courses for industrial workers.

Keywords: Instructional design, ADDIE, Backwards Design, Skill development, Industry 4.0, World Class Manufacturing, Automation.

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1 Introduction

To introduce this thesis this chapter includes background, purpose, goal, research questions and delimitations for this project.

1.1 Background

SKF Sweden AB, located in Gamlestaden Gothenburg, were in need of a course to further educate their operators in automation. Ongoing modernization and improvements in SKF's production create the need of further education for the new automated production equipment. A first level robotics course existed and this thesis dealt with how to facilitate the creation of a second level course. The course created in this thesis was called Robotics course level 2 in the beginning of the project. However the result from this thesis showed that the second level course should include more than robotics and was therefore renamed to Automation course level 2.

1.2 Purpose and Goal

The purpose with this thesis was to increase the level of knowledge for SKF employees towards the company's needs and desires. The purpose was also to help the course participants reach the learning objectives by using scientific learning methods and theories. In addition the result would not only apply to automation courses at SKF but to other courses in the industry as well.

The goal was to investigate and analyze the needs and desires of the employees at SKF to create a framework for Automation course level 2 for SKF employees. The goal was also to create Automation course level 2 including learning objectives and activities and to evaluate this second level course.

1.3 Research Questions

The purpose of this thesis was to increase the level of knowledge at SKF and in the industry overall by creating a course. To create a course with a student-centered approach this thesis had to explore four research questions.

- What learning objectives combines the current first level course and the expectations from different stakeholders?
- What learning methods and theories should be used to help the course participants reach the learning objectives?
- What assessment methods should be used to increase understanding and to evaluate the knowledge gained by the course participants?
- What evaluation methods should be used to evaluate how well the course participants reached the learning objectives and how well the activities supported the learning?

1.4 Delimitations

- The course was not to be changed after the evaluation of it due to lack of time. Only a discussion around the course is written in the report.
- The only exemplified robot, automated conveyor system and PLC used in this thesis belongs to the equipment located in SKF's facilities.
- This thesis was only focused on automation courses.
- The content of the activities in the course was not created in this thesis, except for some examples content to support the teacher in a pilot course. This delimitation was decided due to lack of time and that the teacher is an expert in the area.

1.5 Glossary

This glossary is created to support the reader in understanding technical terms.

Affinity Diagramming A method used to organize data from for example brainstorming (Wilson, 2013).

Automation Cell The automation cell, or robot cell, is a metal cage including a robot, a PLC, conveyors, sensors and in some cases machines.

D-time D-time, or downtime, is the period of time that a system fails to provide or perform.

Industry 4.0 The fourth era of Industry. The current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things and cloud computing (Marr, 2016).

Pendant Hand held controller for an ABB robot.

Robot The robots mentioned in this thesis refers to industrial robots. An industrial robot is a manipulator designed and programmed to perform various programmed tasks during manufacturing (RobotWorx).

Robot Cell See Automation Cell.

World Class Manufacturing World Class Manufacturing, or World Class, is a collection of concepts which set standards for production and manufacturing for another organization to follow (Guide, 2017).

1.6 Acronyms

This list of acronyms is created to support the reader.

5E Engagement, Exploration, Explanation, Elaboration, Evaluation.

ABB Asea Brown Boveri Ltd (robot and PLC manufacturer).

ADDIE Analysis, Design, Development, Implementation, Evaluation.

CNC Computer Numerical Control. CNC is a computer system that control different machines in the industry..

HMI Human-Machine Interface.

HR Human Relations.

ID Instructional Design.

IT Informational Technology.

KUKA Keller und Knappich Augsburg (robot manufacturer).

NC Numerical Control. For more information see CNC..

PLC Programmable logic controller. A PLC is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.

RCFA Root Cause Failure Analysis.

SKF Aktiebolaget Svenska Kullagerfabriken.

STL Student Team Learning.

2

Theory

This chapter describes the theory used in this thesis. The chapter begins with a technical background followed by learning theories and learning methods.

2.1 Technical Background

This section includes a deeper background to the project together with a description of the automation cell and Robotics course level 1.

SKF is currently in a large development phase. SKF is entering Industry 4.0, which is the newest era of industry. According to Marr (2016), Industry 4.0 becomes reality when computers and automation come together in a new way and with robotics connected remotely to systems with machine learning algorithms. In Industry 4.0, cyber-physical systems monitor the factory and make decentralized decisions (Marr, 2016). Machines, devices and sensors are communicating with one another and the system supports both decision making and performs tasks which are too difficult or unsafe for humans to perform themselves (Marr, 2016).

While entering Industry 4.0, SKF also applies World class manufacturing. World class manufacturing is a collection of concepts which set standards for other organizations to follow when it comes to manufacturing and production (Guide, 2017). World class manufacturing is a process driven approach where various techniques and philosophies are combined in one way or another. The idea of World class manufacturing focuses on operational efficiency, reducing wastage and creating cost efficient organization, which leads to the creation of high-productivity organization (Guide, 2017).

Industry 4.0 and World class manufacturing have changed the need for competence of the operators. The automation cell is one of the areas where more competence is needed. An automation cell (robot cell) is a cage including a robot, a programmable logic controller (PLC), conveyors, sensors and in some cases machines. All cells have a mission. The mission could, for example, be to grind, paint or pack something. An example of an automation cell can be seen in Figure 2.1. The automation cell in the figure is the automation cell at SKF Competence Center which was used in this thesis. The figure shows a PLC (1), a conveyor (2), a robot (3) and a pendant (4). SKF has a first level course in robotics which was observed in this thesis.

Figure 2.1: The automation cell at SKF Competence Center. The figure shows a PLC (1), a conveyor (2), a robot (3) and a pendant (4).

2.2 Learning Theories

This section describes the learning theories considered in this thesis. The section includes the following subsections: classical perspectives on learning, teaching adults, motivation, the cognitive perspective on learning, spaced learning, formative assessment and cooperative learning.

2.2.1 Classical Perspectives on Learning

Phillips and Soltis (2012) describe how experience can be seen as the base for creating knowledge. The author also writes that John Locke (1632-1704) states that our experience is the base of all our knowledge and that all our knowledge is deducted from that experience. Locke argues that we can preserve our experiences since we have the ability to remember and that simple ideas can be acquired and added to the ideas already existing (Phillips and Soltis, 2012).

Having an interest in the subject can also be an aspect of how well you learn. Someone who is interested in learning something will more likely do so than someone who is not. John Dewey (1859-1952) advocated affective and active methods and argued that problems need to be brought from situations within the student's area of interest and experience (Phillips and Soltis, 2012). According to the authors Dewey also realized that it's more likely that subjects learned by practical use are accessible. This perspective is known as learning by doing and research has confirmed that there is a relationship between active learning and successful knowledge transfer (Phillips and Soltis, 2012). The authors also write that it was under no circumstances effective to describe a new idea by words only according to Dewey. He means that if the idea is described by words only the student will learn about the idea but won't understand or realize its relevance and relations with other ideas (Phillips and Soltis, 2012).

Lev Vygotskij (1896-1934) had the understanding that young people's ability to learn by imitation is a key factor when it comes to learning in the society (Phillips and Soltis, 2012). Albert Bandura also puts focus on imitation and describes how you learn the main part of the human behaviour by watching and modelling your behaviour according to what you see (Phillips and Soltis, 2012).

These ideas have affected the designing of the course created in this thesis. The participants will have time to present their interests and experiences. There will be a lot of practical education in the course and when there is not, videos will be used rather then just words.

2.2.2 Teaching Adults

The difference between teaching children and adults is that the adult has much more experience (Wilhelmsson, 1998). Wilhelmsson (1998) writes that experiences can create both positive and negative learning spirals. If an adult student finished school as a child with a negative learning spiral the first step might be to break the negative perceptions of the person's own ability to learn. The author describes that an effective way to do this is to start by problematizing what knowledge is since our perceptions of knowledge controls our approach towards our own learning. Adults who are in a positive learning spiral move forward on their own while those who don't believe that they are able to learn have to start by making themselves conscious about what knowledge and learning is. The perception of knowledge affects both how people engage in a learning situation and what they can receive from it (Wilhelmsson, 1998).

Wilhelmsson (1998) distinguishes between superficial learning and deep learning where superficial learning means that the student tries to reproduce the material and deep learning means that students abstract the meaning to understand the reality.

Kitchener and King base their theory on Dewey's thoughts about how learning should enhance critical and reflective thinking (Wilhelmsson, 1998). Kitchener and King (1997) write that Dewey identified reflective thinking as a goal of education and they describe how their work defines a reflective thinker as someone who is aware that a problematic situation exists and is able to bring critical judgement to bear on the problem.

> "*In other words, a reflective thinker understands that there is real uncertainty about how a problem may best be solved, yet is still able to offer a judgment about the problem that brings some kind of closure to it*" (Kitchener and King, 1997, p. 142).

This judgement is based on different criteria such as evaluation of evidence and consideration of expert opinion (Kitchener and King, 1997). What reflective judgement an individual has decides how the individual handle ill-structured problems (problems from reality) (Wilhelmsson, 1998). Wilhelmsson (1998) also writes that teachers working with adults should support the students to develop a more critical and reflecting posture for them to be able to be adults in a complex society.

By creating learning activities with ill-structured problems teachers can create opportunities for critical reflection on every level which causes disequilibrium (Wilhelmsson, 1998). The author describes how disequilibrium creates feelings of discomfort and can in some cases even be frightening but also a kind of creative chaos which creates conditions for exceeding what was earlier taken for granted. Transformative learning that leads to developmental change does not occur without disequilibrium. The author therefore mean that one should also be aware that reflective thinking develops slowly. Wilhelmsson (1998) also writes that according to Mezirows theory of transformative learning a central part for adult learning is to exceed limiting habits for perception and cognition by reflecting over assumptions taken for granted. She means that independent of what kind of transformative learning, problem solving is the central driving force. That is when we are ready to question previous unreflected approaches and start to reflect. According to Jack Mezirow (1923-2014) critical reflection has a just as revolutionary meaning for learning as the shifting of paradigms in science (Wilhelmsson, 1998).

Bron (2005) agrees and describes that when we start to think about what is going on and our role in this situation a change or a transformation of our perspective appears. This kind of learning is what Mezirow calls transformative learning and it is characterized by a certain way to reflect where we challenge the prerequisites of our hypothesis and by questioning our insights. The author describes how our perspectives are transformed by reflection and when our premises are changed, transformative learning occurs.

Mezirow states that education for adults is developing if it takes social context and real-life context that has meaning for the reality in consideration (Wilhelmsson, 1998).

Wilhelmsson (1998) also writes that it is found that the adults' understanding of knowledge impacts on their ability to learn and that formal education contributes to develop adults' understanding of knowledge. To be able to handle complex problems, the students need to develop a critical and reflecting approach.

Many theorists have ideas with an origin in John Dewey's work (Bron, 2005). Bron (2005) writes that David Kolb is one of these theorists. He created a model where he sees learning as a cyclic process where the students learn continuously and again when they are to solve a task or a problem. The model is shown in Figure 2.2. The process is cyclic, from the concrete experience as a first step, to reflection and observation as a second step, generalizations and formulation of abstract concepts based on reflections as a third step and finally active experiment as a fourth and final step. The fourth step, where the students test the implications of the concepts in new situations, leads back to the first step where new experiences are gained. Bron (2005) describes how the adult learners start with a concrete personal experience, then the learners reflect. In the next step the students formulate generalizations and formulations to understand and finally they test their generalizations and formulations in new situations.

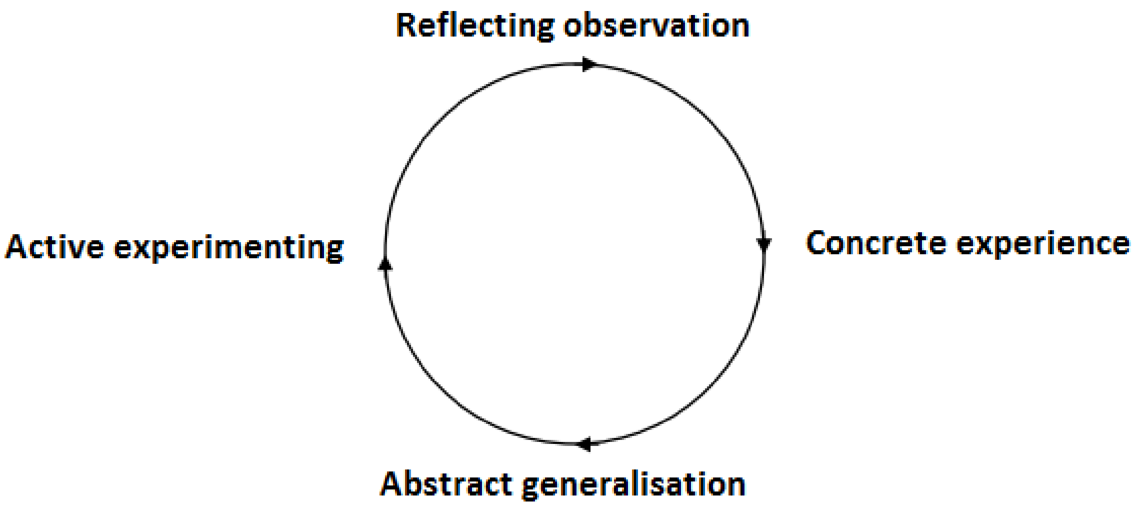


Figure 2.2: Kolb's learning cycle, adapted from Bron (2005, p. 7)

Kolb's learning cycle has been criticized since it treats learning only as a cognitive phenomenon and that it's targeted and based on rational thinking, which can result in more harm than good using the model (Bron, 2005). Peter Jarvis has formulated a theory about experience-based learning which builds on Kolb's theory but he also points out the connection between learning and human development. Bron (2005) writes that Jarvis regards humans as the sum of their learning. Jarvis also describes how learning takes place in a social context and has based his model on empirical studies by for example interviewing adult learners. The model is shown in Figure 2.3. The author describes how Jarvis's model is also time-oriented, it has a start and an end. The learner comes into a learning situation and then learning occurs in these situations by choosing one of the many paths in the model. The model also makes it possible to perceive both learning and non-learning. According to Jarvis someone can be left unchanged after an experience without learning anything. Jarvis's method has also faced criticism for being targeted against an experienced person.

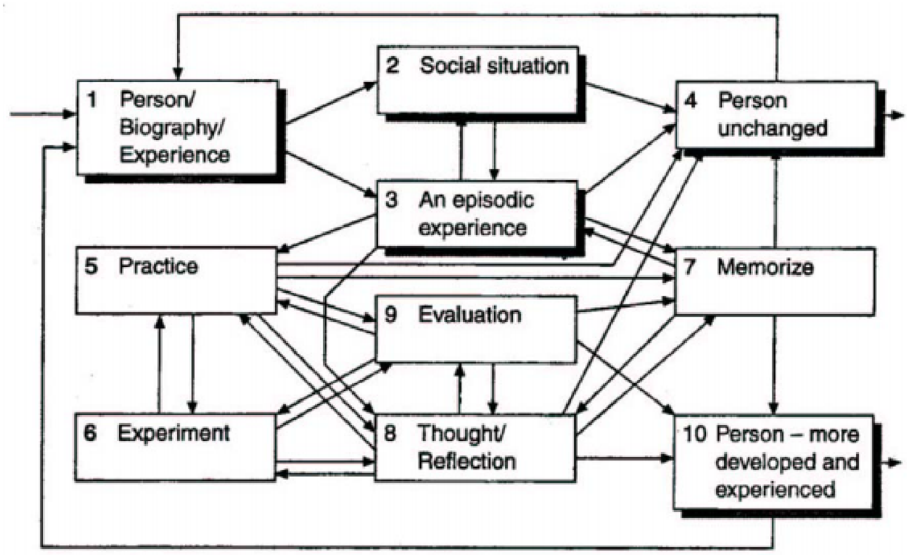


Figure 2.3: Jarvis's model of learning. Source: (Bron, 2005, p. 10).

Biografical learning is described by Peter Alheit who uses the concept of biograficity to describe adults' life constructions and reconstructions (Bron, 2005). The concept gives people opportunity to continuously recreate and form their lives in the context they are living in. Bron (2005) describes how these contexts are not only dynamic meaning that they change as people act in them, they are also changing. This means that people interpret and understand a situation or experience in the moment. Examples of these experiences can be relations, conflicts and careers. The author writes that in the light of new experiences and occurrences new meaning is given to the life that has been lived. By own reflection or by talking to others people can visualize possibilities giving them starting points to new routes in life. Alheit calls this potential to different future lives unlived lives. According to Alheit, life includes both a structural perspective in the shape of prerequisites and limits, but also an intentional action plan, meaning that people have a feeling for how to control their own lives. The author also describes how knowledge is always bound to biographies, and it is when people adapt the knowledge to themselves and their biographies as learning takes place. Biographical learning is characterized by experiences, knowledge and lessons in life stories and people consciously learn from their biographies when they reflect and/or tell about themselves to others (Bron, 2005).

Bron (2005) describes how adult students are a heterogeneous group which has the opportunity to develop but they can move between for example different ethnic cultures or social groups. She means that those who organize the education have to take into account that the ability and ambition of a human to be successful can change quickly. It demands serious attention when the students speak since they have an important role in the learning process. Bron (2005) also describes that it is important to be able to take advantage of the adults' experiences of learning. People in mixed groups enrich each other and the interaction between the participants promotes learning. She also writes that when teaching adults it is important to know what learning possibilities people have had during their lives and how we learn from our own situation.

According to Bron (2005) important events in life can serve as a springboard for learning and participation in education. People reflect over their lives and see how experiences change the situation in life and the way to look at themselves and others.

According to Eva Andersson, low self-esteem occurs in the interplay with others and she argues that there is always a reason for why adults don't already have an education (Hultén, 2013). Some adults can bring negative experiences from the past some don't have the motivation to study and some even see studying as a threat. Hultén (2013) means that to manage their studies they need to feel secure and have support and that taking own responsibility comes gradually.

According to Ingrid Henning Loeb, building a relation is very important in the beginning of a learning situation (Hultén, 2013). The teacher has to put a lot of energy into creating a good atmosphere in the group and to see every student to create trust and a desire to learn. Dialogue, challenging the students with exciting questions, is a good way to make them want to learn (Hultén, 2013).

Hultén (2013) also describes how working in groups works for many people and that it is an effective form of learning. According to Eva Andersson, adult students want to learn in groups and discuss with others.

That participants may have a negative learning spiral has been considered in the thesis. The course starts with easier assignments so that all participants feel that they can learn. The teacher will also present the objectives of the day so that the participants understand what they are supposed to learn and can feel good about themselves when they have accomplished those objectives. A goal throughout the course is for the teacher to try to develop critical and reflecting thinking by challenging and questioning the participants. Ill-structured problems from the industry will be used for this.

Kolb's cyclic process of learning is implemented in the course created in this thesis where the adult learner has experience, then reflects, then formulates generalizations to eventually test these generalizations. Time will be given to the course participants to discuss their experiences and problems that has occurred with each other and with the teacher.

2.2.3 Motivation

> "*Motivation is crucial to successful learning and it is closely linked with understanding and emotions*" (OECD, 2007, p. 70).

According to OECD (2007) one way to describe motivation is to describe it as the resultant force of emotional components. Motivation is strongly related to emotions, since emotions constitute the brain's way of evaluating the situation. From this, the author formulates the hypothesis that emotions create motivation.

Motivation is crucial to learning and there are different kinds of motivation. OECD (2007) writes that a distinction between external and internal factors can be drawn. The author writes that external factors are factors such as rewards and punishments, while an example of an internal factor might be the wish to fulfill a desire. OECD (2007) also describes how neuroscience has its focus on external factors since the internal factors are not well understood and difficult to study. However the author admits that internal factors are very important and that neuroscience need to address this more. Boekaerts (2010) presents some key principles about motivation in Table 2.1.

- Students are more motivated when they feel competent to do what is expected of them.
- Students are more motivated to engage in learning when they perceive stable links between specific actions and achievement.
- Students are more motivated to engage in learning when they value the subject and have a clear sense of purpose.
- Students are more motivated to engage in learning when they experience positive emotions towards learning activities.
- Students direct their attention away from learning when they experience negative emotions.
- Students free up cognitive resources for learning when they are able to influence the intensity, duration and expression of their emotions.
- Students are more persistent in learning when they can manage their resources and deal with obstacles efficiently.
- Students are more motivated to engage in learning and use motivation regulation strategies when they perceive the environment as favourable for learning.

Table 2.1: Key principles about motivation. Source: (Boekaerts, 2010, p. 96-105).

The course created in this thesis starts with easier assignments to make the participants feel competent and safe in the situation. Clear objectives for the course and clear objectives for each assignment each day were created to motivate the participants. The same or similar equipment as the participants use in their own work environment will be used during the course.

2.2.4 The Cognitive Perspective on Learning

One of the premises of the cognitive perspective is that when a person gains new information in a learning situation, this person must be able to use that information in completely different situations (Schneider and Stern, 2010). This demands that the information is correctly understood and correctly stored in the long-term memory (Schneider and Stern, 2010).

> "*The cognitive perspective on learning is based on the assumption that knowledge acquisition lies at the very heart of learning*" (Schneider and Stern, 2010, p. 70).

Cognitive research tries to uncover the mechanisms which underlie knowledge acquisition and storage (Schneider and Stern, 2010). The authors describe how it, through cognitive research, has been recognized that students have an active role in learning. They give a list of bullets that highlights different aspects of how learners can build up knowledge structures. This list is presented in Table 2.2. According to Schneider and Stern (2010), the ten bullets in Table 2.2 maximize the motivation by making sure that the content is meaningful, has clear objectives, has relevance and is interesting for the students.

- Learning is an activity carried out by the learner.
- Optimal learning takes prior knowledge into account.
- Learning requires the integration of knowledge structures.
- Optimally, learning balances the acquisition of concepts, skills and meta-cognitive competence.
- Learning optimally builds up complex knowledge structures by organizing more basic pieces of knowledge in a hierarchical way.
- Optimally, learning can utilize structures in the external world for organizing knowledge structures in the mind.
- Learning is constrained by capacity limitations of the human information-processing architecture.
- Learning results from a dynamic interplay of emotion, motivation and cognition.
- Optimal learning builds up transferable knowledge structures.
- Learning requires time and effort.

Table 2.2: Aspects of how learners build up knowledge structures. Source: (Schneider and Stern, 2010, p. 72-84).

The participants of the course created in this thesis will build up their knowledge by starting with less complicated assignments and move on to more complicated assignments. The participants will get time to express their prior knowledge which will affect the course and its content.

2.2.5 Spaced Learning

Spaced learning involves repeated long intervals, in contrast to massed learning that involves short or no intervals (Smolen et al., 2016). In many cases the author write that it leads to a more robust memory.

> "*For example, spaced learning is more effective than massed learning for facts, concepts and lists, skill learning and motor learning, in classroom education (including science learning and vocabulary learning), and in generalization of conceptual knowledge in children*" (Smolen et al., 2016, p. 1).

Kornell and Bjork (2008) write that spaced learning is better in the long term and that it has been demonstrated in a variety of domains and write: "*Spacing is the friend of recall, but the enemy of induction*" (p. 585). Kornell and Bjork (2008) also performed a test to see if spacing is more effective than massing in inductive learning situations. According to Michalski (1983), inductive learning is "*a process of acquiring knowledge by drawing inductive inferences from teacher- or environment-provided facts. Such a process involves operations of generalizing, transforming, correcting and refining knowledge representations*" (p. 115). Michalski (1983) writes that the starting premises are specific facts in inductive learning, compared to deductive learning where they are general axioms. Michalski (1983) also describes how the goal with inductive learning is to formulate general assertions that explain the given facts and predict new facts. According to the author the results showed that spacing is more effective, but that most people will prefer massing anyway, since spacing appears more difficult. "*Spacing appears to be sometimes, if not always, a desirable difficulty*" (Kornell and Bjork, 2008, p. 591).

Smolen et al. (2016) present how the length of the interval between the first trial and the reinforcement trial affects the spaced learning. The author writes that a longer interval gives the student a larger net gain but that it is less probable that the reinforcement, where the trial is repeated, reactivates the previous learning if the interval is too long.

Each subject in the course will be brought up several times during the course created in this thesis. The subjects will also be brought up in different forms in different activities. An example is that a combination of practical and theoretical education is used throughout the course.

2.2.6 Formative Assessment

Assessment is an important part of education (Wiliam, 2010). Historically, assessment has mostly been used as certificates for student achievements and to hold educational institutions accountable for their education according to Wiliam (2010). The author describes that the use of assessment has changed during the past 40 years. One of the changes is that assessment can be used during the learning process instead of only at the end of the process. Wiliam (2010) also describes how assessment can be used to provide feedback and correctives and that formative assessment should be separated from grading to be most effective.

> "*The concept of "formative assessment" emerged with recognition of the importance of feedback and application of navigational metaphors about staying on course through corrective steering*" (Wiliam, 2010, p. 135).

Formative assessment is used partly to give feedback to the students. Hattie and Timperley (2007) present three questions that must be answered to give effective feedback. The questions are: "*Where am I going?*" (What are the goals?), "*How am I going?*" (What progress is being made toward the goal?), and "*Where to next?*" (What activities need to be undertaken to make better progress?) (Hattie and Timperley, 2007, p. 86). Each of these questions operates at four different levels: Feedback about the task, feedback about the process, feedback about self-regulation and feedback about the self as a person (Wiliam, 2010) (Hattie and Timperley, 2007). According to Hattie and Timperley (2007) feedback about the self as a person is the least effective. In terms of deeper learning and mastery of a task feedback about self-regulation and feedback about the process are the most powerful. Feedback about the task is the most powerful when the task information is useful for improving strategy processing or enhancing self-regulation (Hattie and Timperley, 2007).

According to Wiliam (2010), formative assessment has entailed five key strategies to improve instructional decisions. These are presented in Table 2.3. The strategies involve activating the student, moving the student forward, eliciting evidence of learning and learning intentions.

- Clarifying, sharing and understanding learning intentions and criteria for success.
- Engineering effective classroom discussions, activities and tasks that elicit evidence of learning.
- Providing feedback that moves learners forward.
- Activating students as instructional resources for one another.
- Activating students as the owners of their own learning.

Table 2.3: Key strategies to improve instructional decisions. Source: (Wiliam, 2010, p.154).

Wiliam (2010) writes that the different kinds of formative feedback should also be used in different situations. In the beginning of the learning, for procedural learning or for very difficult assignments, immediate feedback seems most powerful according to (Wiliam, 2010). Delayed feedback seems more powerful when the learner is more comfortable with the area or when the learner needs to transfer knowledge to a new context (Wiliam, 2010). Wiliam (2010) presents his classroom strategies for formative feedback in Figure 2.4.

	Where the learner is going	*Where the learner is right now*	*How to get there*
Teacher	Clarifying learning intentions and sharing and criteria for success (1)	Engineering effective classroom discussions, activities and tasks that elicit evidence of learning (2)	Providing feedback that moves learners forward (3)
Peer	Understanding and sharing learning intentions and criteria for success (1)	Activating students as instructional resources for one another (4)	
Learner	Understanding learning intentions and criteria for success (1)	Activating students as the owners of their own learning (5)	

Figure 2.4: Classroom strategies for formative feedback. Source: (Wiliam, 2010, p. 151).

Formative assessment is used in different forms throughout the course created in this thesis. The participants will get feedback on group assignments, individual assignments and individual tests. Direct feedback about the task and the process will be used more frequently in the beginning of the course when the assignments are less complicated. Delayed feedback about self-regulation is used more frequently later on in the course, when the assignments become more complicated.

2.2.7 Cooperative Learning

> ”*In more recent times, however, teachers are more likely to encourage students to interact with each other in cooperative learning groups. Yet having students work in group can be enormously beneficial or it can be of little value. How can a teacher make best use of this powerful tool?*”
> (Slavin, 2010, p. 162)

According to Slavin (2010) there are two categories of cooperative learning methods. These are ”Structured Team Learning” and ”Informal Group Learning Methods”. The first category of methods focuses on learning for the individuals while the second category focuses on social dynamics, projects and discussion (Slavin, 2010). The most common method in experimental studies of cooperative learning is ”Student Team Learning” (STL) (Slavin, 2010). STL is a structured team learning method.

"*STL also emphasises the use of team goals and collective definition of success*" (Slavin, 2010, p. 163). For a collective definition of success to work all members must reach the learning objectives according to (Slavin, 2010). The author means that the focus must be to learn something as a team.Slavin (2010) also describes how STL makes the student focus on explaining concepts to one another, to make sure that everyone on the team is ready for the individual quiz (or other assessment) that is coming up. Slavin (2010) has found two essential elements of STL to make students motivated; team rewards and individual accountability. The author describes how the students need a reason to take one anothers' achievement seriously and students do better if they are rewarded compared to their own past results rather than compared to other students' results.

Slavin (2010) gives one example of informal group learning where you first give different assignments to each individual in a team. In a situation where there are many of these teams the individuals from each team with the same assignment are put together in new groups to discuss the common assignment. The members from the different teams with the same assignment will then go back to their teams to teach the other members what they have learned.

There is a general consensus that cooperative learning has a positive effect on students' achievements and results but it can be more or less effective (Slavin, 2010). In Figure 2.5, Slavin (2010) shows how cooperative learning might improve learning.

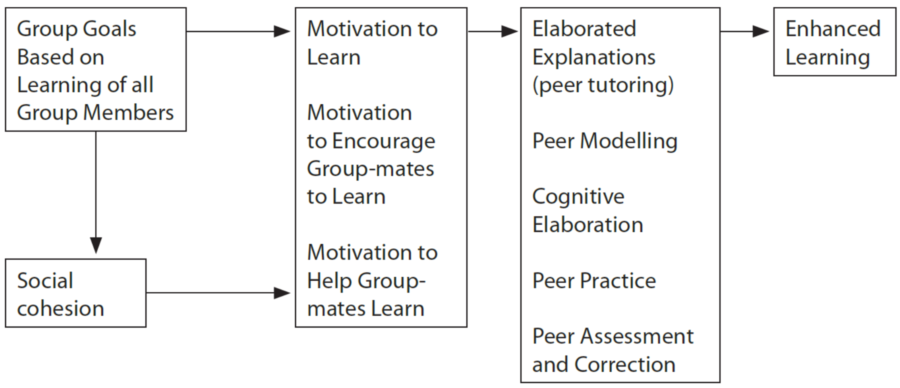


Figure 2.5: Different factors that influence the effectiveness of cooperative learning. Source: (Slavin, 2010, p. 172).

STL has influenced the group assignments in the course created in this thesis. All the participants in the group have to contribute to finish the assignment. The main focus is always that each participant will gain knowledge.

2.3 Learning Methods - The 5E Model

The 5E model is a planning tool for instructors proposed by science educator Rodger Bybee and his colleagues (Tanner, 2010). This section will describe the 5E model.

> "*The 5E model is an attempt to translate what is known from research in a variety of disciplines about how humans learn from cognitive science, psychology, and science education into a tool that can guide instructors in planning effective learning experiences*" (Tanner, 2010, p. 160).

Tanner (2010) describes that the first thing needed from the students is to be interested and engaged about what they are learning. Second, the students must be involved in the learning process and construct new understandings by comparing new information to previous knowledge and ideas (Tanner, 2010). As a third step, students need to apply the new knowledge in new situations and evaluate their learning (Tanner, 2010).

The idea of an optimal learning cycle isn't new. Two science educators, J. Myron (Mike) Atkin and Robert Karplus (1927-1990), came up with a learning cycle that involved exploration, term introduction, and concept application (Tanner, 2010). According to Tanner (2010), Bybee and his BSCS colleagues described the 5E model as a descendant of the Atkin and Karplus learning cycle and suggested the following sequence of key elements of an effective lesson:

- Engagement
- Exploration
- Explanation
- Elaboration
- Evaluation

The 5E model is based on both a conceptual change model of learning and a constructivist view of learning, meaning that the learner must be open to new ideas and knowledge and also to do the work of identifying and changing their conceptions (Tanner, 2010). Tanner (2010) also describes how the 5E model also leads the instructor to design learning environments that are accessible to students with a variety of different learning styles and preferences.

Tanner (2010) describes how the Engagement phase has the goal to capture the students' interest and encourage them to want to learn more. The author writes that teachers often use engagement to spark the learner's interest by for example using surprising or unusual examples. The Engagement phase often occurs in the beginning of a class session but can also be used to introduce a new conceptual unit.

Tanner (2010) further describe how the Exploration phase exists so that the students can identify the gap between their previous and new knowledge. The Exploration phase provides an opportunity to increase students' interest and should occur before any explanation or introduction of new terms or information.

Optimally, the Explanation phase involves active participation by both instructor and students, even though it is often an instructor-led lecture (Tanner, 2010). This is also an opportunity to address questions, confusions and ideas that have arisen in the process of exploration. Tanner (2010) further describes how students are more likely to have questions and demonstrate confusion after the Exploration phase which can make the Explanation phase more meaningful. For a successful Explanation phase, experiences from the former phases need to be addressed and the students should get the opportunity to show their conceptual understanding (Tanner, 2010).

> "*A major goal in science education is for students not only to master the biological concepts being presented, but also be able to apply those ideas appropriately to novel contexts and situations*" (Tanner, 2010, p.161).

The Elaboration phase lets students try out their new knowledge and can be any assignment or project that follows the Explanation phase but precede the evaluation of student learning (Tanner, 2010). The author describes how students develop deeper and broader understanding through new experiences.

The Evaluation phase provides opportunities for students to reflect on and demonstrate their knowledge (Tanner, 2010). The author describes how this can be demonstrated in many ways, such as presentations, exams or a final paper and that the evaluation can be beneficial for both the teacher and the students.

The course created in this thesis is influenced by the 5E model. The teacher uses pictures, movies, programs or the robot to engage the participants each day. The assignments are created and placed in the schedule so that the students explore, elaborate and evaluate their new knowledge. The assignments mixes exploration with explanation.

3

Methodology and Methods

This chapter is divided into six sections. The methodology section describes project methods used to structure the project. The sections about data collection methods, data analysis methods, brainstorming, evaluation methods and ethics describe the different methods used in this project and how they are applied. A flow chart of the entire project is presented in Figure 3.1. The flow chart is divided into four different steps according to the ADDIE model. The ADDIE model is described in section 3.1.2, the ADDIE model.

3.1 Methodology

The structure of this project is based on Backwards Design together with the ADDIE model. Backwards Design and the ADDIE model are both parts of instructional design (ID) which is a process for organizing and planning for training (Rothwell et al., 2016).

> "*The term instructional design has gained a broader meaning associated with the myriad ways by which to achieve improvement in human performance*" (Rothwell et al., 2016, p. xxvii).

As the quote from Rothwell et al. (2016) says, instructional design is associated with improvements in human performance and more precise improvements in human performance through effective training. According to Rothwell et al. (2016) a course is training to improve human performance in their field.

Wiggins and McTighe (2005) concur and write that teachers are designers. They write that a teacher must design learning experiences that meet learning objectives and design assessment to test if students reach the objectives.

This section will describe what Backwards Design and ADDIE are and how they were used in this project.

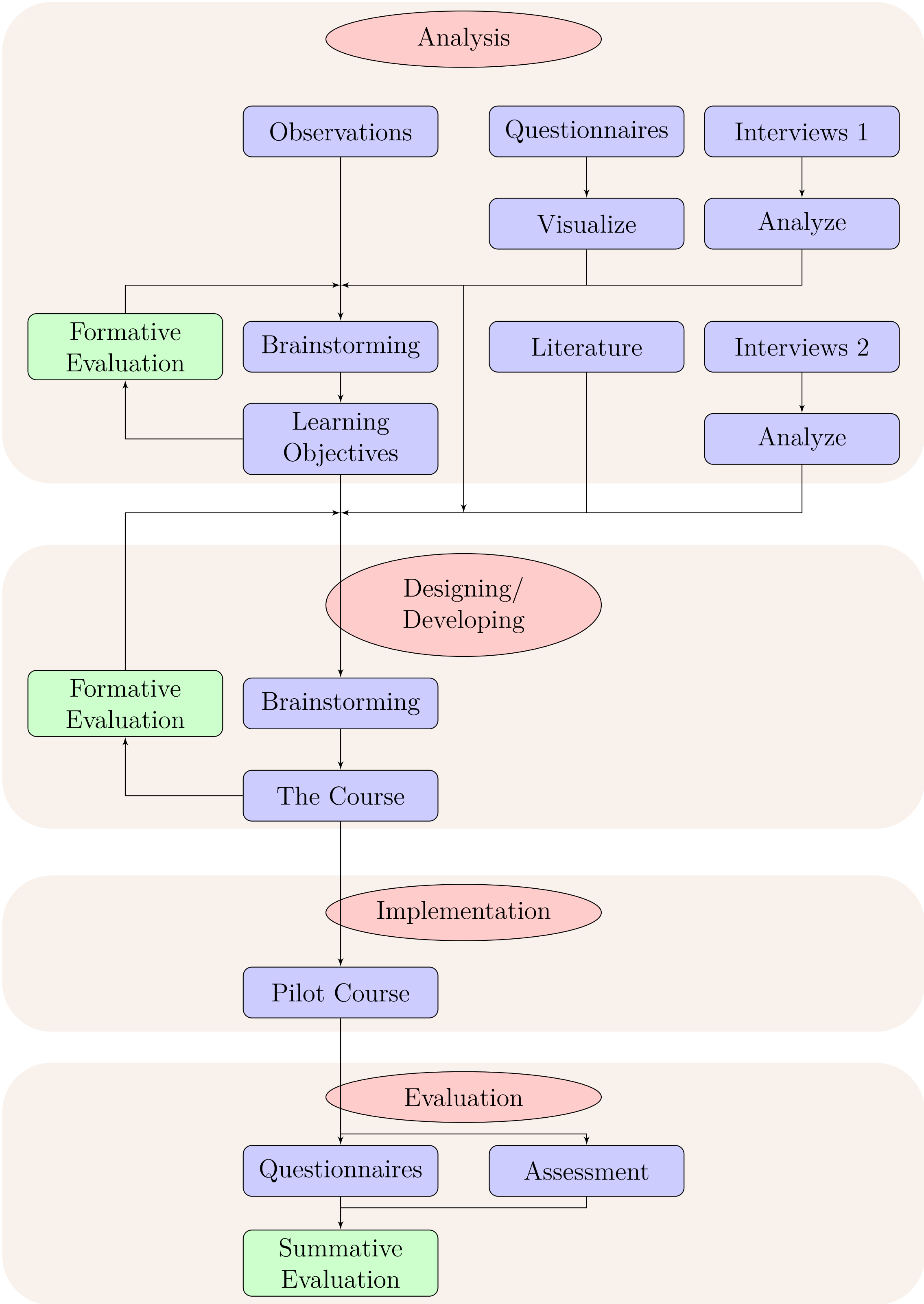


Figure 3.1: Flow chart of this project according to the ADDIE model

3.1.1 Backwards Design

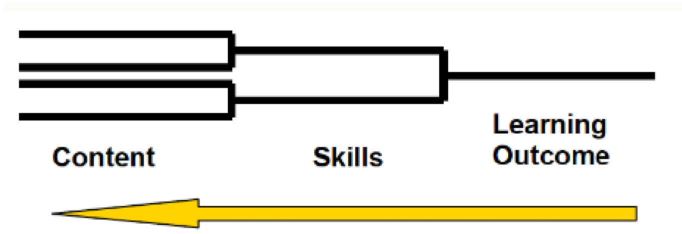


Figure 3.2: Backwards design. Source: (Stanford-University, p. 379).

It is easy to find fun and interesting activities but more difficult to make them steer towards the right goal. Educators love to talk about activities they like but they tend to forget to talk about the desired result (Wiggins and McTighe, 2005). According to Wiggins and McTighe (2005) backwards design is focused on learning while forward design is focused on teaching. The focus in backwards design lies on the output rather than the input (Wiggins and McTighe, 2005). Stanford University is using backwards design in their courses, partly because "*the outcome goals will be treated throughout the course*" (Stanford-University). Stanford University presents backwards design with Figure 3.2.

> "*We cannot say how to teach for understanding or which material and activities to use until we are quite clear about which specific understandings we are after and what such understandings look like in practice*" (Wiggins and McTighe, 2005, p. 14-15).

Backwards design can be divided into three stages. Stage one is about identifying the desired results (Learning Outcomes). Stage two is about determining acceptable evidence (Skills) and stage three is about planning learning experiences and instructions (Content) (Wiggins and McTighe, 2005).

Backwards Design was used to create a course in this thesis starting with the learning outcomes and finishing with the content/activities. The learning outcome is what is sold to all stakeholders. Therefore at first it is important to find out what learning outcome the stakeholders look for and then create course content leading towards it. The goal of this course was to create and expand understanding. It was not until it was clear what understanding the operators need that meaningful content could be created.

3.1.2 The ADDIE Model

Instructional design can be used with different models, and the most common is the ADDIE model (Rothwell et al., 2016). "*ADDIE is an acronym for Analyze, Design, Develop, Implement and Evaluate*" (Branch, 2009, p. 2). ADDIE can be visualized in a few different ways. The way ADDIE is visualized with its five different steps in Figure 3.3 is the most common.

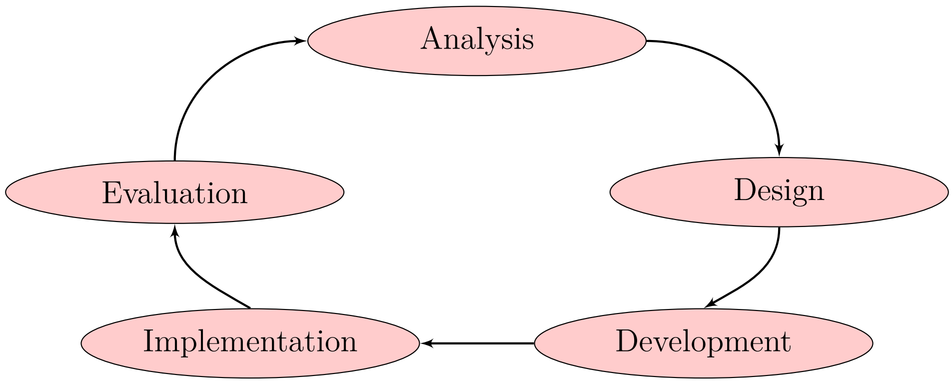


Figure 3.3: ADDIE model, adapted from Peterson (2003, p. 228)

The future participants are in focus and it is important to distinguish between what they know today and what they should know at the end of the course (Peterson, 2003). Peterson (2003) writes: "*In the analysis step, the designers' main consideration is the target audience*" (p. 228). As a part of the analysis step, learning objectives are developed (Shibley et al., 2011).

The analysis step was the most time consuming part in this thesis. The analysis step included data collection and data analysis to answer the first research question: "*What learning objectives combines the current first level course and the expectations from different stakeholders*". The methods used in the analysis step are described in section 3.2 Data Collection Methods and section 3.3 Data Analysis Methods.

Activities and assessment were then designed in the design step to answer the second, third and fourth research questions:

- "*What learning methods and theories should be used to reach the learning objectives?*"
- "*What assessment methods should be used?*"
- "*What evaluation methods should be used?*"

Design, as a noun, is defined as "*A preliminary sketch; an outline or pattern of the main features of something to be executed*" (Porter, 1913). The design step is about identifying objectives and determining how the objectives should be reached (Peterson, 2003). Another important part of the design step is to find the best and most meaningful assessment methods (Peterson, 2003). Peterson (2003) also gave two pieces of advice, presented in Table 3.1.

• If goals, objectives, and assessments do not align, learners may find themselves losing interest in the course or program furthermore, influencing perceptions of the instructional quality. • Designers who refer to analysis findings and carefully select assessment methods that include a variety of techniques, may find that learners are more likely to become actively engaged in the course content.

Table 3.1: Advice about designing assessment. Source: (Peterson, 2003, p. 230).

The development step follows the design step. During the development step, the designers must refer to the results from the previous two steps and construct a product for the delivery of the information (Peterson, 2003, p. 231).

In this thesis the course was created with the method brainstorming in the development step including activities, course material and exams meeting the objectives from the analysis step. How the method was used in the design and development step is described in section 3.4 Brainstorming.

When the developed course has been delivered and implemented the evaluation step follows. Peterson (2003) describes how the evaluation step can occur during different parts of the project. Different parts of the product has been evaluated in different ways. How the evaluation was performed is described in section 3.5 Evaluation Methods.

To answer the first research question only empirical data was used. The second and third research questions were answered mainly by using theoretical methods but empirical data was also collected. The theoretical data gave a general picture while the empirical data gave a more specific picture of what SKF and the future participants prefer regarding learning. The fourth research question was answered only by using theoretical data.

3.2 Data Collection Methods

"*The six major methods of data collection are questionnaires, interviews, focus groups, tests, observation and secondary data*" (Johnson and Turner, 2003, p. 298).

Johnson and Turner (2003) write that questionnaires are good for measuring attitudes, eliciting other content from research participants that they are inexpensive and can be administrated to large samples. Interviews are useful when it is difficult to anticipate the answers and uncertainties may occur, since the interviewer can ask for clarification if something is not clear (Johnson and Turner, 2003).

According to Kitzinger (1995) focus groups are a form of group interview which explicitly uses group interaction as a part of the method. Instead of asking each attendant to respond to a question in turn the attendants in the focus group are encouraged to communicate with each other (Kitzinger, 1995). Tests are sometimes used as a data collection method, for example intelligence tests and personality tests (Johnson and Turner, 2003).

To observe a group or a person instead of asking questions gives an opportunity to see what he/she or they do with your own eyes (Johnson and Turner, 2003). The authors write that sometimes people are not honest about what they are doing and sometimes they do not even know what they are doing. To note is also that secondary data does not always apply to the research population and that it might be influenced by the original data collector (Johnson and Turner, 2003).

Questionnaires, interviews and observations were used for data collection in this thesis. Focus groups and tests were considered too expensive since it would have required personnel from SKF to leave their work.

3.2.1 Interviews

Qualitative interviews are used in similar research as this thesis. According to Tierney and Dilley (2001) the use of qualitative interviews is most widespread in the education field. Warren (2001) writes that it gives a better understanding of the respondents' experiences compared to for example questionnaires.

> "*The design of a qualitative interview research, for Kvale, is open-ended in the sense that it is more concerned with being attuned to who is being traveled with, so to speak, than with setting out a precise route for all to follow, as in survey research*" (Warren, 2001, p. 86).

Qualitative interviews are normally used for a smaller group of individuals compared to quantitative data collection methods. "*In qualitative inquiry, the researcher interviews a small but theoretically significant number of individuals*" (Tierney and Dilley, 2001, p. 461). The most common format for an interview is an individual interview where the interviewer records the answers with a technical device or writes them down with a pen on a paper (Tierney and Dilley, 2001).

It is important to be aware of that people will react differently when a recording device is used (Warren, 2001). Some will be disappointed that they are not video recorded while some will be more restrained than normal. The author also writes that some interviewees may also want to add some information ”off the record”.

There are a few very important things to take into account to create a good atmosphere in the interview. The interview should not begin with questions of a sensitive nature since they can be seen as intrusive (Brace, 2008).

Cohen et al. (2011) among others mention seven steps that can be used to plan an interview study. These steps are thematizing, designing, interviewing, transcribing, analyzing, verifying, and reporting (Cohen et al., 2011). The most important thing in the planning is to establish the purpose of the interview before you create the questions. The thematizing needs to come before designing. Cohen et al. (2011), Tuckman (1972) and Brace (2008) all mention this in the following quotes:

> ”*The preliminary stage of an interview study will be the point where the purpose of the research is decided*” (Cohen et al., 2011, p. 415)
>
> ”*The first step in preparing items for an interview schedule is to specify the variables that you are trying to measure; then construct questions that focus on these variables*” (Tuckman, 1972, p. 191).
>
> ”*Once the researcher knows the definition of the research universe, the data collection medium and the survey design, the questions themselves can be drafted*” (Brace, 2008, p. 35).

One of the reasons why interviews were used in this thesis is that it gives the interviewer more room for spontaneous follow up questions which led to better understanding in the research. Interviews are normally used for smaller groups of individuals since and that is why qualitative interviews were restricted to managers and teachers in this research.

Since the whole interview can be ruined if sensitive questions are asked too early, these questions were asked when the interviewee and the interviewer had established a relationship. This creates a better chance of getting an honest answer. The interviews started with important questions and waited with more personal or difficult questions. The recordings were necessary for the analysis but it was also important to make the interviewee calm. Therefore no interviewee was forced to be recorded.

Eight interviews with nine interviewees were conducted. All interviews were conducted in Swedish and the quotes used in this thesis were translated into English. There were two rounds of interviews. The first round of interviews consisted of six interviews and was used to define learning objectives and collect empirical data about learning activities and assessment. The second round of interviews consisted of two interviews and was used to learn more about common problems and faults in the factory. The interviewees’ titles and aliases are listed in Table 3.2. Aliases are used since the interviews were anonymous.

Table 3.2: Table over the interviewees aliases

Title	Alias
Manager Maintenance	I1
Manager Maintenance	I2
Maintenance Technician	I3
Manager Industrial Engineering	I4
Manager Industrial Engineering	I5
Project Manager	I6
Teacher	I7
Manager Maintenance	I8
Maintenance Technician	I9

3.2.1.1 Middle Management & Maintenance Technician

The interview questions were the same for all middle managers and the maintenance technician interviewed in the first round of interviews. Five middle managers on different levels and departments and one technician were interviewed. The interview questions are found in Appendix B.1.

The focus of these interviews was to define the focus of the course to be able to define learning objectives and to answer the first research question. The first two interview questions were asked to find out if and why the management at SKF is interested in investing time and money in the course. The third question with supplementary questions was used to define the gap between present knowledge and wanted knowledge. The fourth question was used to define the need for assessment and how the result of the assessment should be presented for the managers.

It is important to define who should gain from the used assessment. Different stakeholders will gain from it depending on how the assessment is created. The assessment can be created to gain the participants, the teachers or the management. The participants might gain more from a case assignment where they get to practice and reflect about what they have learned. The managers might gain more from having a test where they get to know exactly what the participants learned.

3.2.1.2 Teacher

The teacher from Robotics course level 1, who is also the teacher in Automation course level 2 which was created in this thesis, was interviewed in the first round of interviews. The interview questions can be found in Appendix B.2. The main objective with this interview was to collect empirical data to answer the second and third research questions regarding learning methods and assessment. The second and third questions from the interview were used to collect this data. The questions focused on what learning activities and assessment the teacher had previously used and what the result from this was. The first question in the interview in Appendix B.2 was used to complement the observation of Robotics course level 1.

3.2.1.3 Second Round of Interviews

The second round of interviews was held to explore good conditions for learning activities regarding troubleshooting. The main objective with these interviews was to learn more about what can go wrong in the production and what is expected of the operators when a problem occurs. Two questions were asked during the interviews and the questions can be seen in Appendix B.3.

3.2.2 Questionnaires

Questionnaires are in many ways similar to interviews where the planning strategy with the seven steps is the same. The steps (mentioned in section 3.2.1 Interviews) are: thematizing, designing, interviewing, transcribing, analyzing, verifying, and reporting (Cohen et al., 2011). Johnson and Turner (2003) write that questionnaires are inexpensive and good for measuring attitudes. A guide from Cohen et al. (2011) was used to design the questionnaires. This guide is presented in Figure 3.4.

BOX 20.1 A GUIDE FOR QUESTIONNAIRE CONSTRUCTION

A Decisions about question content
1 Is the question necessary? Just how will it be useful?
2 Are several questions needed on the subject matter of this question?
3 Do respondents have the information necessary to answer the question?
4 Does the question need to be more concrete, specific and closely related to the respondent's personal experience?
5 Is the question content sufficiently general and free from spurious concreteness and specificity?
6 Do the replies express general attitudes and only seem to be as specific as they sound?
7 Is the question content biased or loaded in one direction, without accompanying questions to balance the emphasis?
8 Will the respondents give the information that is asked for?

B Decisions about question wording
1 Can the question be misunderstood? Does it contain difficult or unclear phraseology?
2 Does the question adequately express the alternative with respect to the point?
3 Is the question misleading because of unstated assumptions or unseen implications?
4 Is the wording biased? Is it emotionally loaded or slanted towards a particular kind of answer?
5 Is the question wording likely to be objectionable to the respondent in any way?
6 Would a more personalized wording of the question produce better results?
7 Can the question be better asked in a more direct or a more indirect form?

C Decisions about form of response to the question
1 Can the question best be asked in a form calling for check answer (or short answer of a word or two, or a number), free answer or check answer with follow-up answer?
2 If a check answer is used, which is the best type for this question – dichotomous, multiple choice ('cafeteria' question), or scale?
3 If a checklist is used, does it cover adequately all the significant alternatives without overlapping and in a defensible order? Is it of reasonable length? Is the wording of items impartial and balanced?
4 Is the form of response easy, definite, uniform and adequate for the purpose?

D Decisions about the place of the question in the sequence
1 Is the answer to the question likely to be influenced by the content of preceding questions?
2 Is the question led up to in a natural way? Is it in correct psychological order?
3 Does the question come too early or too late from the point of view of arousing interest and receiving sufficient attention, avoiding resistance, and so on?

Source: Adapted from Sellitz *et al.*, 1976

Figure 3.4: A guide for questionnaire construction. Source: (Cohen et al., 2011, p. 379).

Questionnaires were administrated to operators, technicians, maintenance personnel and middle management. The goal was to investigate their attitudes towards an automation course and their expectations for it. It was possible to reach these people without much cost which led to good quantitative data. The questionnaires created for the middle management were sent to fewer participants and the questions were more qualitative meaning that the questions were more open. The questionnaires are presented (in Swedish) in Appendix A. The questionnaire was sent out to more than 200 employees at SKF and 74 operators, 13 technicians, four Operation Managers, three Channel Group Managers and one Production Manager conducted the questionnaire.

3.2.2.1 Questionnaires - Operators/Technicians/Maintenance

The questions in the questionnaires administrated to the operators, technicians and maintenance personnel were designed to provide quantitative data. The reason for this was to easier analyze more answers. The objective with the questionnaires was to answer the first and second research questions.

Questions about motivation, interest, lack of competence and experience were asked to collect information about the first research question. Questions about earlier experiences and preferences, such as questions about practical versus theoretical education and individual versus group assignments, were asked to collect information about the second research question. There were also questions about if the participant wanted material before or after the course.

A final question was added in the questionnaire for the maintenance personnel. They were asked what they think that the operators should learn more about. The final question was added as the maintenance personnel are the ones who help the operators when they run into problems.

3.2.2.2 Questionnaires - Middle Management

The questionnaire created for the middle management consisted of fewer questions and was designed to provide more qualitative data compared to the questionnaires sent to the operators, technicians and maintenance personnel. The objective of the questionnaire was to answer the first and third research questions. The questions were asked to get the managers' perspective on what the operators, technicians and maintenance personnel should learn more about and their view on assessment.

3.2.3 Observations

Observations were used to study the entire Robotics course level 1. The gained knowledge was summarized after the course. The gained knowledge together with an interview with the teacher gave an overview on what Robotics course level 1 is about. The observations were qualitative which is also called naturalistic observations (Johnson and Turner, 2003). Johnson and Turner (2003) write that qualitative observations are exploratory and open-ended meaning that anything that happens can be noted. It is easy to miss something important that was not predicted when a quantitative observation is created. Observation is also an important method since people do not always do what they say they do (Johnson and Turner, 2003).

All observations were undisguised meaning that the observer makes no attempt to hide (Jackson, 2014). All participants were aware of why the observers were there and one of the reasons for this is that it can be ethically wrong not to tell the participants that they are being observed.

An observer can take on different roles. Johnson and Turner (2003) write: "*The researcher doing a qualitative observation may take on four different roles*" (Johnson and Turner, 2003, p. 313). The different roles range from complete participant to complete observer (Johnson and Turner, 2003). The role "participant-as-observer" was used in the observation of Robotics course level 1 meaning that the observers participated in the course. The course was held for the purpose of this thesis and the observers were the only participants. Both authors of this thesis observed the course. The first of the two objectives with this observation was to investigate the expected level of knowledge after the course. The second objective was to observe and evaluate different learning activities.

3.3 Data Analysis Methods

This section will describe how different methods were used to analyze the qualitative and quantitative data.

3.3.1 Qualitative Analysis

Miles et al. (2013) describe how qualitative data is rich in descriptions and explanations of human processes and how the findings have a quality of "undeniability". They also describe qualitative research as intense and/or involving prolonged contact with participants in a naturalistic setting to investigate their lives (Miles et al., 2013).

Qualitative data was brought into this thesis from questionnaires and interviews. The interviews were first transcribed verbatim. Miles et al. (2013) describe how transcription can be done at different levels of details. From sounds, pauses, word emphases, mispronunciations, and incomplete sentences of an apparently incoherent speaker to a smooth, apparently straightforward summary of the main ideas presented by a fluent speaker. The words including mispronunciations and pauses were included in the transcripts from the interviews in this thesis. The researcher needs to decide whether to analyze only the manifest content or the latent content (such as silence, sighs, laughter and posture) as well. Since analysis usually involves interpretation, there has been some debate as to whether hidden meanings found in documents can be analyzed (Elo and Kyngäs, 2008). Elo and Kyngäs (2008) also describe how the researcher strives to make sense of the data and to learn what is going on and obtain a sense of the whole.

In this thesis, the pauses were included to distinguish if the interviewee hesitated or changed subject in the middle of a sentence. Latent content such as silence, sighs, laughter etc. were chosen to be excluded from the transcripts since the questions were straightforward and not personal. The transcripts were first printed and read through to get immersed in the data. The printed transcripts were grouped as per question to focus on one question at the time instead of every interviewee separately.

Elo and Kyngäs (2008) describe how there are numerous approaches for analyzing qualitative data and that content analysis is a method for analyzing written, verbal or visual communication messages. To describe content analysis Neuendorf (2002) writes: "*Content analysis may be briefly defined as the systematic, objective, quantitative analysis of message characteristics*" (p. 1). According to Neuendorf (2002), content analysis has a long history of use in communication, journalism, sociology, psychology and business. Content analysis is a research technique for making replicable and valid inferences from for example texts to the context of their use (Krippendorff, 2004). "*As a research technique, content analysis provides new insights, increases a researcher's understanding of particular phenomena, or informs practical actions*" (Krippendorff, 2004, p. 18).

It is possible to distill words into fewer content-related categories through content analysis (Elo and Kyngäs, 2008). The authors writes that content analysis has a flexibility in terms of research design and is a content-sensitive method which is concerned with meanings, intentions, consequences and context. Content analysis in this thesis categorized the content to gain a good overview of the data. Miles et al. (2013) describe how a classic set of analytic moves arranged in sequence could be to first assign codes or themes to later on sorting and sifting through these codes to identify relationships between variables, patterns, themes, categories, distinct differences between subgroups and common sequences.

Miles et al. (2013) write that the analytic challenge for all qualitative researchers is finding coherent descriptions and explanations that still include all of the gaps, inconsistencies, and contradictions inherent in personal and social life. The authors also describe how qualitative data are not so much about behaviour as they are about actions. Some actions involve how people want others to see them, which requires plenty of care and self-awareness on the part of the researcher.

Miles et al. (2013) write about strengths of qualitative data: "*One major feature of well-collected data focus on naturally occurring, ordinary events in natural settings, so that they have a strong handle on what "real life" is like*" (p. 11). Miles et al. (2013) also describes that the fact that the data was collected in close proximity to a specific situation, where the influences of a local context are taken into account, makes it possible to understand latent, underlying or non obvious issues.

> "*Qualitative data, with their emphasis on people's lived experiences, are fundamentally well suited for locating the meanings people place on the events, processes, and structures of their lives and for connecting these meanings to the social world around them*" (Miles et al., 2013, p. 11).

Miles et al. (2013) see analysis as three concurrent flows of activity; data condensation, data display and conclusion drawing/verification. All of these three flows were used when working with the data gained from the interviews in this thesis. Data condensation was followed by data display and conclusion drawing/verification.

Data condensation refers to the process of selecting, simplifying, abstracting, and/or transforming the data and make it stronger (Miles et al., 2013). The authors write that when it comes to handling the qualitative data, the condensation refers to events such as writing summaries, coding, developing themes, generating categories and writing analytic memos. "*Data condensation is a form of analysis that sharpens, sorts, focuses, discards, and organizes data in such a way that "final" conclusions can be drawn and verified*" (Miles et al., 2013, p. 12).

Looking at displays helps us understand what is happening by assembling organized information into an immediately accessible, compact form and can be for example matrices, graphs, charts and networks (Miles et al., 2013). "*Generally, a display is an organized compressed assembly of information that allows conclusion drawing and action*" (Miles et al., 2013, p. 12-13).

In the third stream of analysis activity, the qualitative researcher interprets what things mean and makes conclusions by noting patterns, explanations, causal flows and propositions (Miles et al., 2013). Miles et al. (2013) write: "*The competent researcher holds these conclusions lightly, maintaining openness and skepticism, but the conclusions are still there, vague at first, then increasingly explicit and grounded*" (p. 13).

The verification can either be a thought crossing the analyst's mind during writing, or it may be thorough and elaborated (Miles et al., 2013).

> "*The meanings emerging from the data have to be tested for their plausibility, their sturdiness, their confirmability - that is, their validity. Otherwise, we are left with interesting stories about what happened but of unknown truth and utility*" (Miles et al., 2013, p. 14).

The three streams together with the collecting of data can be presented so that they form an interactive cyclical process where the researcher steadily moves among these four nodes (Miles et al., 2013). Miles et al. (2013) give an example:

> "*The coding of data, for example (data condensation), leads to new ideas on what should go into a matrix (data display). Entering the data requires further data condensation. As the matrix fills up, preliminary conclusions are drawn, but they lead to decisions, for example, to add another column to the matrix to test the conclusion*" (p. 14)

Miles et al. (2013) describe how you should not do data collection and then work over your notes since it rules out the possibility of filling up the gaps with new data and rival hypotheses. The authors advice interweaving data collection and analysis from the very start.

Codes were created to distill the words in the transcripts to fewer content-related categories. Codes are prompts or triggers for deeper reflection on the data's meanings and enable you to retrieve the most meaningful material and to assemble chunks of data that go together (Miles et al., 2013).

> "*Codes are labels that assign symbolic meaning to the descriptive or inferential information compiled during a study*" (Miles et al., 2013, p. 71).

According to Miles et al. (2013) codes are first assigned to data chunks to detect reoccurring patterns. Similar codes are then clustered together to create a smaller number of categories or pattern codes. The authors describe how an interrelationship of the categories with each other are then constructed to develop higher level analytic meanings.

The coding can be divided into two cycles. Saldaña (2009) writes:

> "*The portion of data to be coded during the First Cycle coding processes can range in magnitude from a single word to a full sentence to an entire page of text to a stream of moving images. In Second Cycle coding processes, the portion coded can be the codes themselves developed thus far*" (p. 3).

There are different methods for First cycle coding and some of them can be "*mixed and matched*" (Miles et al., 2013). Miles et al. (2013) describe that descriptive, In Vivo and process coding, are three basic approaches to coding.

Descriptive coding is especially helpful for studies with a wide variety of data forms such as field notes, interview transcripts and documents (Miles et al., 2013). "*Descriptive codes are perhaps more appropriate for social environments than social action*" (Miles et al., 2013)(p. 74). The authors then write that the data is summarized into a word or a phrase which eventually provides an inventory of topics for indexing and categorizing.

Miles et al. (2013) describe how In Vivo coding is one of the most well-known qualitative coding methods and uses words or short phrases from the participants own language in the data record as codes and write: "*In Vivo coding is appropriate for virtually all qualitative studies but particularly for beginning qualitative researchers learning how to code data, and studies that prioritize and honor the participant's voice*" (p. 74). Miles et al. (2013) also write that phrases used repeatedly are good leads since they often point to regularities or patterns in the setting.

Process coding uses gerunds (ing-words) to connote observable and conceptual action in the data and is appropriate for virtually all qualitative studies, but particularly for grounded theory research that extracts participant action/interaction and consequences (Miles et al., 2013).

Elo and Kyngäs (2008) describe that it is important to plan the process and that you need to select the unit of analysis which can be a word or a theme and decide what to analyze in what detail. The authors also mention how a unit of meaning can contain several meanings which could make the analysis difficult and challenging. On the other hand, they also write that if the analysis unit is too narrow, for example one word, this can result in fragmentation.

Elo and Kyngäs (2008) describe how data are being classified as belonging to a particular group which reduces the number of categories. The researcher decides what to put in the same category by interpretation and the purpose of creating categories is to increase understanding. The authors also write that the key feature of all content analysis is that the many words of the text are classified into much fewer content categories.

Miles et al. (2013) describe that a problem with documenting qualitative data is that it is hard to be objective. Researchers can not be truly objective when they write about what they see, hear and experience in the field. Miles et al. (2013) write that their personal values, attitudes, beliefs and earlier experiences will affect the used words.

> "*The words we choose to document what we see and hear in the field can never truly be "objective", they can only be our interpretation of what we experience*" (Miles et al., 2013, p. 11).

In Vivo coding was used in the first cycle coding in this thesis. The data was organized by extracting quotes as codes to retrieve the most meaningful material. The codes consisted of sentences from the transcripts which were then displayed in a column of a table.

The codes were clustered together into pattern codes depending on their underlying meaning in the second cycle coding to increase the understanding of the phenomenon. The pattern codes were displayed in the column next to the corresponding codes.

The pattern codes along with selected quotes from the transcripts were summed up and included in the result. The method is created to fit this thesis. As Miles et al. (2013) write: "*No study conforms exactly to a standard methodology; each one calls for the researcher to bend the methodology to the uniqueness of the setting or the case*" (p. 7).

3.3.2 Quantitative Analysis

You must acknowledge the origin of your data, called the units of analysis (Wetcher-Hendricks, 2011). For social research, these units are often human beings with data indicating for example the responses to survey questions and behaviors observed during field studies (Wetcher-Hendricks, 2011).

Continuous variables describe subjects according to their positions along a sliding scale of values (Wetcher-Hendricks, 2011). The author writes that the continuous variable seeks to identify a placement within a range of amount and typical areas of use are temperature, prices of items or calories consumed. According to Wetcher-Hendricks (2011) concrete relationships between data points can be identified if mathematical operations are applied to these values. Continuous variables have been used in different ways in this thesis. It has been used to find out how many of the respondents who has the same opinion and it has also been used to find out what every respondent think about a certain subject on a scale from 1-10.

Wetcher-Hendricks (2011) describes how there are different levels of measurement. These levels are shown in Figure 3.5 together with their capability. Wetcher-Hendricks (2011) writes that the lowest level of measurement is the nominal level which reflects the use of names to distinguish between categories and has no numerical value. The author then writes that the ordinate level of measurement is the second level and produces numbers that specify ranking. As the name indicates, the subjects can be placed in order but cannot indicate the amount of difference between the ranked elements (Wetcher-Hendricks, 2011). "*The difference between the highest-ranked subject and the next-highest-ranked subject may not be the same as that between any other two consecutively ranked subjects*" (Wetcher-Hendricks, 2011, p. 12). Degrees of difference between units of analysis can only be acknowledged when data result from interval or ratio measure and many researchers refer to them as the interval-ratio level of measurement (Wetcher-Hendricks, 2011). Wetcher-Hendricks (2011) describes how in interval level of measurement, negative values can exist and 0 does not necessarily represent the absence of a behaviour and you must use caution when making comparisons between values. "*As a result of the presence of an absolute zero point, ratio levels of measurement allow you to make the relative comparisons not permissible when using an interval measure*" (Wetcher-Hendricks, 2011, p. 13). According to Wetcher-Hendricks (2011) a good example of using ratio level of measurement is when dealing with cost, where the size of each unit and difference between units forms a consistent, predictable system of values and a value of 0 indicates no cost.

TABLE 1.1. Measurement–Level Summary[a]

Capability	Nominal	Ordinal	Interval	Ratio
Allows for recognition of subjects' distinguishing factors	√	√	√	√
Allows for ranking of subjects	—	√	√	√
Allows for understandings of differences between subjects	—	—	√	√
Allows for relative comparisons between subjects	—	—		√

[a]Columns represent each of the four levels of measurement, progressing from the weakest level, on the left, to the most powerful level, on the right. The checkmarks below each column title indicate the extent to which the relevant measure allows researchers to describe data.

Figure 3.5: Levels of measurement. Source: (Wetcher-Hendricks, 2011, p. 13).

The quantitative data collected from the questionnaires was visualized in the result with bar charts. The charts were used to draw conclusions about what interested the respondents and their opinions on different questions such as learning methods. The quantitative data belong to the interval level of measurement since the ranking of the subjects also allows understanding of the difference between them. An example would be a scale from 1-10, where 1 and 10 are extremities. The respondents were asked to mark if they prefer theoretical learning only (1 on the scale), practical learning only (10 on the scale) or somewhere on the scale in between.

3.4 Brainstorming

Brainstorming is a creative method where you generate ideas to solve a certain problem. To get the best result out of the data, many ideas need to be generated. Brainstorming is "*perhaps the most well-known method for ideation*" (Wilson, 2013, p. vii). The best result from a brainstorming is gained when the group consists of between three and ten participants with different backgrounds.

> "*No idea is rejected, no matter how irrelevant it appears, until it has been thoroughly discussed and evaluated. A major rule of brainstorming is that the discussion of ideas should not be inhibited*" (Law, 2016, p. 76)

Wiggins and McTighe (2005) write that there is no recipe on how to design a perfect course, there are too many if/then. Teachers and course designers rather need to use creative brainstorming and trials (Wiggins and McTighe, 2005).

Affinity diagramming is a method used to organize data from for example a brainstorming (Wilson, 2013). All ideas from the brainstorming are divided into groups and sub-groups and then all groups are named (Wilson, 2013). The groups are then prioritized for the future of the project (Wilson, 2013).

Brainstorming was first used to create the learning objectives of Automation course level 2. The first brainstorming also included affinity diagramming and is described further in section 3.4.1 Analysis with Brainstorming. Brainstorming was also used to design and develop the course and is described in section 3.4.2 Designing/Developing the Course with Brainstorming.

The two authors were the only participants in the brainstorming activities during this thesis. The authors also had similar backgrounds. Limitations in resources did not allow more participants. The input from the interviews, questionnaires and literature filled the void.

3.4.1 Analysis with Brainstorming

Brainstorming was used to create learning objectives out of the results gained from the interviews, questionnaires and observations. The method is illustrated in Figure 3.6.

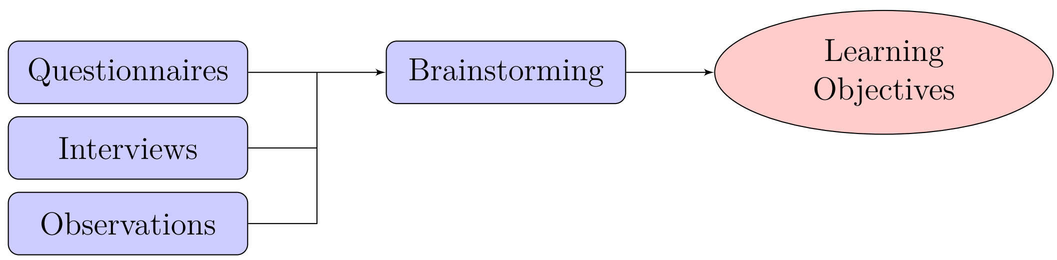


Figure 3.6: Flow chart of how brainstorming led to learning objectives

The results from the brainstorming is found in section 4.6, learning objectives. The goal of the first session was to summarize what the interviewees and the respondents to the questionnaires wanted (or wanted their employees) to learn more about. The second session of the brainstorming was to find out what the interviewees and the respondents to the questionnaires wanted to include in a course.

In the brainstorming, ideas were written on post-it notes based on information gained from the questionnaires, interviews and observations. After the brainstorming, the ideas regarding what the interviewees and respondents wanted to learn more about were analyzed with affinity diagramming. All ideas were grouped in the affinity diagramming and the groups were then prioritized.

After the affinity diagramming, all groups were evaluated based on what the interviewees and the respondents to the questionnaires wanted to include in a course. The resulting ideas became the final learning objectives. Based on the interviews and questionnaires, purposes with the course were also created.

3.4.2 Designing/Developing the Course with Brainstorming

Brainstorming was first used to design a preliminary sketch of the course and then to develop the course. The learning objectives for the course were in focus when learning and assessment methods were chosen for the course.

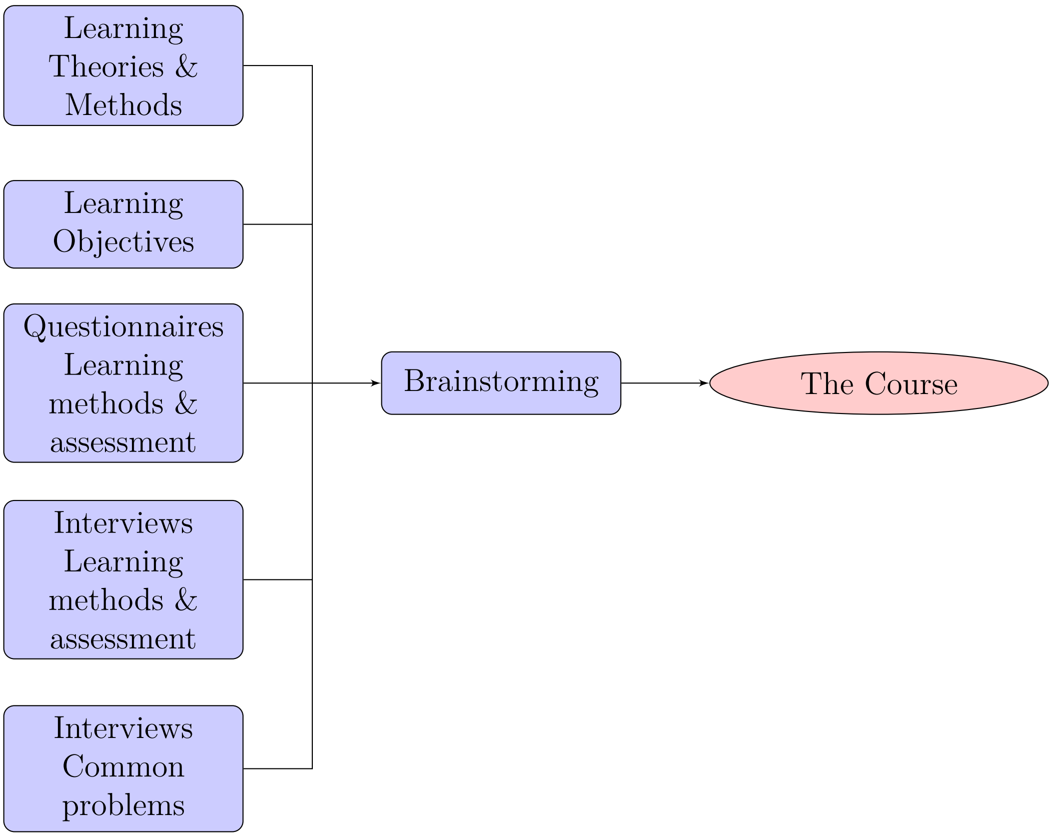


Figure 3.7: Flow chart of how brainstorming led to the course

As seen in Figure 3.7, multiple results influenced the brainstorming. The literature study, the questionnaires, the interviews and the learning objectives were all used in the creation of the course. The operators' and the technicians' view on learning methods and assessment were an important input from the interviews and the questionnaires. The interviews regarding common problems and faults gave input on how to use troubleshooting in the course. The learning objectives were used to create activities and assessment, giving the participants possibilities to gain the necessary knowledge and to show that they have reached these learning objectives.

3.5 Evaluation Methods

Peterson (2003) describes how the evaluation step can occur in different stages of a project. It can occur during the development step by formative evaluations, throughout the implementation step with the aid of the participants and at the end of the implementation of a course or program in the form of a summative evaluation (Peterson, 2003).

Rothwell et al. (2016) compare how an instructional designer engages in evaluation with a scientist conducting research by writing: "*Many of the same principles, strategies, and techniques apply*" (Rothwell et al., 2016, p. 235). To collect and analyze data to perform systematic evaluations is central to the role of the evaluator, regardless of whether the evaluator is a researcher or an instructional designer (Rothwell et al., 2016). Rothwell et al. (2016) describe two different types of evaluation, summative and formative. In summative evaluation information is gathered after the course has been deployed and in formative evaluation information is gathered during the design and development (Rothwell et al., 2016).

According to Rothwell et al. (2016) there are four different approaches to formative feedback as well; expert reviews, management rehearsals, individualized pretests and pilot tests, and group pretests and pilot tests. Management rehearsal builds support by involving a key stakeholder early in the process (Rothwell et al., 2016). Expert reviews ensure that the instructional package follows current or desired work methods or state-of-the-art thinking on the subject (Rothwell et al., 2016). The expert reviews are often prepared by instructional designers experts (IDEs) who may not be versed in the specialized subject (Rothwell et al., 2016). Pretests and pilot tests focus on learners' reactions and responses (Rothwell et al., 2016). Pilot tests provide valuable information about the instructional materials (Rothwell et al., 2016). The drawback is that they can be time consuming and require participants to leave their work (Rothwell et al., 2016).

Every step in the creation of the course was evaluated through discussions with the future teacher who was a key stakeholder in this project. The discussions combined the advantages of management rehearsal with the advantages of expert reviews in a time-efficient way. For example, the learning objectives generated from the brainstorming were evaluated by the teacher before they were considered definite.

At the end of this project, Automation course level 2 was held at SKF Competence Center as a pilot course. At the end of the course, the participants replied to a questionnaire. The purpose of the questionnaire was to investigate the participants' view on the design of the course, if they felt that they learned what they should have learned and if they felt that they will have use of the gained knowledge. The participants were also supposed to write a test at the end of the course to demonstrate what they had learned. However the teacher felt that there was not enough time to manage a test during the pilot course and the test was performed after the end of this thesis instead. The questionnaires were analyzed and used to evaluate the course.

3.6 Ethics

When working with social and educational research where people are the interesting objects it is important to consider ethics. This is most important when the data is collected but also when thinking about how the data is treated after the collection.

Punch and Oancea (2014) write: "*Ethics is the study of what are good, right or virtuous courses of action*" (ch. 4.1). Israel and Hay (2006) write: "*Ethical behaviour helps protect individuals, communities and environments, and offers the potential to increase the sum of good in the world*" (p. 2)

During all data collection the participants were informed that their contribution would be a part of this master thesis. All participants in the observations were informed that they were observed and why. All data presented in the report is anonymous. No participants were underage or declared legally incompetent.

4

Analysis Results

The first five sections in this chapter present the results from the observations, the questionnaires and the first round of interviews. These sections are; previous knowledge, motivation, important knowledge, learning methods and assessment. The learning objectives for the course are presented in the sixth section. The learning objectives were based on the results from the previous knowledge and important knowledge sections. The seventh section, common problems and faults, presents results from the second round of interviews. The literature is presented in the theory chapter. A flow chart of how the analysis lead to the designing/development is presented in Figure 4.1.

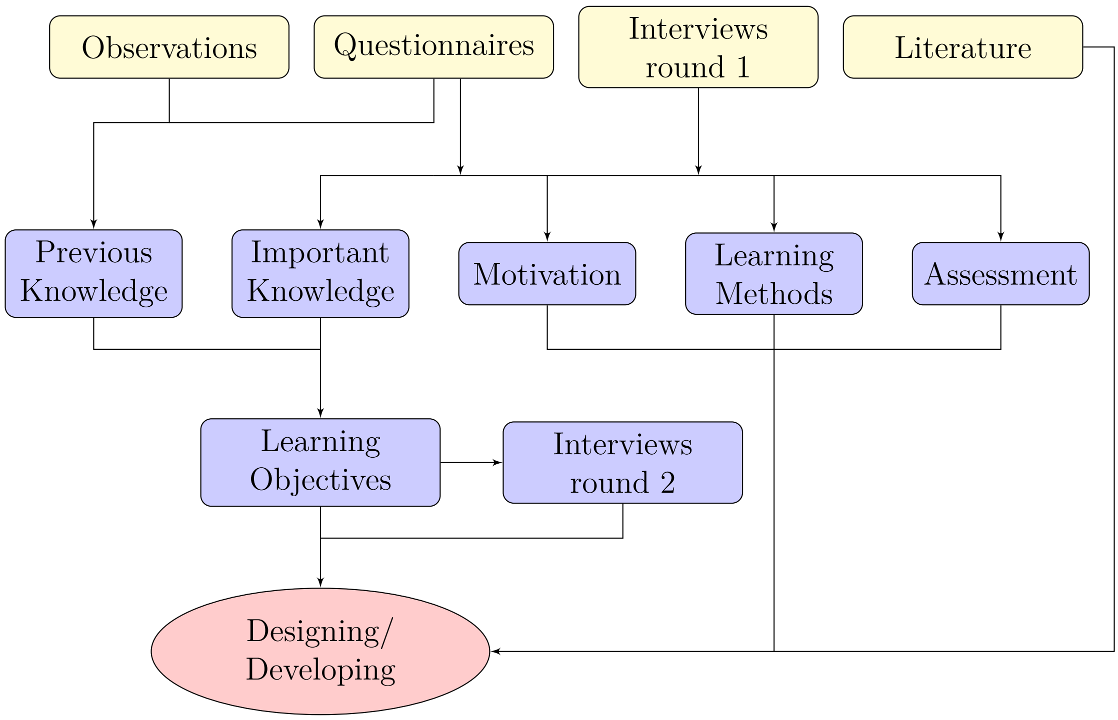


Figure 4.1: Flow chart of the analysis

4.1 Previous Knowledge

This section contains results from the observation of Robotics course 1 followed by results from the questionnaires concerning the previous knowledge of the operators and technicians according to themselves.

4.1.1 Observations from Robotics Course 1

The purpose with Robotics course 1 is to give operators more knowledge about the robots that they use in their work. The course gives the participants good basic knowledge in how to control the robot, both manually and automatically. What the participants learn from the first level course is how to

- calibrate the robot
- jog the robot
- define and redefine work objects
- define new tools
- use subroutines
- program the robot with the following commands:
  - MoveL, MoveJ, MoveC
  - Wait
  - PulseDO

The knowledge listed above was seen as previous knowledge for the participants entering Automation course level 2.

4.1.2 Previous Knowledge of the Operators

This subsection contains results from the questionnaires concerning the previous knowledge of the operators according to themselves.

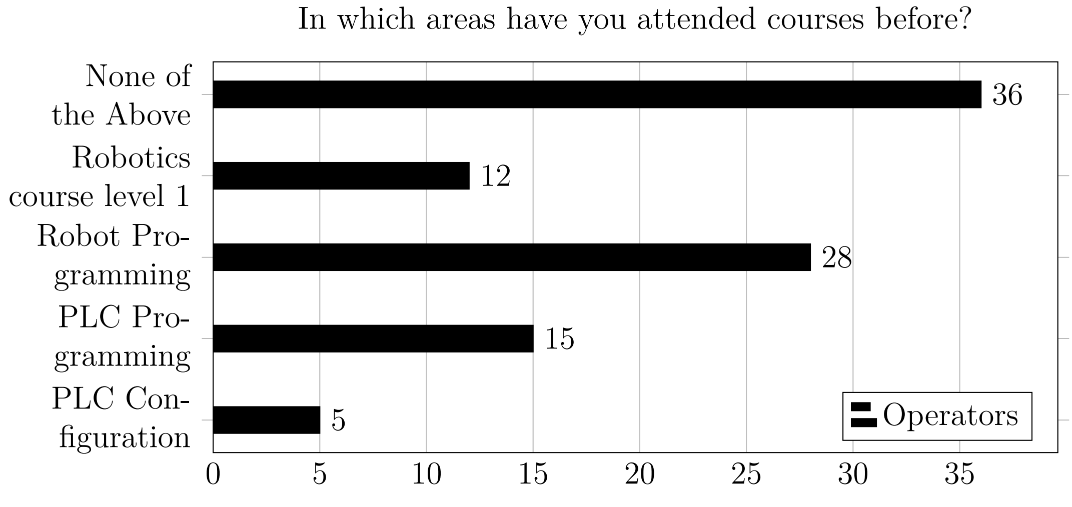


Figure 4.2: Bar chart of operators experience from previous courses

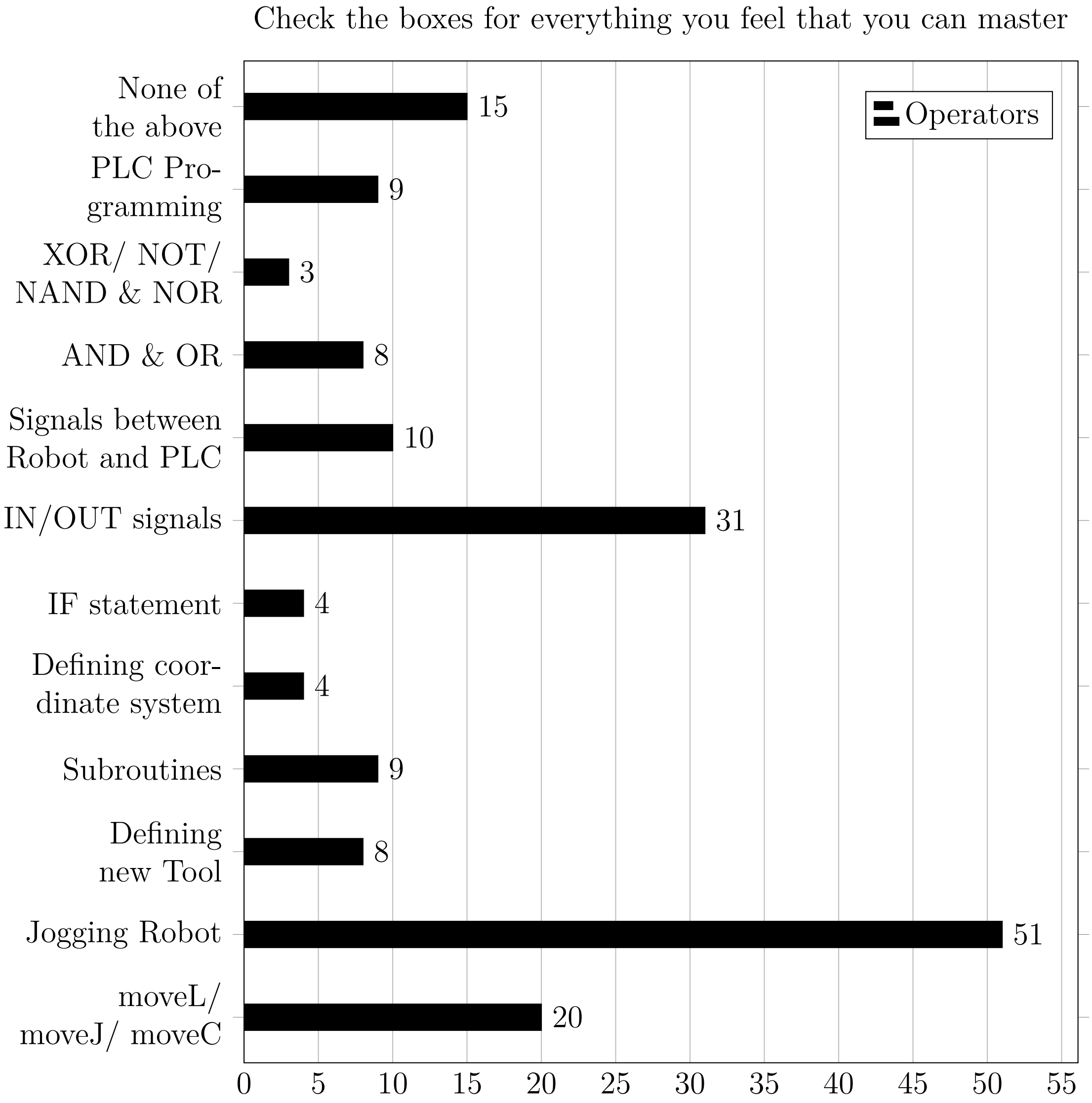


Figure 4.3: Bar chart of subjects that operators master

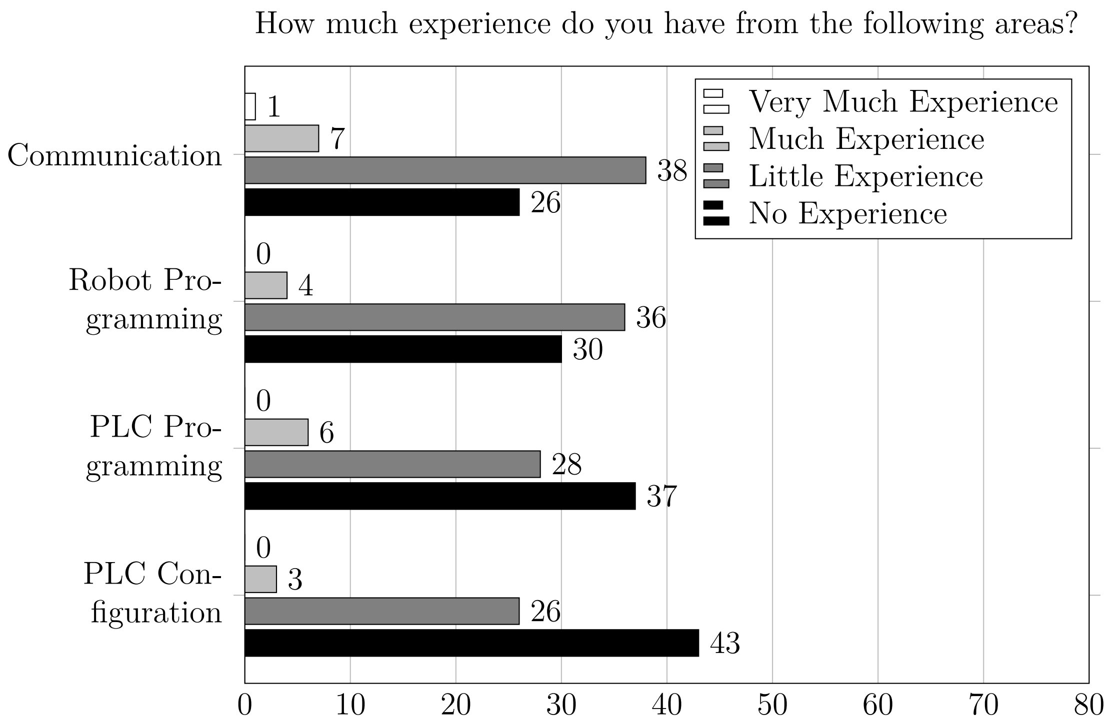


Figure 4.4: Bar chart of operators experience

The majority of the operators have no or little experience from robot, PLC and communication between them (Figure 4.4) even if only 36 operators have not attended any courses (Figure 4.2). The majority of the operators said that they can jog the robot and a little less than half of them can master IN/OUT signals (Figure 4.3). These results were used to create learning objectives using brainstorming.

4.1.3 Previous Knowledge of the Technicians

This subsection contains results from the questionnaires concerning the previous knowledge of the technicians according to themselves.

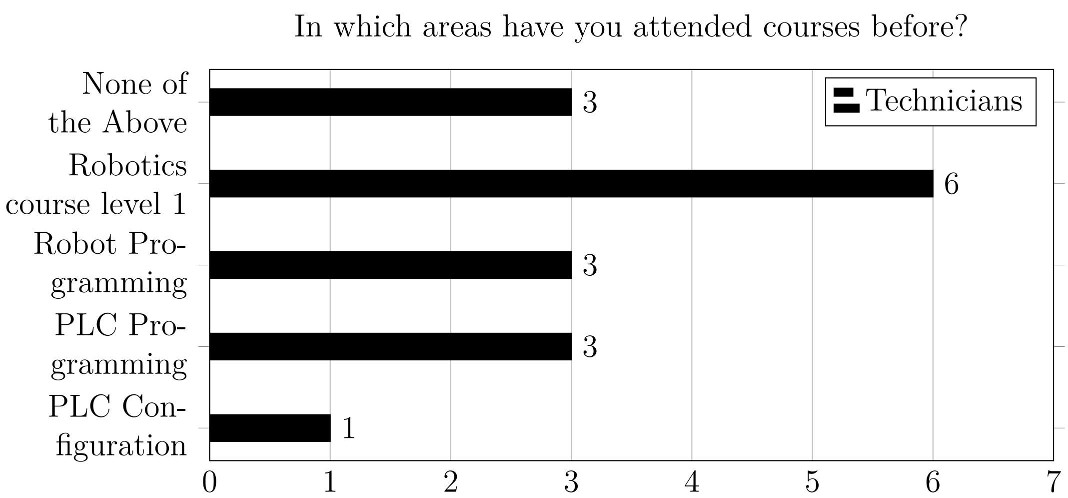


Figure 4.5: Bar chart of technicians experience from previous courses

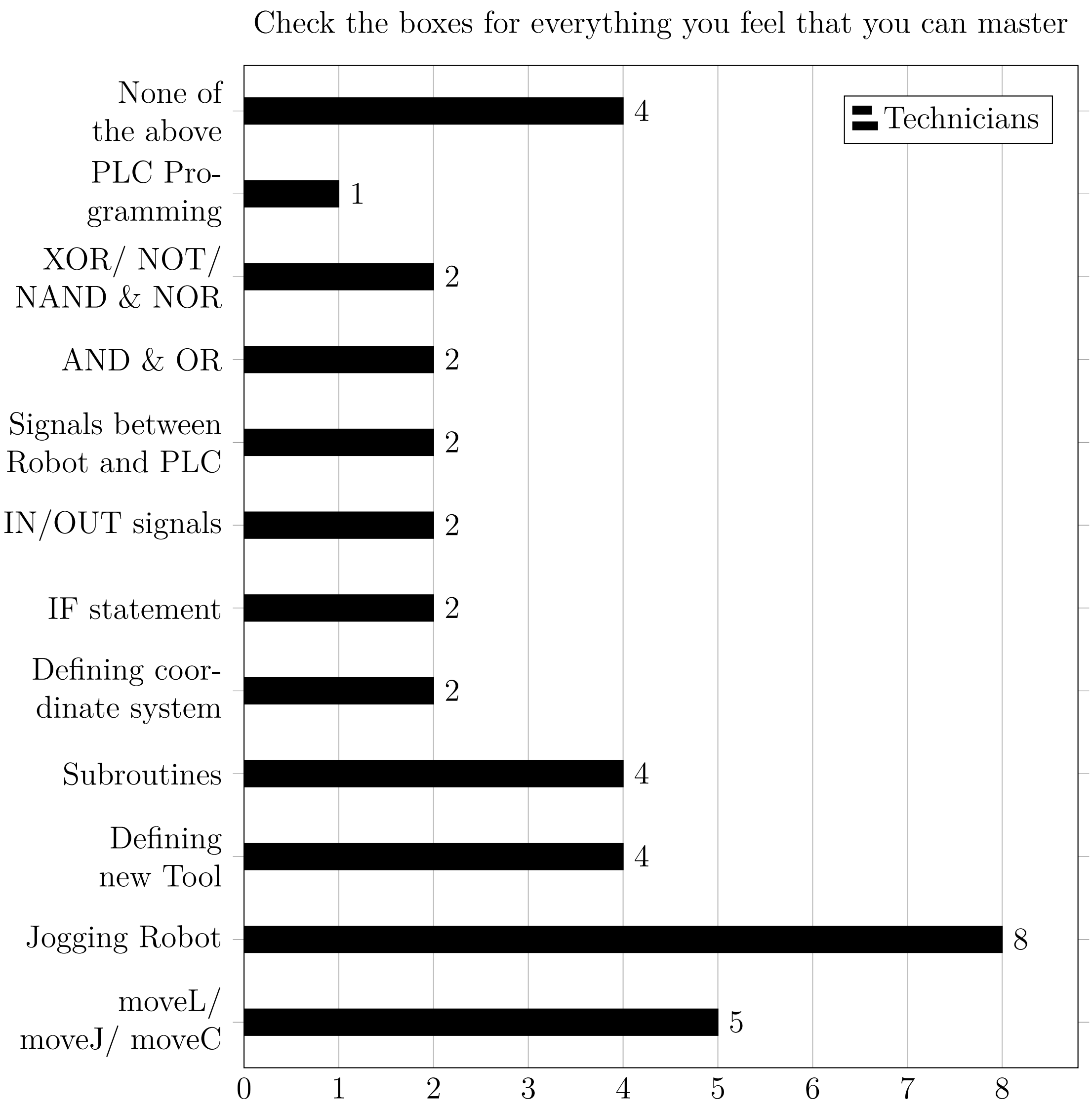


Figure 4.6: Bar chart of subjects that technicians master

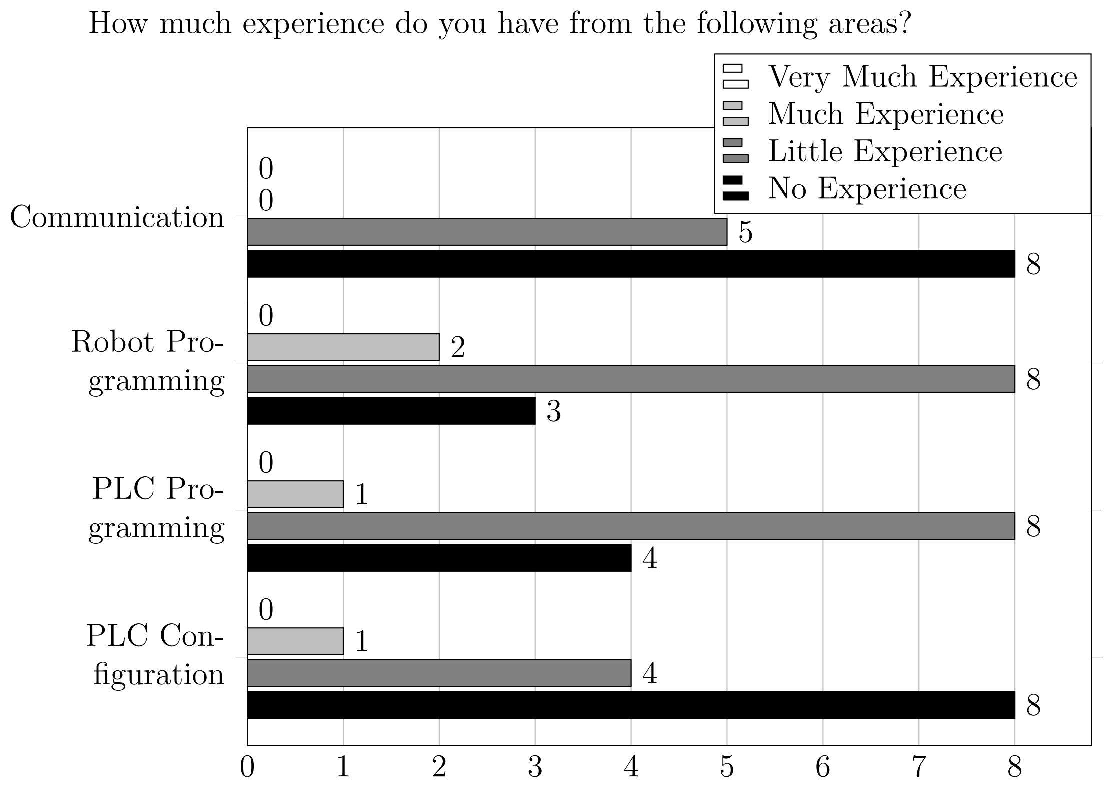


Figure 4.7: Bar chart of technicians experience

The majority of the technicians, similar to the operators, have no or little experience from robot, PLC and communication between them (Figure 4.7) even though almost half of them have attended Robotics course level 1 (Figure 4.5). Figure 4.6 shows very similar results as Figure 4.3. These results were also used to create learning objectives using brainstorming.

4.2 Important Knowledge

This section contains results from the questionnaires and the interviews concerning what knowledge is important for the employees according to themselves and their managers. The results from two specific questions in the interviews are followed by results from the questionnaires.

4.2.1 World Class and Industry 4.0

The responses to the question "*How will "World Class" and "Industry 4.0" influence the skill development in the company?*" in the interviews were clustered together in seven pattern codes. These pattern codes are presented in Figure 4.8 which shows how the new advanced technology leads to development in IT and automation. It also shows that the development creates lack of competence in several areas.

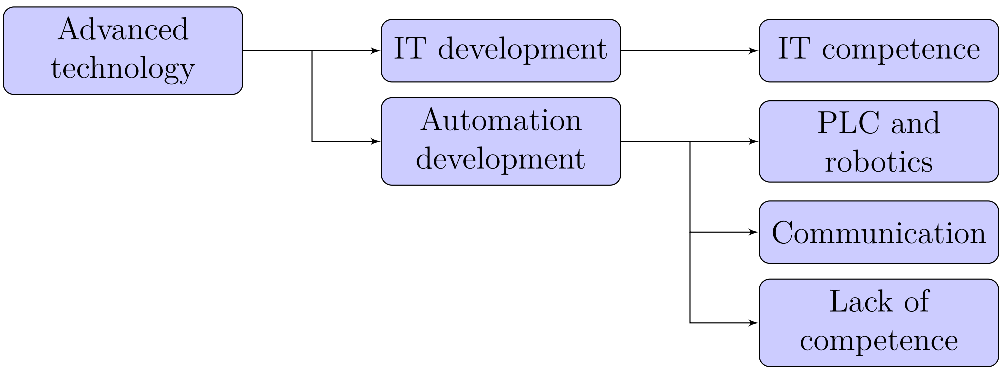


Figure 4.8: Flow chart of the pattern codes for World Class and Industry 4.0

The interviews showed that IT development has taken an important role in the industry.

> "*It is the first time that we tie the machines together in the cloud*" (I2).

> "*We will definitely have more to do with big data systems since we are changing to SAP, which means that we will also connect the machines later on*" (I6).

> "*We move from that things are physically graspable towards that they are somewhere in an IT or data world. You can not move a ring physically anymore*" (I5).

> "*It is new knowledge we need, that we previously did not have. And it is particularly with the IT and OT issues, I think*" (I1).

> "*We have data, we are going to have traceability as you say. We will save a lot of measurement data for each ring. It will then follow the process. The requirement to keep track on our products is increasing tremendously here now*" (I3).

Interviewees I5 and I6 mentioned Big Data as something new that will affect the skill development and the IT competence. "*A lot of data is generated, we need to learn how to analyze it in order to benefit from it. And that is something we are not used to at all. It requires skill development*" (I5). The employees need to know the network and understand the process. I6 said that both technicians and operators need knowledge about the information systems.

> "*Thus higher demands on IT skills, everything in IT*" (I6).

> "*It falls under the same as all IT really, but you need to know the network in some way*" (I6).

> "*It needs to be the basic knowledge now, that we understand how this works. What is it that we build, we build up a traceability for each individual, for each ring. The map is the reality now*" (I3).

I5 said that the communication is changing. I1 agreed and said that it is important to understand how you communicate in the new system. I1 specifically talked about the communication between different interfaces.

According to I2 and I3, both the IT and the automation is developing. I6 said that all of these changes in the automation process will set the skill requirements much higher. According to I5, the new advanced technology is presenting brand new possibilities but will also affect the skill development. "*It requires a great skill development to take advantage of it*" (I5). I2 agreed and said: "*the proportion of instruction time per year and employee will probably increase for us*".

The big changes have resulted in lack of competence. "*It is new knowledge we need that we have not previously had*" (I1). I5 said that they have not come far and that they are not used to this at all. "*It requires skill development*" (I5).

Other areas mentioned were PLC and Robotics. The communication is depending on the PLC and I6 said that all logic is kept in the PLC in the new cells. I6 said that the robot is important and that it is especially important to know how to use the robot pendant and jog the robot from difficult locations.

> "*In all new cells that we build we put all the logic in the PLC because the PLC is very good at that. The robot has the same opportunities really, but it is not quite as good at it. So we build routines in the robot which are called from the PLC. But you still have to know the robot itself*" (I6).

> "*You need to be used to taking a look, go in and look at a PLC program. For example to troubleshoot, it is a great advantage. Maybe not at an operator level, but definitely on a production technician level*" (I6).

Industry 4.0 and World Class will increase the need for skill development in IT, robotics, PLC and communication. These results affected the learning objectives of the course.

4.2.2 Important Knowledge According to Interviews

The responses to the question "*With the company in mind, what areas do you consider important for technicians/maintenance personnel/operators to learn more about?*" were clustered together in pattern codes. These pattern codes are presented in Figure 4.9 under the three headings "Handling the Components", "Understanding the Process" and "The Pyramid of Knowledge".

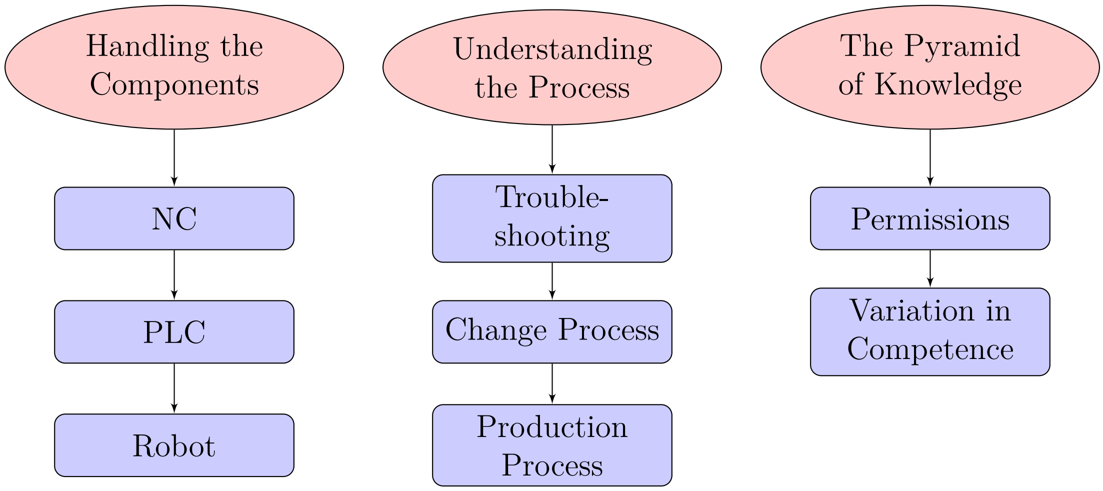


Figure 4.9: Flow chart of the pattern codes for important knowledge

4.2.2.1 Handling the components

The importance of understanding the robot cell was brought up by I1, I2, I3 and I7.

I1 and I3 said that you need to be able to see the big picture and understand the function of the robot cell and its components.

> "*So it is just the understanding of the whole mission*" (I1).

> "*What the operator need is an understanding of the function*" (I3).

When I3 was asked what is important to have in a robotics course, I3 also described that the operator should be able to handle his cell and said: "*Cancel a cycle, start a cycle*". I3 also said that the robot cell should be "*self instructive and work*". Regarding what is important to know for an operator, I3 also said: "*They have to know what the cell can do, its performance*". I3 also said that it should be possible to handle the cell via HMI. To understand how the robot cell is programmed, I2 said that it is important to practice how to "*stop in different steps in the process and practice to run back and start over*".

I4 described how production technicians need a stronger ability when it comes to programming. I4 said: "*It is the automation and it is the NC. To be able to troubleshoot, to be able to create programs*". I4 also said: "*The operators rather need to troubleshoot*". I4 also mentioned maintenance work with RCFA (Root Cause Failure

Analysis) and that it needs to change with industry 4.0. I5 mentioned that NC-programming and CNC-programming is something that is brought up when courses are discussed with the technicians.

I4 specifically talked about how they work with calculating cycle times and that they might create new programs for cycles. I4 described the need of understanding but that the competence is not there. "*I am willing to admit that there are not many who are kind of sharp at it*" (I4).

The interviewees frequently mentioned PLC and robots. "*We become more and more automatized, so it is really the whole automation process which I see that you need more of. That includes both PLC, robot and whatever it can be*" (I7). "*If you look at particularly technicians and maintenance, it is PLC and robot*" (I6). I6 also emphasized that it is more difficult now since they control the logic from the PLC. Before you could change a lot in the programs yourself, on the robots.

When it comes to PLC more specifically, I5 and I6 saw the use of including PLC in a course. I5 said that PLC-programming is what comes up during personal development dialogues with the technicians. I6 was positive regarding including PLC in a course for operators.

> "*The PLC-programs running out here become quite big. But still, I think it should be included a small. I think you should include the discussion around the PLC, since this is the way we do it here. So you should sort of have a basic knowledge about it. An explanation to why you choose the one or the other maybe, would have been very good*" (I6).

I6 also sees the challenge and said: "*For the PLC itself. It is wishful thinking that the operators can handle it too. It is a little more difficult if you say so*" (I6).

I3 said that the operator does not need deep technical knowledge when it comes to PLC.

I4 said that there are delimitations. "*We should not have anything to do with PLC. Production technicians and operators should not have anything to do with PLC. We have the development department and we have the maintenance department with specific resources for PLC*" (I6).

I6 agreed and said the following about the maintenance personnel:

> "*They need to look a lot more at PLC today. We have a number of programmers on the development-side. But if we look at the service-side, we have many maintenance personnel who know a little, but I think we need to be more who know a little more. And I know that it has already started, they have started with training and so on, but it is going to be really important. Production is running around the clock so I mean. We can not get hold of consultants during the weekends*" (I6).

I5 also said that HMI, connection between the HMI and the PLC along with the Siemens-systems in the factories is something to include in a course.

The robot was also frequently mentioned during the interviews. The main focus from the interviewees was on how to operate the robot, not how to program it.

> "*The robotics course should mainly be about the robot*" (I6).

> "*Operate the robot is probably the first thing*" (I2).

> "*Robot, not programming but to understand and operate and communicate, handle a robot and understand what is required for it to work*" (I5).

> "*What should I do when certain things happens, and I need to reteach it or similar. Or find its references*" (I5).

> "*The search function in a robot is quite important*" (I1).

> "*Should be able to operate the robot to its home position. To cancel a cycle, start a new cycle. That is the operator's role*" (I3).

4.2.2.2 Understanding the Process

Troubleshooting was something that many of the interviewees said was important for the employees to learn more about. I1 described how troubleshooting is important for the operators so that they can specify what kind of help they need when they place an order to maintenance. I1 said: "*Maybe they can not fix it but they can at least specify and say what the problem is*". I1 also said: "*It is good for everybody to be able to troubleshoot, to be able to see in the error code why it stopped*".

I6 agreed with I1 when it came to troubleshooting and said that World Class and industry 4.0 will affect the skill development in the company when it comes to PLC.

> "*It will put demands on PLC-skills. Maybe not that you need to do programming, but you need to know a lot more. You need experience to maybe go in and look at a PLC-program. For example troubleshooting is a big advantage*" (I6).

I1 also described how the troubleshooting needs to be applied to new technology. An example from I1 was vision systems, since the robot searches for rings with vision now.

I1, I2 and I5 mentioned that a standardized change process is important. I1 said: "*We should do improvements all the time but they should be controlled and go through a change process*". I2 said: "*There might be those who are very progressive and believe that they have a lot of knowledge and start to re-program themselves and so. Then we quickly leave a standard, and we certainly do not want that*". I1 and I2 saw that a clear change process is necessary. I5 described how they, in the production, can feel the need of making changes based on their own ideas. I5 gave an example and said: "*Then we would have made sure that every shift team do things the same way*". However I5 agreed with the opinions that I1 and I2 had about changing the programs and said: "*But it is a little dangerous, it should be done in a structured way. Anyone should not be able to go in and make changes*".

I1 and I3 brought up the production process as something important to learn more about. "*What we all have to learn more about is how the process works, how the machines work*" (I1). I3 talked about how IT has changed the process and that operators need to have an understanding of the function. "*What the operator need is an understanding of the function*" (I3). "*The ring changes status after every operation. More and more data is added after every operation*" (I3).

I6 talked about how the operators need to be able to read drawings in production today. "*You need to look at what is specific with this bearing*" (I6).

I6 said: "*I think it would be good if you know about life cycle cost and such too, so that you have understanding for everything that has to do with the maintenance of the machine, both on operator level and and for service technicians*".

4.2.2.3 The Pyramid of Knowledge

The importance of permissions were brought up two times during the interviews. Both of the maintenance managers wanted to make sure that every employee knows what they are permitted to do.

> "*Just as much as we want the process operators to increase their knowledge, we also want them to always be aware of what they are not permitted to do*" (I2).

During the interviews, it became clear that variation in competence was requested. I1 described it as a pyramid of knowledge and said: "*The operator has the basic knowledge, then comes maintenance with more knowledge*". I2 expressed the same opinion and said: "*When the operators can not solve the problem, we will have the competence to do it*".

I2 and I3 talked about how the company has rewarded a wide knowledge through the years and that it might need to change.

> "*The more you know, little about a lot, the higher salary you have got. It might even be so that we need to change this so that we also reward expert knowledge for our operators*" (I2).

> "*You do not find those people in the industry. That is why I believe that this kind of is the future. That you can build your expertise similar to what we do in the maintenance departments. And together we will solve the missions*" (I3).

> "*It will be hard to give one individual all technological knowledge. I do not believe we can find those super humans*" (I3).

I2 also talked about that an idea would be to build expert roles. Even if it is clear that you should reward expertise, I3 also said: "*You should have a general knowledge*".

I2 was of the opinion that the skill development should be divided so that there is a red thread when you are going to deepen your knowledge. "*The first training session can be common for production technicians, maintenance personnel and process operators. Then you can sort of have more depth in this education*" (I2).

I2 had an idea that the whole site can be covered when it comes to maintenance by providing more depth. "*When you put all our workers together, then we should cover the whole site with maybe one individual on the final stage of the education. Then it is maybe 1-2 of all hundred*" (I2).

I1 said that there is no limit for how much knowledge the employees should have.

> "*We shall educate the operators as much as possible, and by the time their knowledge increases, we absorb the knowledge that we are forced to buy from external operators today*" (I1).

I7 talked about how the knowledge and skills differ between different channels in the production.

> "*The channel beside can be almost identical, but they do almost everything by themselves. They only call maintenance when there are major issues. They replace sensors, small things, change the position on the robot, by themselves. While the channel beside basically do not do anything. A little hard haul of course. And in the new production channel, the idea is that the production will do most of the work themselves when it comes to changes in programs etc*" (I7).

I2 and I3 talked about the importance of teamwork.

> "*Maintenance personnel, production technicians and process operators need to kind of become more integrated in each other, and support the process*" (I2).

> "*We have to work together*" (I3).

I4 said that for the technicians, the work includes much more preparation for new types, cycle times and optimization.

The importance of skill development in relation to handling components, understanding the processes and the pyramid of knowledge influenced the learning objectives.

4.2.3 Important Knowledge Specifically for Operators

This subsection contains results from the questionnaires concerning what the operators and the Operations Managers considered important for operators to learn more about.

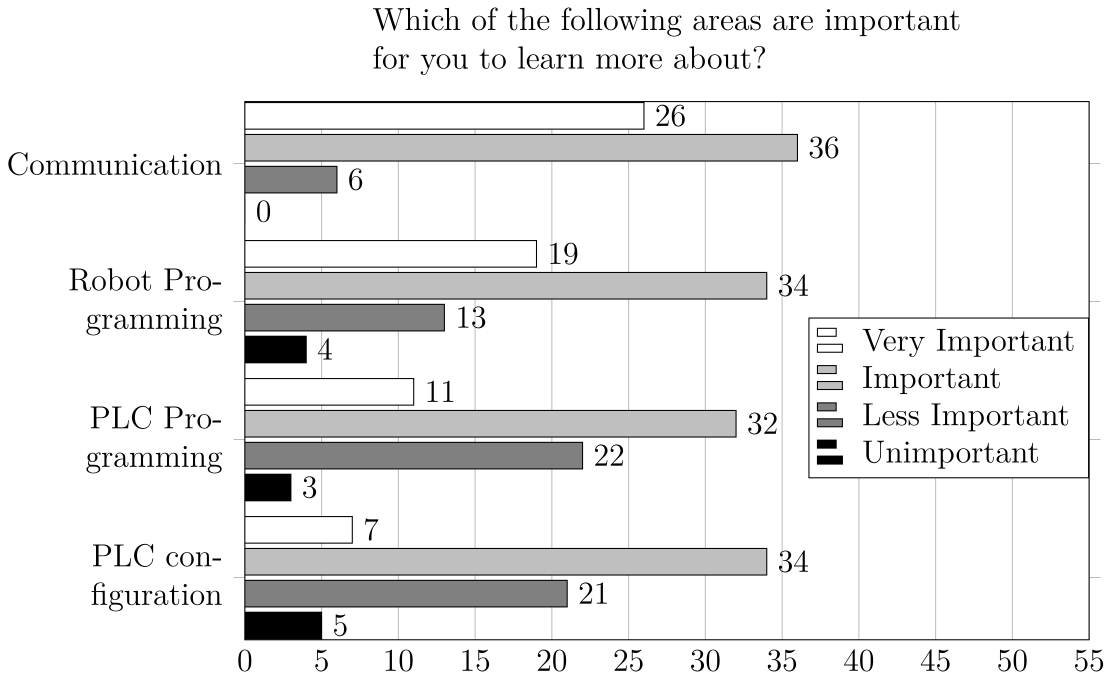


Figure 4.10: Bar chart of areas operators want to learn more about

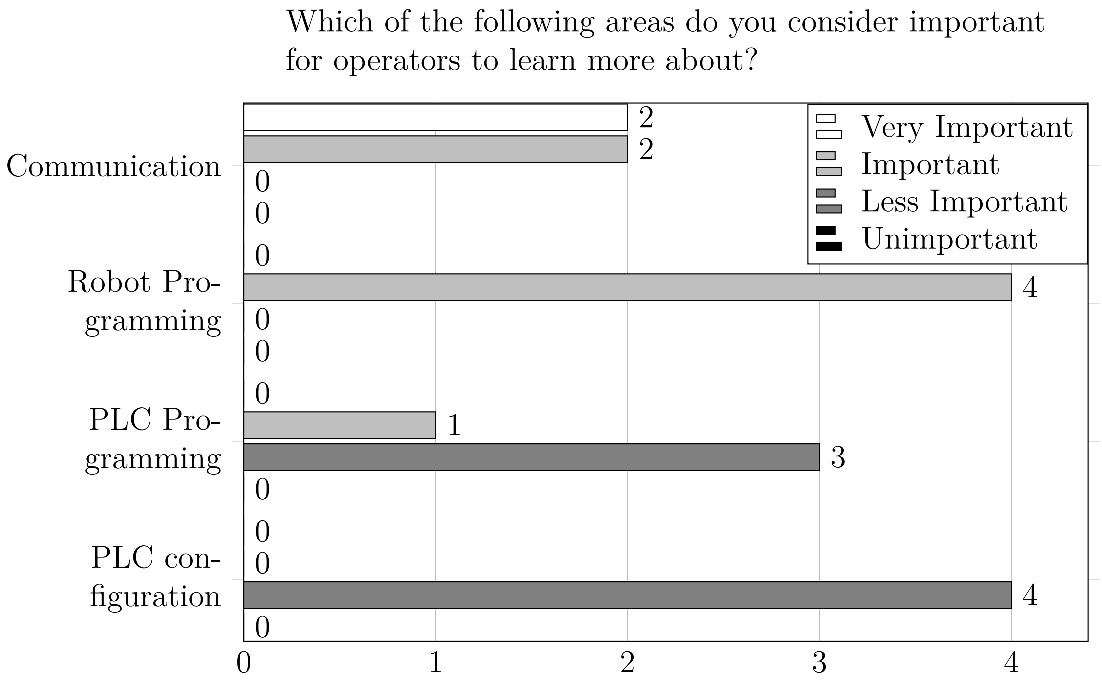


Figure 4.11: Bar chart of areas operators should learn more about according to Operations Managers

The results in Figure 4.10 show no consistent opinion among the operators. All areas were rated as important by the majority, but the tendency showed that communication is most important and PLC configuration is least important. Figure 4.11 shows that the Operations Managers agreed with the tendency in Figure 4.10. The answers from the Operation Managers were more consistent than the answers from the operators.

The question "*Is there anything specific in these areas that you consider important for operators to learn more about?*" was asked to the Operations Managers.

They answered:

- "*No*".
- "*No*".
- "*Handle robots and understand the communication*".
- "*Communication between the equipments*".

The question "*Is there anything else that you consider important for operators to learn more about?*" was asked to the Operations Managers.

They answered:

- "*No*".
- "*No*".
- "*Operating robot*".
- "*What abilities the robot has and what it can accomplish*".

These results affected the focus and content of the learning objectives. Communication between components was the most important area and PLC configuration was the least important.

4.2.4 Important Knowledge Specifically for Technicians

This subsection contains results from the questionnaires concerning what the technicians, the Channel Group Managers and the Manager Industrial Engineering consider important for technicians to learn more about.

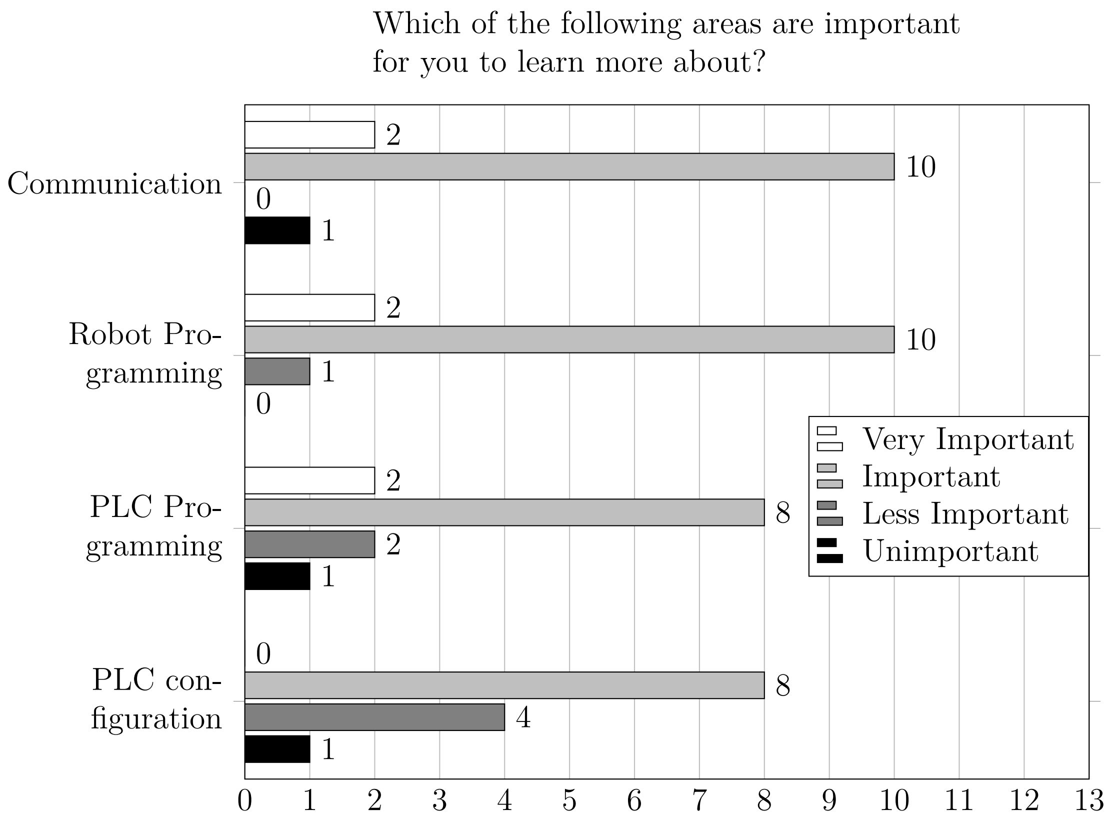


Figure 4.12: Bar chart of areas technicians want to learn more about

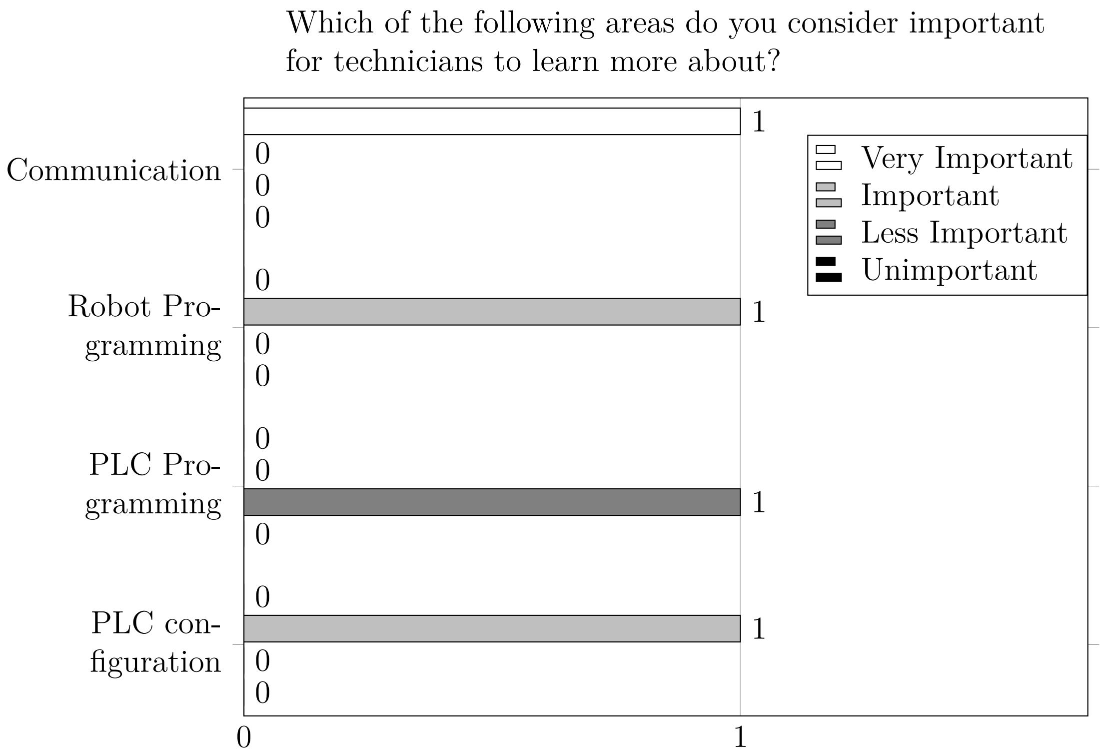


Figure 4.13: Bar chart of areas technicians should learn more about according to the Manager Industrial Engineering

Figure 4.12 shows that the technicians wanted to learn more about all four areas, similar to the operators. The technicians also said that learning about communication and robot is a little more important than learning about PLC. Figure 4.13 shows that the Manager Industrial Engineering said that PLC configuration is more important than PLC programming. Figure 4.14 shows that the Channel Group Managers agree with the technicians and operators. They answered that communication is most important and PLC configuration least important.

The question "*Is there anything specific in these areas that you consider important for technicians to learn more about?*" was asked to the Managers Industrial Engineering.

The manager answered: "*The NC part/PLC is handled by maintenance department and the development department*".

The question "*Is there anything else that you consider important for technicians to learn more about?*" was asked to the Managers Industrial Engineering.

The manager answered: "*Understanding about how programs are built, handling alarms and of course creating NC programs*"

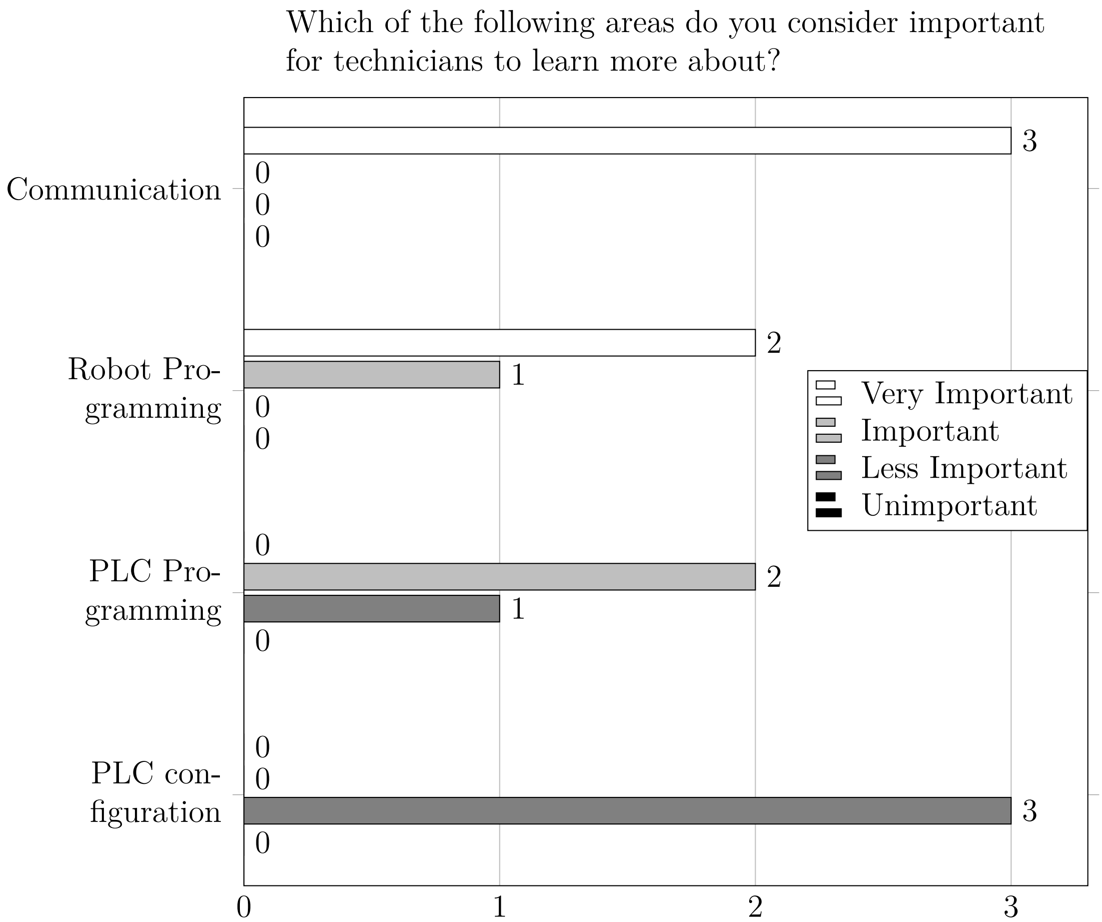


Figure 4.14: Bar chart of areas technicians should learn more about according to Channel Group Managers

The question "*Is there anything specific in these areas that you consider important for technicians to learn more about?*" was asked to the Channel Group Managers.

They answered:
- "*To understand how the systems "talk to each other". Partly to be able to give support when errors occur but also to understand how we can improve the robot systems!*"
- "*No*".
- "*I suppose that we with "technician" mean operator (the alternatives would be production technician or service technician)*".

The question "*Is there anything else that you consider important for technicians to learn more about?*" was asked to the Channel Group Managers.

They answered:
- "*Programming so that they can make smaller improvements*".
- "*No*".
- "*The basics in how a robot works, handling the robot manually. Optimization of the movement pattern*".

The results show that communication is very important, programming is important and that PLC configuration is less important for both technicians and operators. This result affected the focus and content of the learning objectives.

4.3 Motivation

This section contains results from the questionnaires and interviews concerning motivation for education.

4.3.1 Motivators for Operators

This subsection contains results from the questionnaires concerning motivators for operators.

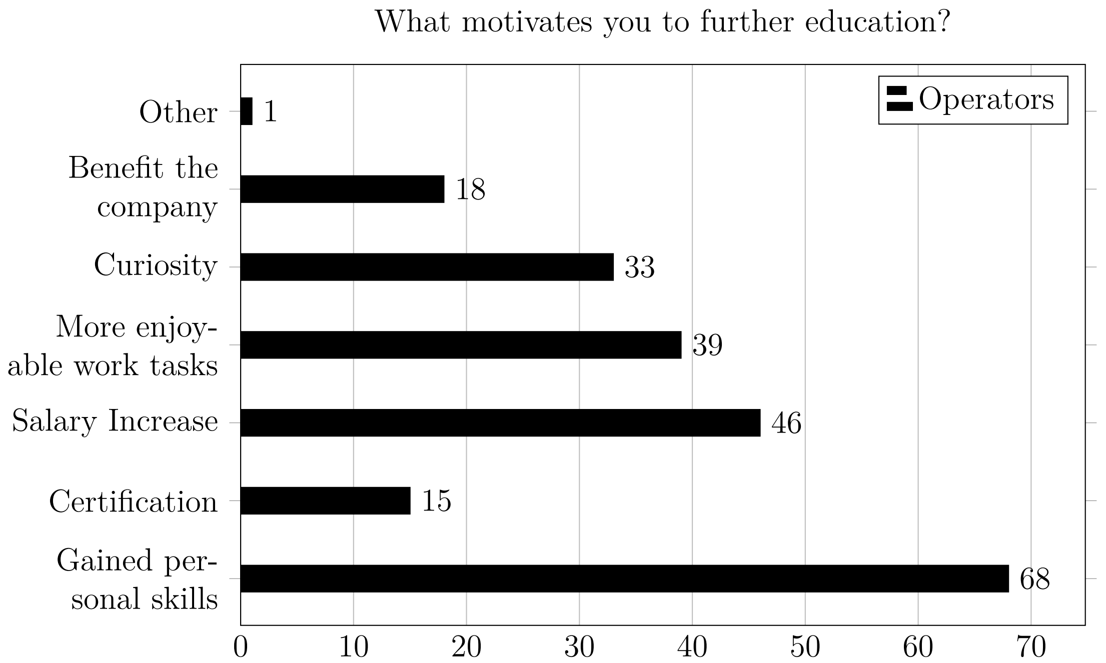


Figure 4.15: Bar chart of motivators for operators

The box "*other*" was checked by one operator who wrote: "*I do not have the first level course*".

Figure 4.15 shows that the biggest motivator is "gained personal skills". This result was considered when the learning activities were created using brainstorming.

4.3.2 Motivators for Technicians

This subsection contains results from the questionnaires concerning motivators for technicians.

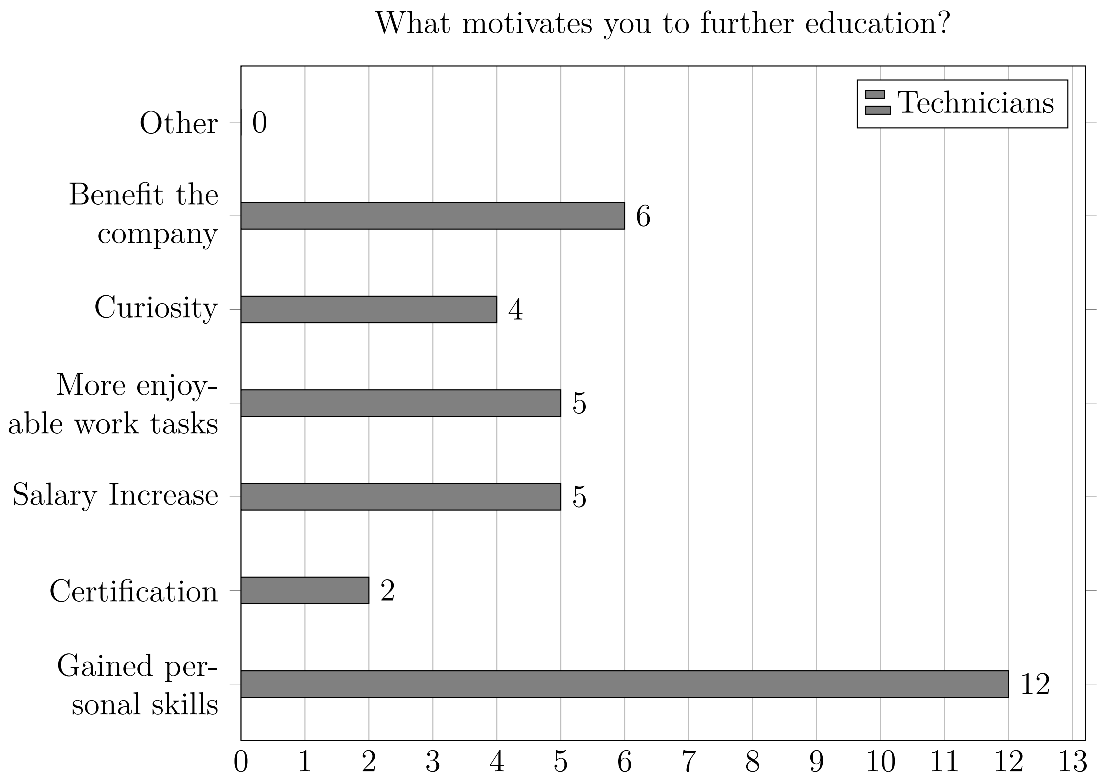


Figure 4.16: Bar chart of motivators for technicians

Figure 4.16 shows a similar result as Figure 4.15, that "gained personal skills" is the most common motivator.

4.3.3 Motivators for the Company

This subsection contains results from the questionnaires and the interviews concerning motivators for the company. The results from the questionnaires are followed by results from the interviews.

4.3.3.1 Questionnaires

The question "*What use has the company of a course in robotics according to you?*" was asked to the Operations Managers, the Managers Industrial Engineering and the Channel Group Managers.

The Operation Managers answered:

- "*Reduce D-time [downtime], be able to redress smaller issues by themselves*".
- "*Good with spread knowledge*"
- "*Reduced D-time and optimization*".
- "*Robots are used in more operations*".

The Manager Industrial Engineering answered: "*Reduced interference and to develop the processes, we head further and further towards automated operations in the production and we need to be one step ahead*".

The Channel Group Managers answered:

- "*To optimize robot cells we have today! In the projects we have carried out at SKF we have lost a lot about how we get efficient robot operations!*"
- "*Increase the competence. We are dependent on a few people with this competence today. This makes all the activities or interruptions in the channels, where the robots are involved, to take a lot more time than necessary*".
- "*Problem solving that reduces downtime, and increased possibilities for continuous improvements*".

The question "*Is there anything more you would like to mention or add?*" was asked to the Operations Managers, the Managers Industrial Engineering and the Channel Group Managers.

All of the managers except one of the Channel Group Managers left the question blank or wrote: "*No*". The Channel Group Manager who gave a longer answer wrote: "*If we do not invest in creating competence in automation, we will be very dependent on other companies consulting us all the time! This is both expensive and time consuming*".

The answers show that skill development is important since it reduces D-time. D-time (or Downtime) is the time when a machine fails to perform as it should. Reducing D-time saves money and time for the company.

4.3.3.2 Interviews

The interviews unanimously showed that skill development is important for the company. The responses to the question "*Do you consider skill development important? Why?*" were clustered together into five pattern codes. All pattern codes were reasons for why skill development is important, as seen in Figure 4.17.

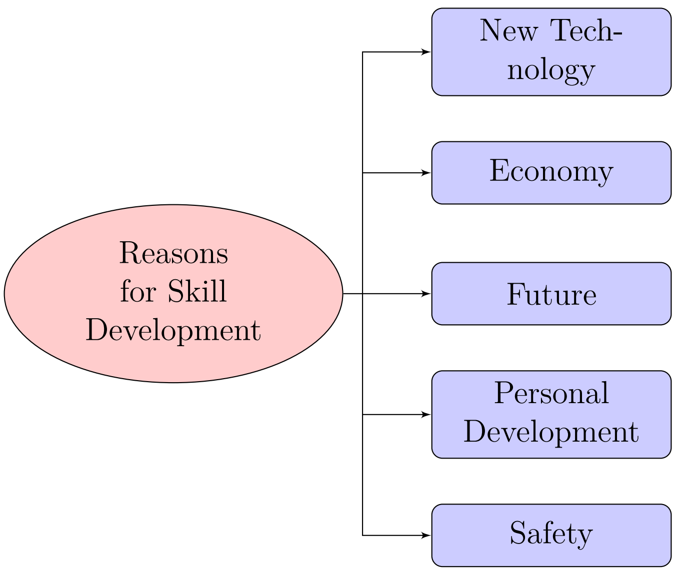


Figure 4.17: Flow chart of the pattern codes for skill development

The interviews showed that new technology puts demands on skill development. I2 mentioned that skill development is very important since you need to know what you are and are not allowed to do and said: "*And then it is very important now that the technology is becoming more and more difficult*". I1 said that skill development is important for the simple reason that otherwise no one can do their job. I3 said: "*We can not troubleshoot a system which we do not know how it works*". It was also understood that a problem is that new technology is not only new, it is also very different. I2 said: "*The technology becomes more digital*" and "*workshop industry heads towards process industry in a completely different way which changes our mission to maintain the facilities*". I1 and I5 also mentioned new technology.

> "*Specifically we are now in a situation where there will be new skill requirements which we have not got any knowledge about*" (I5).

> "*Be able to understand the equipment and to be able to handle it*" (I1).

> "*The people who work in the system today are trained in an older system than the one we are about to create*" (I5).

The interviews showed that the technology is not only getting more digital, it is also getting more automated. "*We are getting more and more automated, so it is really the whole automation process which I see that you need more of*" (I7). I4 talked about a specific channel in one of the factories at SKF and said:"*We have the E02 that is now fully automated, it is rather complex*". I4 said that the automation and "World Class" is spreading over the company. I4 also said that the need for education about automation is continuously growing and that it is important to keep up with the technology.

Economy was brought up by several interviewees. Interviewee I1 said the following about skill development: "*It is a prerequisite for being able to take care of the equipment that we shall take care of*". I2 said: "*So that we do not create major downtime, major accidents or other risks*". If they can not take care of the equipment, it will cost the company both time and money. I3 said: "*They should have an availability of 97 %, or what is it you are saying? It should run and we have no time to stand still because we do not understand how it works*". I6 said that it is important with skill development since they are producing 24 hours per day and that it is impossible to get consultants in on a weekend. I1 said that when the operators' knowledge is getting deeper, they will not have to buy knowledge from external companies, like they do today. I4 said that skill development will lead to "*less downtime and quality losses*" (I4).

When asked about skill development, interviewee I4 mentioned the future multiple times and said: "*Extremely important. Since we will meet the future*". I4 also said that they need to stay ahead of their competitors and that skill development is important since the company is losing experienced employees due to retirement and transfers to other companies.

Interviewee I6 emphasized personal development and said that it can lead to better self esteem and self confidence. Interviewee I6 also said that the work will be more enjoyable the more you know.

Safety was mentioned by interviewee I2. Everybody needs to know what they are allowed to do and what they are not allowed to do.

The results from the interviews are similar to the results from the questionnaires regarding new technology, economy, future, personal development and safety. It shows that skill development is important to reduce D-time, which saves money and time for the company.

4.4 Learning Methods

This section contains results from the questionnaires and interviews concerning learning methods. Results from the interviews are followed by the results from the questionnaires.

4.4.1 Learning Methods According to Interviews

Thoughts, earlier experiences and suggestions regarding learning methods were brought up by the interviewees during the first round of interviews. What the interviewees brought up regarding learning methods were clustered together in three pattern codes. These pattern codes are presented in Figure 4.18.

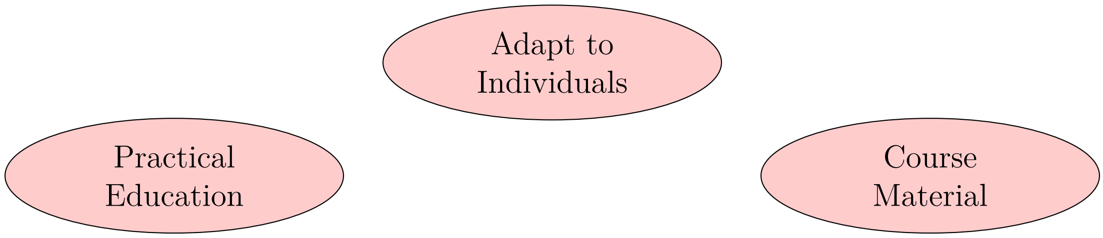


Figure 4.18: Flow chart of the pattern codes for learning methods

The interviews showed that there needs to be a lot of practical education in a course.

> "*It should not just be to sit back and be fed with information. Practical learning has to be a part of it. And I believe that we get the most out of it by having it in the factories*" (I4).

> "*If you will have a course to learn, you have to add some more exercises*" (I3).

> "*Combine theory and hands-on, at least when it comes to robot programming. It is fun to see, get the feedback. You get direct feedback very quickly when programming the robot*" (I6).

Some of the interviewees expressed the importance of that the practical education must include the same equipment as used in the factories. I4 even wanted to have the education in the factories. Another thing brought up by I4 and I7 was that it is different in different factories. They are using both KUKA and ABB robots according to I4 and both Siemens and ABB PLC according to I7. KUKA and ABB are two manufacturers in the automation industry.

> "*What I hear about when people participate in robotics courses is that it gets very theoretical, it gets very, it can be a different robot so that you do not recognize yourself*" (I5).

Several interviewees brought up how different individuals need different amount of time to learn. I7 also expressed how the participants are not used to be in school.

> "*You, who are in the middle of it, might have better reception capability than many who are between 40 and 60 and have worked for 20-25 years. Then a course might be a bit slow and you need to have more training in the course. You need to perform some elements physically too, to make it stick*" (I2).

> "*It is often easier to absorb things when you are younger*" (I7).

> "*You might need more time. And then we are all different individuals. Some people learn easy and some people need more time*" (I7).

According to I7, lectures are rarely good for robotics courses. I7 usually tries to mix theory with exercises and said that it works very well. "*I believe that you learn when you get to do it yourself*" (I7). Robotics course level 1 usually has four participants and one robot. According to I7, that is the reason for why all exercises are performed in group in that course.

I3 expressed a problem with course leaders who consider to much what the participants already know instead of teaching about how the equipment works.

> "*I think that our suppliers, when they have their training for us maintenance technicians, they take too much consideration in what we already know and what we do not know instead of providing information about how the system works*" (I3).

I3 explained how it is their responsibility to understand the equipment during and after courses.

> "*If we do not understand what they explain, we have to move back a little, and educate ourselves were we do not understand*" (I3).

When it comes to course material, I7 has handed out material after a course has finished before, but never prior to a course. "*Unfortunately, I usually have not got time before. I have had a vision about it sometimes, but it has not happened*" (I7).

After a course has finished, I7 has sent out manuals, links and important instructions, which has been appreciated. There are always those who want more but it does not exist enough good material to hand out according to I7.

I3 emphasized the importance of having written material for the participants.

> "*One thing I want to emphasize is that when you have an education, there should be written material as well. So that you have an opportunity to take home and study or repeat what was said. I think that is important. You remember approximately 20 % of what you hear and 80 % of what you do*" (I3).

4.4.2 Learning Methods According to Operators

This subsection contains results from the questionnaires concerning the operators own preferences about learning.

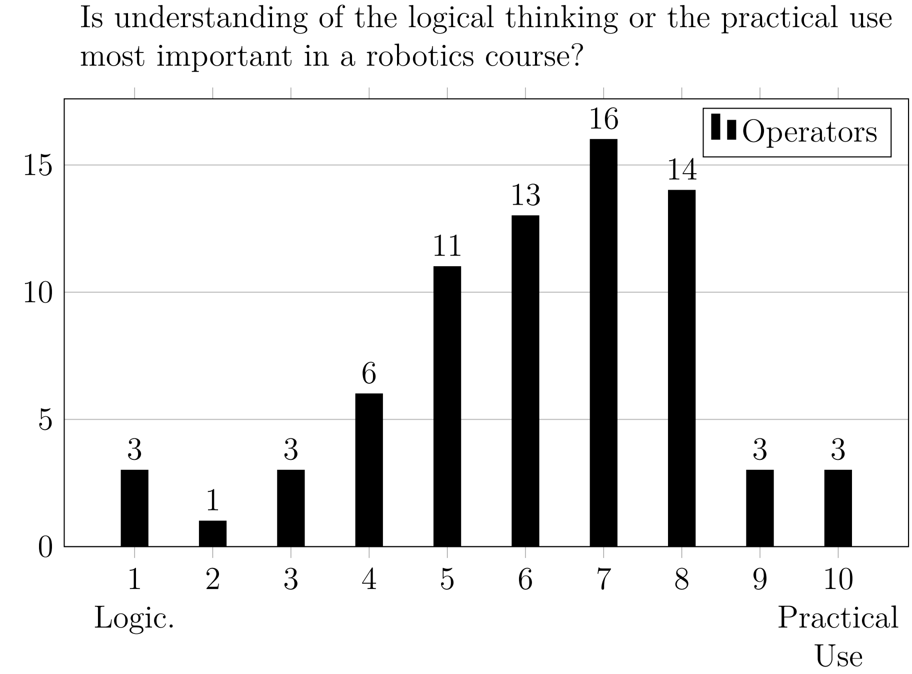


Figure 4.19: Bar chart of operators view on understanding

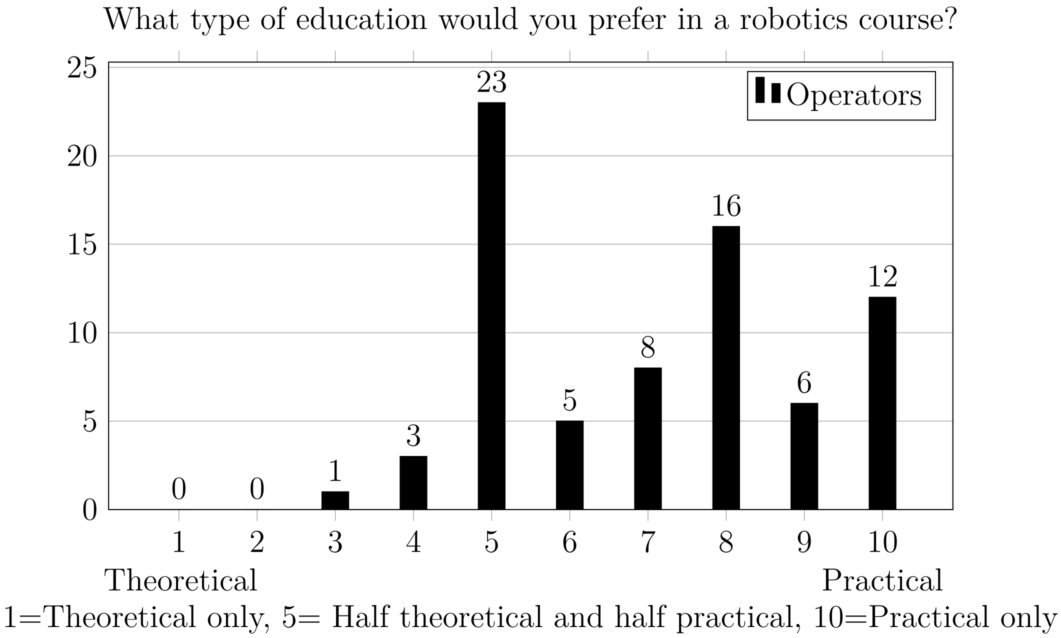


Figure 4.20: Bar chart of operators view on education

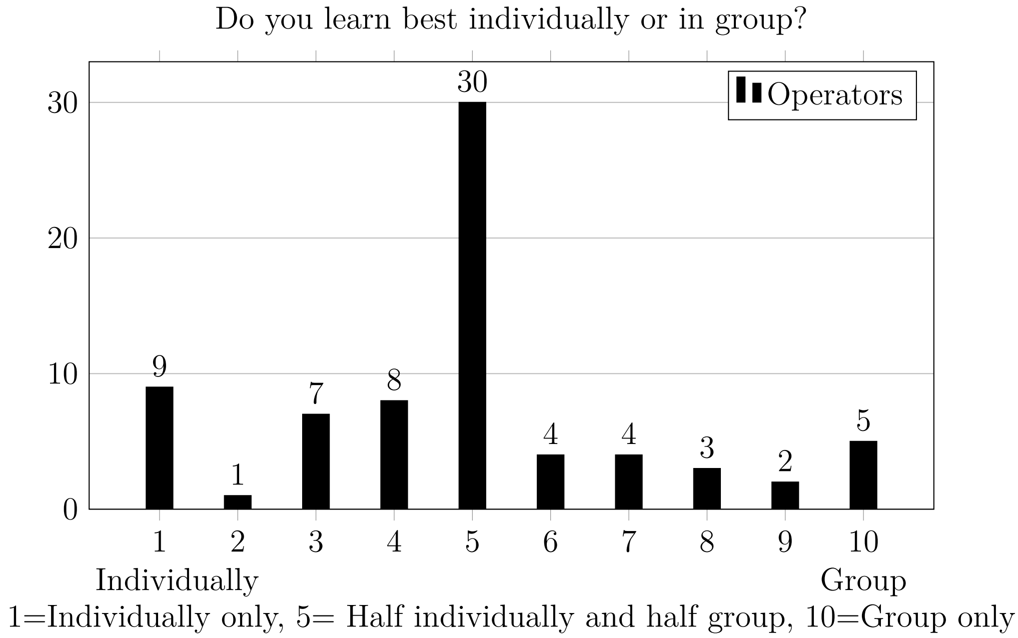


Figure 4.21: Bar chart of operators view on individual versus group education

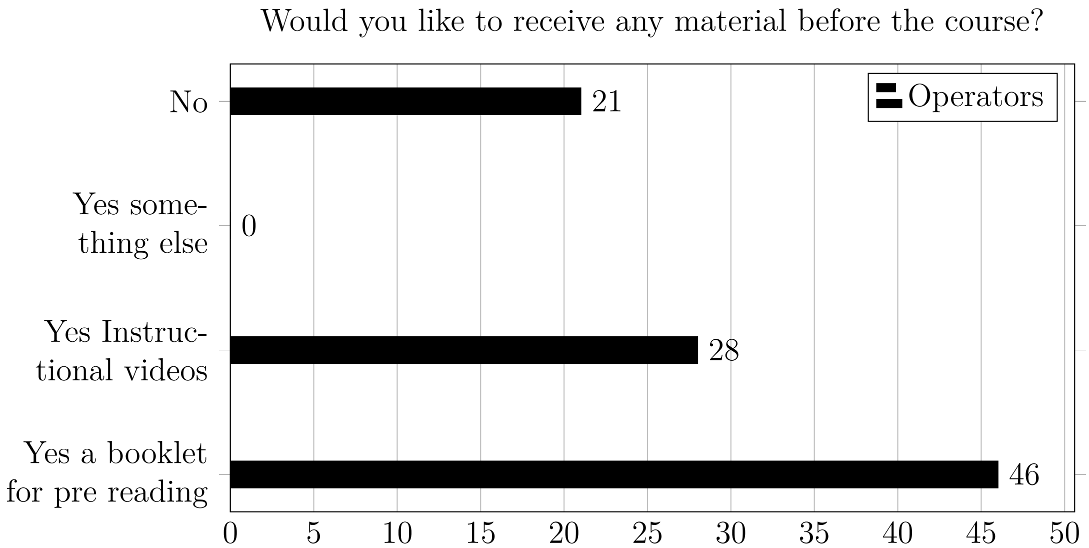


Figure 4.22: Bar chart of operators preferences about material before the course

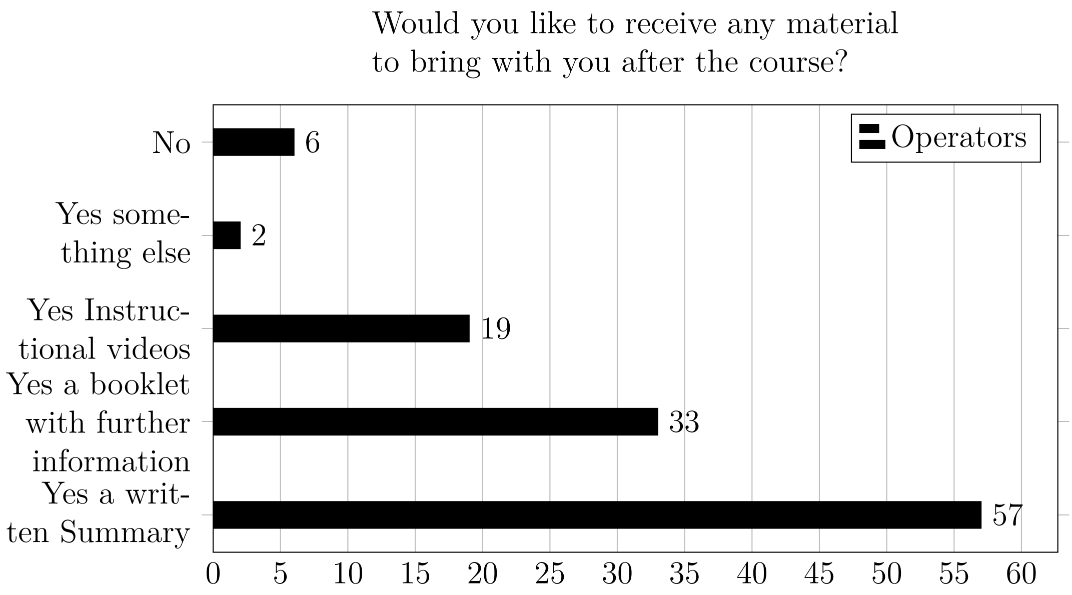


Figure 4.23: Bar chart of operators preferences about material after the course

The box "*other*" was checked by two operators. The first operator wrote "*Slitz*" and the second operator wrote "*Manuals prg*".

Figure 4.19 and Figure 4.20 show that operators slightly prefer practical education over theoretical and that the course should focus on the understanding of practical use rather than on logical thinking. Figure 4.21 shows that the majority of the operators prefer to combine individual education and group education. Figure 4.22 and Figure 4.23 shows that more than two thirds of the operators would like to receive some material before the course and almost everyone would like to get some material after the course. The majority prefer to have written material, rather than instructional videos. These results affected the learning activities.

4.4.3 Learning Methods According to Technicians

This subsection contains results from the questionnaires concerning the technicians own preferences about learning.

Is understanding of the logical thinking or the practical use most important in a robotics course?

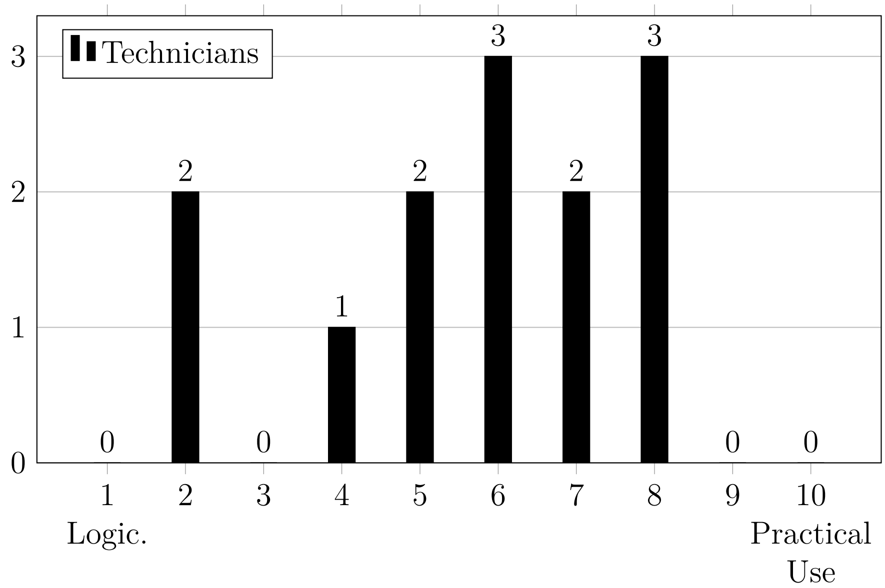
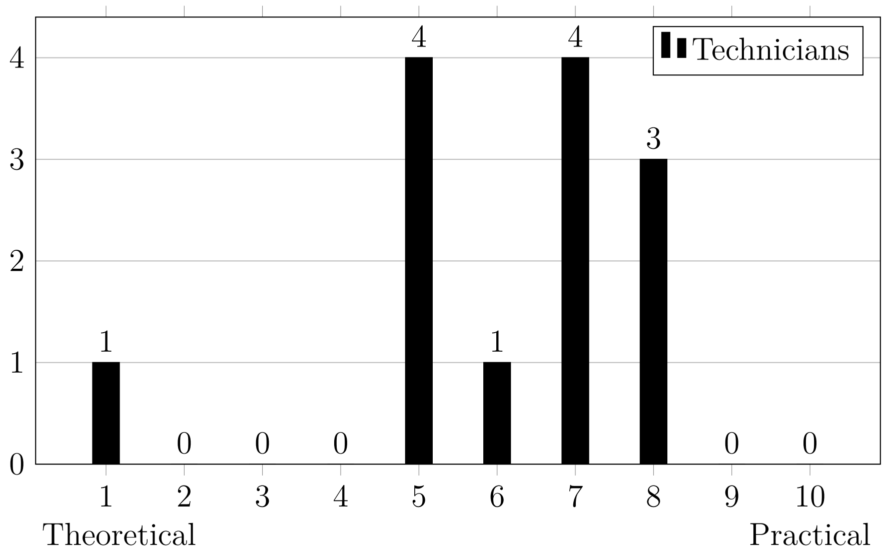


Figure 4.24: Bar chart of technicians view on understanding

What type of education would you prefer in a robotics course?



1=Theoretical only, 5= Half theoretical and half practical, 10=Practical only

Figure 4.25: Bar chart of technicians view on education

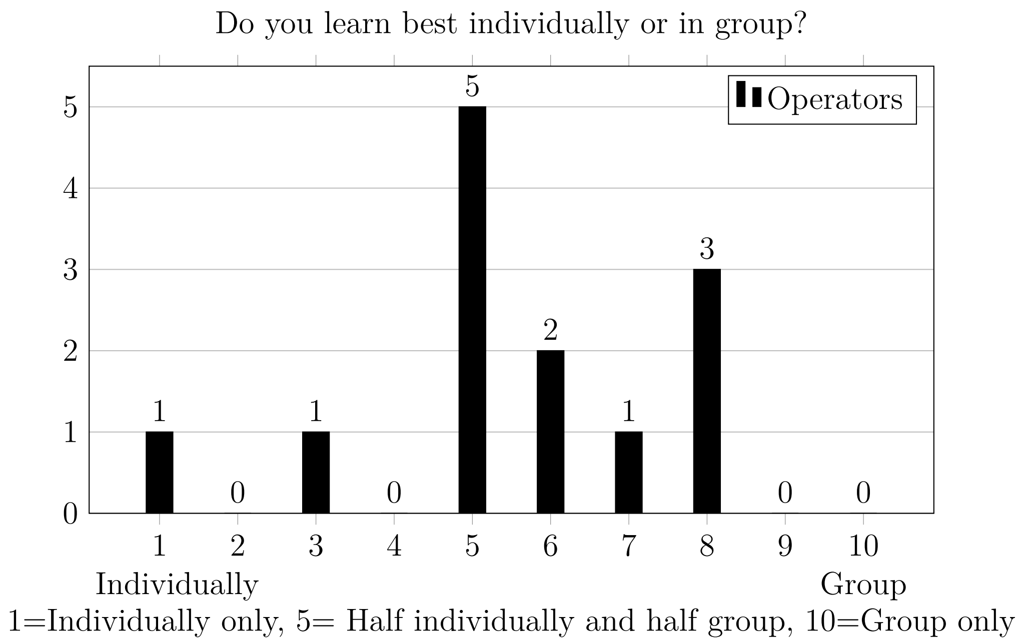


Figure 4.26: Bar chart of technicians view on individual versus group education

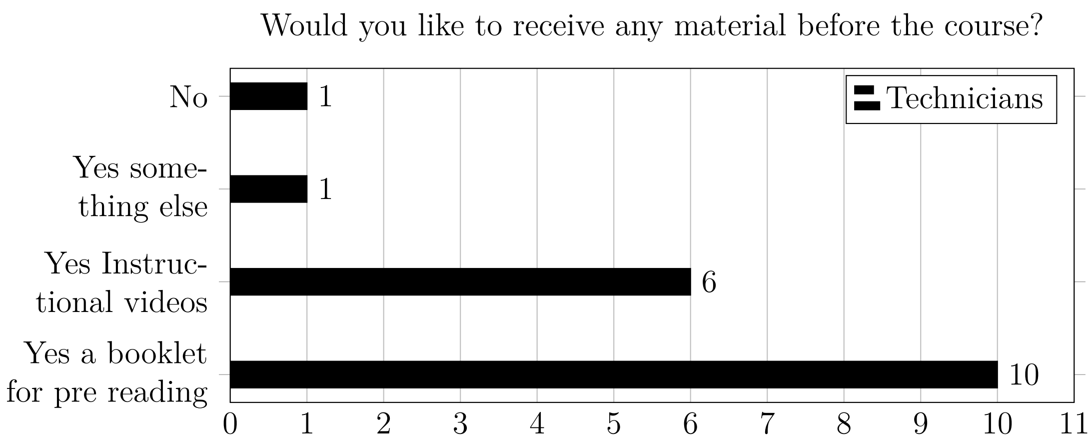


Figure 4.27: Bar chart of technicians preferences about material before the course

The technician who checked the box "*Yes something else*" wrote: "*For example a short summary of the course content to be mentally prepared*".

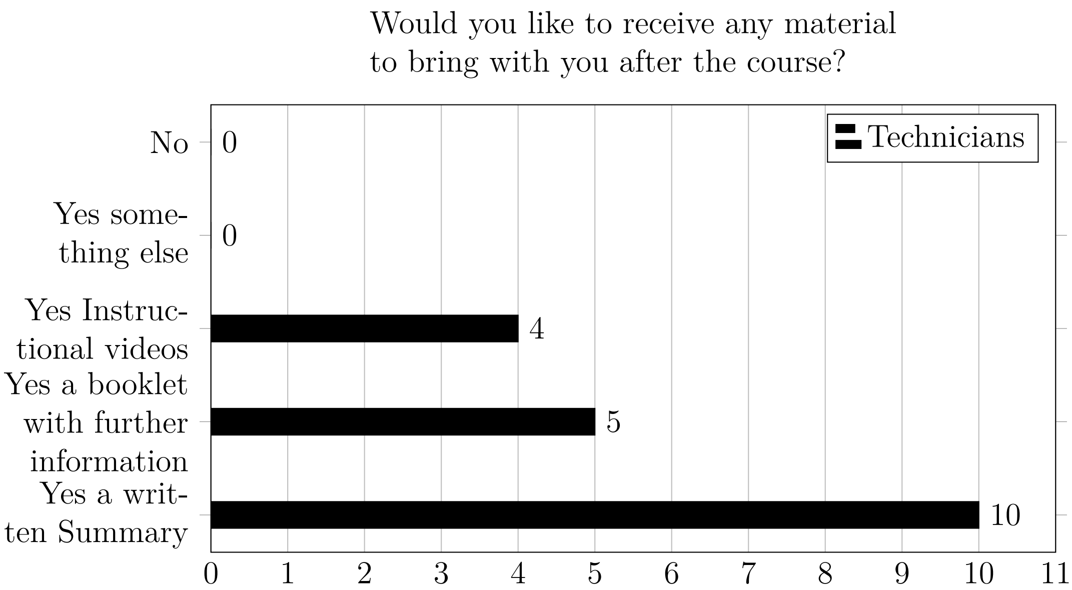


Figure 4.28: Bar chart of technicians preferences about material after the course

The technicians agreed with the operators on all questions. As shown in Figure 4.24, the focus should be slightly more on the understanding of practical use than on logical thinking. As shown in 4.25, the education should be a little more practical than theoretical and according to Figure 4.26 the technicians want to combine individual and group learning. Figure 4.27 and Figure 4.28 show that the technicians, similar to the operators, would prefer written material both before and after the course. These results affected the learning activities.

4.5 Assessment

This section contains results from the questionnaires and interviews concerning assessment. The results from the interviews are followed by the results from the questionnaires.

4.5.1 Assessment According to Interviews

This subsection contains results from the interviews concerning preferences regarding assessment.

The responses to the question "*Do you want the course participants to take a test as evidence of increased competence?*" were clustered together in seven pattern codes. These pattern codes are presented in Figure 4.29 and are either positive arguments or concerns regarding assessment.

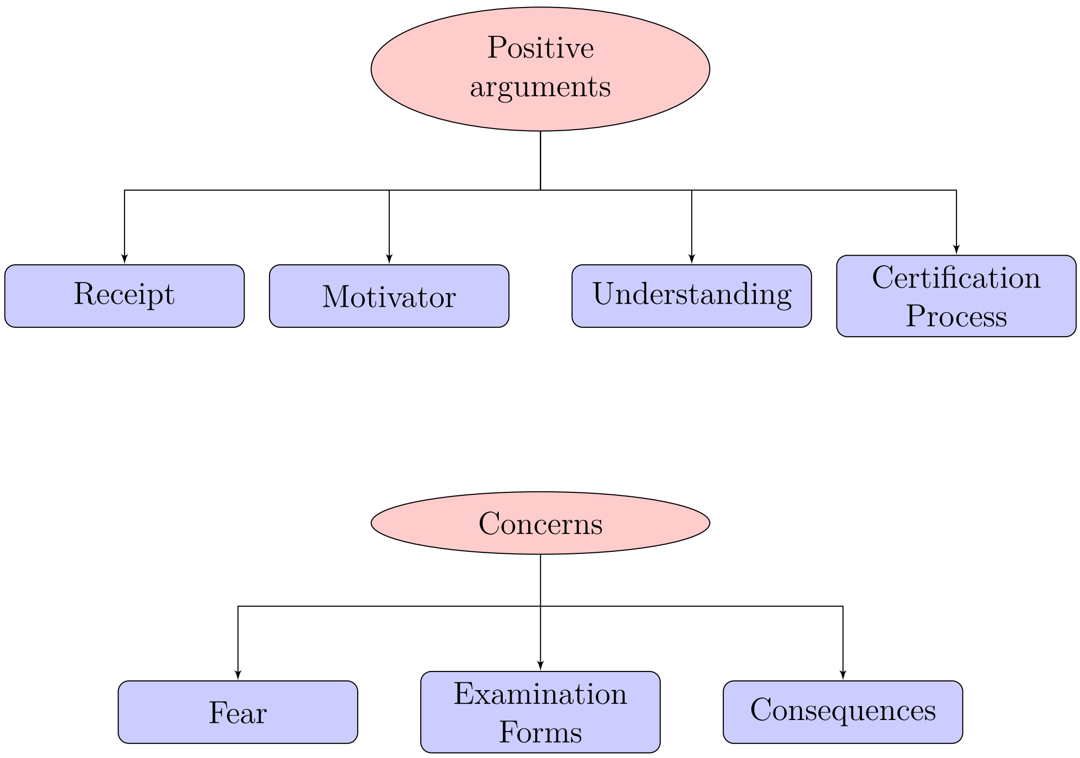


Figure 4.29: Flow chart of the pattern codes for assessment

I2, I3, I4 and I5 were clearly positive towards a test. I1 said that he wants something to sharpen up the participants. I6 was more hesitant towards a test and said: "*It is probably not necessary since it is a bunch of guys and girls who want to learn, and then it is not a problem*". I6 was uncertain at first, but eventually said:

> "*I hesitated a little bit. Then I came to the conclusion that either you can have a test or an assignment to solve in the end. So that. so that you know that you have it in front of you, then you might be more active during the course*" (I6).

The interviewees in favor of a test see it as a receipt and a motivator. "*I think it is important, it is a receipt showing that you have understood what has been communicated during the course*" (I4). "*The receipt, it is the only way to quantify if you have really learned anything*" (I1). The interviewees see the receipt as important for the participants, the participants managers and the teacher. According to I2 having a test is a way to ensure that your employees have the expertise needed for the assignments.

> "*As a manager, you often get the question: How do you ensure that your staff has the competence for what you order them to do? Then a course certificate describing the course content is sort of. That is the receipt for me as a manager, both for the safety, but also for competence*" (I2).

I1, I3, I4, I6 and I7 all mentioned that a test can work as a motivator. A test sharpens up the course and makes it more difficult to be inactive.

Some of the interviewees also mentioned that a test could increase the learning and understanding about what you have learned for the participants. I3 said: "*You should learn from the test as well*". I6 said that a test can make you feel that you have received knowledge. I2 said that it is a receipt on what you have understood, which makes you aware of what you have understood.

The most common reason for not having a test among the interviewees was that participants could be afraid of a test. I7 mentioned a former course participant who disappeared during an examination as an example. I6 also brought up the fear and that he proposes alternative examination forms.

> "*But I have been through this a few times, when the participants starts to ask what the test is about and how big it is, already on the first day. It results in wrong focus on the actual course. They often work in production or somewhere else. A student who is studying is used to be assessed. They become anxious, what if I get incorrectly rated, will it be passed on to my boss? Will it affect my salary, my employment?*" (I7).

Another problem with tests in a robotics course is that the examination form is not always obvious and that tests are hard to create. Both I5 and I7 talked about this problem.

> "*It is difficult to make a test that is good, I think. It is easy to make a test that asks for facts but is that really what is important?*" (I7).

> "*You make a theory test, I believe that it also makes demands on those who are running the course. That you reflect on how to create a good test that is difficult in itself. I can get some kind of anxious feeling, okay then we might set demands on having a test and then it is very difficult to obtain a good test. And then it will be waste*" (I5).

> "*It is not supposed to break somebody or bust somebody*" (I7).

A practical test was proposed as an alternative examination form by I6 and I7. I6 said: "*If people are afraid of a test, maybe it is better to have a project to do instead*". I6 also said that if a project form is used, it is important that the participants show that they are independent. I7 normally uses written exams when the education consists of lectures, but not in robotics courses. "*When it comes to adults there has not really been an examination form. But they get exercises, they get less and less. You continuously ask what happens, seeing that they are still following*" (I7). For high school students, I7 has used theoretical examination.

The participants have the possibility to succeed on a test, but they can also fail it. Failing a test needs to have some kind of consequence. "*Then, the next question when we are talking exams and grades is: What happens if an individual fails the test? And then you have to participate the course again or learn more until you pass the test. But it feels good to have some kind of reference*" (I5).

If the course leads to a certification, some kind of assessment is necessary. The certification process was mentioned by I2, I5 and I7. I2 described how the managers would benefit from a certification. I5 talked about how SKF as a company talks about certification and the importance of finding a balance. I5 presented two extreme examples. One example was a certification so difficult that almost no one made it. The other example was a certification made too easy. The operator just had to watch a colleague do something once to get the certification. I5 wants something in between these two examples.

> "*How do you find good balance in the certification process? So that you can raise it up a level. The question exists with us. There are people at HR working on it, specifically for the new channel, where there actually is a stated objective that there should be a certified process for skill development*" (I5).

I7 talked about different kinds of certifications and validations.

> "*I run it in some courses, mostly when it is about regulations on electricity and stuff. Then, it is often competence education with requirements, and then you want to see*" (I7).

> "*We have talked about some kind of robot driving licence. It is nothing wrong with that*" (I7).

The results show that the majority of the interviewees prefer some kind of assessment. The arguments for this is that a test is a receipt on gained knowledge, a motivator for the course participants, a method for learning and it facilitates a certification process. The biggest concern is that the course participants might fear the test and lose focus on learning.

4.5.2 Assessment Specifically for Operators

This subsection contains results from the questionnaires concerning what preferences the Operations Managers have regarding assessment.

Do you want the course participants to carry out a test as a certificate for increased knowledge?

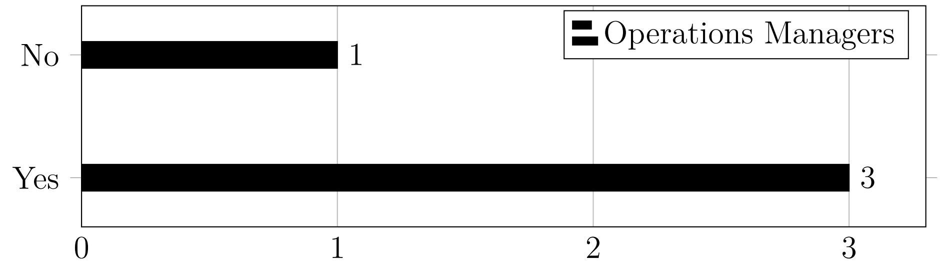


Figure 4.30: Bar chart of Operations Managers preferences regarding assessment for operators

The question "*Why do you consider it important/unimportant?*" was asked to the Operations Managers.

They answered:

- "*To ensure the competence is always important*".
- "*N/A*".
- "*So you know that they understand what has been taught*".
- "*It is good to get confirmation that the participant have understood*".

The majority of the Operations Managers want to have a test (Figure 4.30). They want to have it since it is important to ensure the competence and that the participants have understood what have been taught.

4.5.3 Assessment Specifically for Technicians

This subsection contains results from the questionnaires concerning what preferences the Manager Industrial Engineering has regarding assessment.

Do you want the course participants to carry out a test as a certificate for increased knowledge?

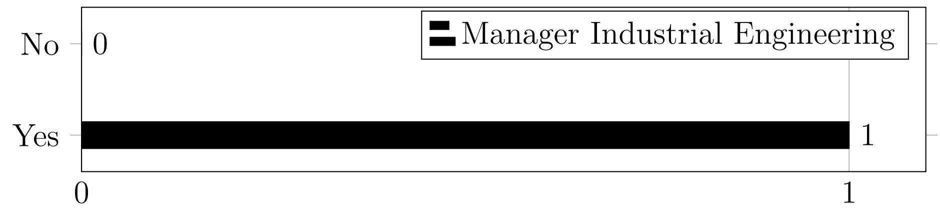


Figure 4.31: Bar chart of Managers Industrial Engineering preferences regarding assessment for technicians

The question "*Why do you consider it important/unimportant?*" was asked to the Managers Industrial Engineering.

The manager answered: "*Test on how well the education has been received*".

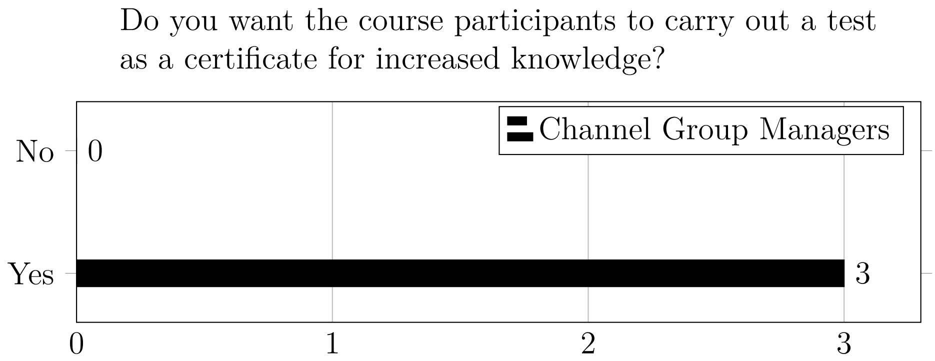


Figure 4.32: Bar chart of Channel Group Managers preferences regarding assessment for technicians

The question "*Why do you consider it important/unimportant?*" was asked to the Channel Group Managers.

They answered:
- "*To ensure that the participants have understood what you try to teach and to ensure that the education material is good and easy to take in!*"
- "*To ensure that you have learned during the course and that you can carry out necessary operations*".
- "*To ensure that the education has been received the way we want*".

The Channel Group Managers, the Manager Industrial Engineering, the Operation Managers and the interviewees all agree that a test is important. Figure 4.31 and Figure 4.32 show their unanimity and the reasons for having a test is similar according to all of the respondents and interviewees.

4.6 Learning Objectives

This section contains results from the brainstorming after the affinity diagramming and the evaluation of the groups were conducted. The brainstorming did not only focus on which areas the operators lack competence in but also overall what came up in the questionnaires and during the interviews. The ideas were divided in fifteen groups and prioritized through discussion during the affinity diagramming.

The following areas came up:

1. The cell
   What is a cell?
   What is the purpose of the cell?
   Process understanding.
   Different parts, for example the conveyor
   Communication between the interfaces of the HMI, PLC, Robot and IT.
2. Troubleshooting
   Troubleshoot to know who to ask.
   Troubleshooting the system. The cell, PLC, Robot, IT and sensors.
   Resetting.
   Examples on what can go wrong.
   Troubleshooting tools.
3. Robot
   Start/Stop a cycle.
   Jog back from difficult positions.
   Troubleshoot.
   Operate and find your way in the menus of the pendant.
   Read and understand code
4. PLC
   What is a PLC?
   How does a PLC work?
   How does a PLC communicate?
   Control the Robot with a PLC.
   Control other components with the PLC.
   Read and interpret code.
   Code to understand code.
   No configuration.
5. Safety
   Show what is dangerous.
   Importance of safe changes and the change process.
6. The assignment for an operator
   Expert on your process, self esteem.
   Know more than what is necessary.
   Dare, but know when you should pass it on.
   Feel comfortable and safe.
7. Permissions
   What am I allowed to do?

Pyramid of knowledge, who should know what? Who should I ask?

8. Sensors
   How they affect.
   Some types of sensors, for example vision.
9. HMI
   What can you do?
   What possibilities do you have?
   How does the HMI communicate with the PLC and Robot?
10. Different systems
   What differs the old versus the new?
   KUKA versus ABB.
   Siemens versus ABB.
   Recognize yourself when you come back to the factory.
11. IT
   Article number.
   Why does everything have to happen in a certain order? (the map becomes the reality)
   What is IT good for?
   How does the IT, which is used today, work?
12. NC
   Programming.
   Troubleshooting.
   Understanding.
   Should this be in a robotics course?
13. Methods and Tools
   Developing process.
   Life cycle cost.
14. Drawings
15. Maintenance of the equipment

After the brainstorming and the affinity diagramming all groups were evaluated and discussed based on what the interviewees and the respondents to the questionnaires wanted to include in a course. Some groups were removed and some groups were merged.

The first group is the cell/understanding the automated process. This group combines the cell with HMI, sensors and the IT that affects the process. The groups safety and permissions were also merged into one group.

NC, drawings, maintenance, the rest of IT, methods and tools were removed. They did not fit into an automation course according to the interviews and the brainstorming. The purpose of the course was based on the areas in the group ”the assignment for an operator”.

The evaluation and discussion resulted in purpose and learning objectives for Automation course level 2. The purpose and the learning objectives were then evaluated through a discussion with the future teacher.

4.6.1 Purpose of the Course

The course participant shall after completed course, with self confidence, be able to perform the tasks in their existing work environment. The course shall also lead to development of the processes in the company and more satisfying work for the company's production workers.

The course participant shall after completed course
- have a deeper understanding of the automated process
- handle their assignments with self confidence
- feel comfortable and secure in their work inside and around the automation cell.

For the company, the course shall also lead to
- optimization of the process
- distribution of knowledge in the company
- development of the robotics systems that exist today
- inspiring work assignment for the production workers
- gained competence for the production workers.

4.6.2 Learning Objectives of Automation Course Level 2

The course participant shall after completed course have worked with the different systems and functions around the automation and production process used at SKF. Depending on the importance and complexity of the system or process in the overall production process the course participant shall either have seen, know about or be able to handle them.

Automation cell/Understanding the process

The course participant shall after completed course have an understanding about what the cell includes, how the cell works and how the interaction between various components and systems, inside and outside of the cell, works.

The course participant shall
- know what is included in an automation cell
- know how the process works and how it is affected by IT
- know what controls the automation cell
- know what an HMI is and how it is used
- know how the communication between the different components works
- be able to start and stop a cycle
- be able to reset the automation cell.

Robot

The course participant shall after completed course be able to handle the robot and have an understanding about the robot programs and commands.

The course participant shall
- be able to jog the robot back from any position in a safe way
- be able to handle the pendant and use its menus
- be able to read and understand programs which includes the most common commands used in the factory today
- be able to program the robot with the most common commands used in the factory today.

PLC

The course participant shall after completed course know what a PLC is, what its function is in the process and be able to program a PLC enough to understand code.

The course participant shall
- know what a PLC is and what its function is in the automation cell
- know how a PLC communicates
- be able to read, interpret and follow PLC programs that are used in the factory today
- know basic PLC programming
- be able to operate the robot and other components with the PLC.

Troubleshoot

The course participant shall after completed course be able to handle troubleshooting and specify what is wrong to simplify the communication with maintenance.

The course participant shall
- to some degree be able to troubleshoot the process and specify what is wrong
- have seen examples of what can go wrong.

Safety

The course participant shall after completed course understand the importance of a safe change process and what permissions he or she has relative to other professions in the company, such as maintenance and construction.

The course participant shall
- have seen examples of what can go wrong and its consequences
- know the importance of a safe change process
- know what permissions he or she has to do changes and repairs, and when the work should be assigned to maintenance or construction
- understand safe stops.

Different systems

The course participant shall, after completed course, be able to apply the obtained knowledge to their own workplace.

The course participant shall

- have seen the differences between the different systems that are used at SKF today
- be able to apply the obtained knowledge to their own working place in the factory.

4.7 Common Problems and Faults

This section contains results from the second round of interviews concerning common problems and faults in the company's automation cells. The result, which leads to the learning objectives, showed that it is important for the operators to be able to troubleshoot when problems or faults occur. A second round of interviews was conducted to get more information about what these problems and faults are.

4.7.1 Common Problems and Faults in Automation Cells

The responses to the question "*What problems and faults are common in the company's automation cells?*" were clustered together in five pattern codes. These pattern codes are presented in Figure 4.33 and are either problem caused by an operator, technical problems or the importance of process understanding.

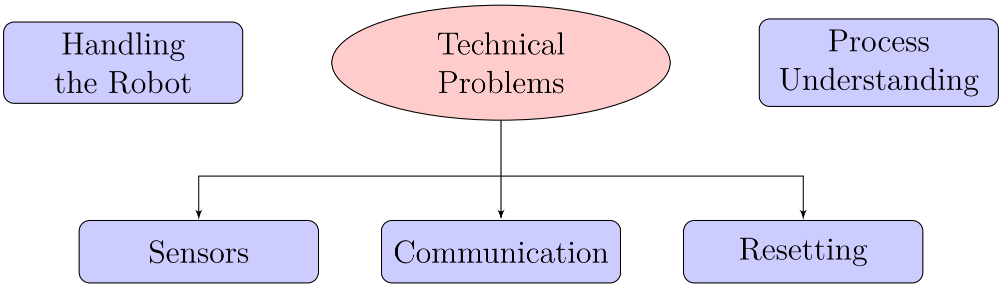


Figure 4.33: Flow chart of the pattern codes for common problems and faults

Handling the components of the automation cell was the focus area when it came to the common problems and faults. Both I3 and I9 described problems with operators handling the machines.

> "*They go in and restart a machine, turning it off and back on again. They go in and remove a ring or something. They come up with something to fix the problem, it can be many strange things*" (I3).

> "*They might have done the wrong settings to the machine when changing type. Let us say that you make the wrong settings to the machine and then the robot does not load right. Then they think that it is a problem with the robot, for example. Then it is the handling, that they did not really know what they did when they did the settings to the machine*" (I9).

Both I8 and I9 described that it is rarely the robot's fault if a problem or a fault occur in the automation cell. It is often the handling of the automation process in the cell. I8 said that the reason for a fault could be that you stop the process at the wrong time by for example walking into the automation cell. I9 gave an example of how the handling of the robot can be a problem even if there is not a problem with the robot itself.

> ”*Let us say that the robot hits something. Then they run ”go to home position”, and a robot always goes the shortest way to it is home position, even if it is inside a machine. It always asks ”Is it free to move here?”, then you press ”yes”, and the robot hits a part of a machine. So it is often the handling that is the problem in the automation cells*” (I9).

I3 and I9 said that the communication between the different components in the automation cell is something that causes problems and faults. I9 mentioned the communication between the camera looking at the rings, telling us about their position, and the computer controlling the cell itself. I3 said: ”*Something that normally occurs is that the robot does not get an assignment. It stands still, nothing happens. And it depends on logical terms, that they are not fulfilled*”.

Another thing mentioned by I8 is that problems can occur with sensors and other parts of the robot tools. I3 said that there can be problems with resetting for example the security. I9 said that a problem could be that there is a stop which is not planned for. I9 talked about the process understanding in a new part of the factory and said: ”*We do not have a real stability in the handling for us to work there*”.

The common problems and faults were clustered together into the three groups shown in Figure 4.33. The first group is about the operators' ability to handle the robot in the right way. The second group is about technical problems such as broken equipment in the automation cell, for example a sensor. The third group is about problems that will occur because the operator does not understand the process. These results were used in learning activities regarding troubleshooting.

4.7.2 Who Should Handle the Problems and Faults?

The responses to the question ”*Which of these problems and faults should the operator handle themselves and when should it be assigned to the maintenance department?*” were clustered together in seven pattern codes. The pattern codes are presented in Figure 4.34 and are divided in two areas depending on if the operators or the maintenance department should handle the fault.

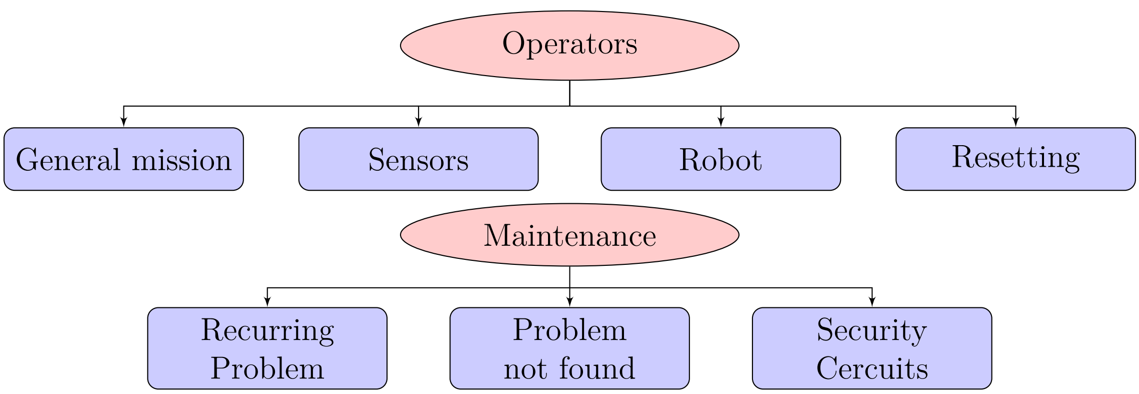


Figure 4.34: Flow chart of the pattern codes regarding responsibilities

The general thing that the operators should know is how their cell works accordin to I8 and I9. "*Yes, especially this by knowing how the cell works*" (I8). "*All operators should be able to operate a robot and know how the cell works*" (I9).

When it comes to resetting the cell, the most important thing to know is how to jog the robot to a basic position according to I8 and I9. I8 said: "*Be able to jog it to a basic position, or start over*". I8 also said that the operators needs to know how their cell works. "*Know how all security gates and similar should be. In what position they should be in. It is often that too. You have walked through a gate without resetting it*" (I8).

The operators need to be able to handle the robot to reset the cell. "*All operators should be able to jog home, know how they get a robot to its home position*" (I9). I9 also said "*just to be able to handle it is very important*" and "*If you can jog it out here, you can jog it in there as well*". about the robot.

I9 said that an operator should be able to replace a broken sensor: "*lets say that we have a broken sensor. Of course, they can replace the sensor, in my opinion*" (I9). However, I9 also said that it is not always easy to replace a sensor. I9 said: "*Many people think that sensor replacement is very easy, it is just screwing. But it is not always like that, it is hard to say that all operators should be able to replace a sensor*".

Three situations when an operator should call for maintenance are presented in Figure 4.34. These situations are when the problem can not be found, when the problem is recurring and when security circuits are involved.

> "*When they do not find the problem or do not understand what it is. Or if it is a recurring error. They know that they can solve it but it will come back, several times, so we can get a system for that. Safety circuits and stuff, then you should usually call maintenance immediately, if it can not be reset. Because it should be able to be reset*".

The operators should be able to handle the robot and jog it to home position for resetting and they should be able to replace most of the sensors. In other situations, the operator should leave it to the maintenance department. These results were used in learning activities regarding troubleshooting.

4.7.3 Troubleshooting Process

Interviewees I8 and I9 were asked the question: "*Do you have a process that you follow when a fault or a problem has occurred? What do you check first and what do you check second?*" The responses were clustered together in two pattern codes, troubleshooting process and handling.

According to I8 and I9, no process is used by maintenance when a problem occurs. However, they saw the benefits of a troubleshooting process for the operators.

> "*It is very different how it behaves. What kind of alarm it. It might not be an alarm at all, it might just be so that it does not do anything. And then you have to figure out what it is waiting for. You might have to connect to the PLC to see what it should do. Then maybe it was an alarm*" (I9).

> "*It is very much dependent on how it behaves. But we do not have a fixed process*" (I9).

> "*If you have a process, it is easier to know what operators should be able to do as well. Can you jog it to the home position, for example?*" (I9).

When it comes to handling, I8 also mentioned one common problem that maintenance gets called out for, which is easy for the operators to check themselves. This common problem is that the machine is not in automatic mode.

5

Designing the Course

This chapter describes how the results were used in designing the course. The flow chart in Figure 5.1 shows the results which led to the design of the course. The chapter is divided into three sections; Learning theories and methods, questionnaires and interviews and learning objectives. The course is found in Swedish in Appendix C.

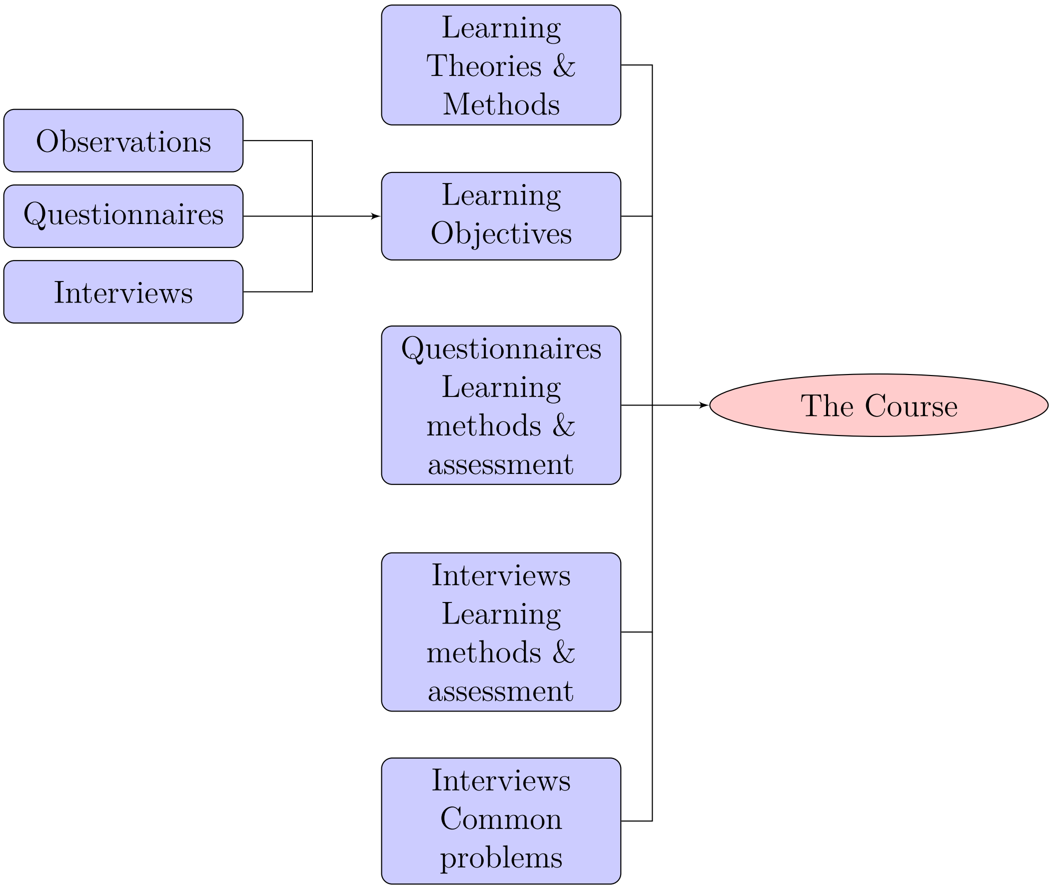


Figure 5.1: Flow chart of which results led to the course

5.1 Learning Theories and Methods

This section describes how learning theories and methods have been used in designing the course in this thesis. The learning theories and methods are described in section 2.2 and section 2.3.

5.1.1 Essentials of learning

John Locke's idea that our experience is the base of all our knowledge and that simple ideas can be added to already existing ideas is used throughout the course. The course starts by dealing with the basic functions of the robot, PLC, automation cell, basic logic and other functions to eventually add all the pieces together in a program operating the automation cell. The participants will also have the possibility to share their experiences and interests so that the teacher will be able to adapt the course accordingly. This also follows John Dewey's theory, saying that someone who is more interested in learning something will more likely do so and that problems need to be brought from situations that lie within the student's area of interest and experience. The questions in the questionnaires regarding wanted knowledge is also a way to find out what the operators and technicians are interested in. Mezirow also emphasizes the importance of the social context.

5.1.2 Learning by Doing and by Viewing

The results from the questionnaires showed that both technicians and operators prefer practical education in a robotics course. Research has confirmed that there is a relationship between active learning and successful knowledge transmission and according to John Dewey, just explaining an idea is not enough for a student to understand it or to realize its relevance and relations with other ideas. The course will therefore involve a lot of practical education where the participants will operate the robot, create programs for both the robot and the PLC and solve problems practically in the automation cell in different cases involving different components.

Besides using active learning methods imitation will be used in accordance with Lev Vygotsky and Albert Bandura. The participants will see videos of accidents that won't be able to be tested practically. The participants will also see pictures and animations showing how the automation cell is structured, how an HMI works and what a more advanced PLC and robot code looks like. The participants will also be able to observe and imitate each other as they progress.

5.1.3 Learning by Disequilibrium

One of the differences between teaching children and teaching adults is that adults have more experience. Not only from technology but from learning overall. Therefore the teacher will start with easier assignments to create a positive learning spiral and break eventual negative perceptions of the participant's ability to learn. The first day, the participants will get to complete a small test already during the first day to show themselves that they have learned. To create deep learning the assignment won't just be to reproduce what they have done during the day, but to use their knowledge to solve a new problem. The teacher will bring up the purpose and goal for the day so that the participants understand what they should learn and so that they can feel that they have accomplished those goals at the end of the day.

A goal throughout the course is to help the participants to develop a more critical and reflective stance. Transformative learning is to be achieved by using ill-structured problems from reality. According to Mezirow's transformation theory a central part of transformative learning is problem solving and reflection on assumptions which are taken for granted. All the components used in this course are used in the factories at SKF and the participants are familiar with them. Ill-structured problems are created by creating problems around these components in different cases similar to the reality. Using these ill-structured problems will create opportunities for critical reflection and cause disequilibrium. Disequilibrium is a creative chaos which can be frightening and create feelings of discomfort, but it creates conditions for accessing what was earlier taken for granted.

5.1.4 Learning by Reflecting and Communicating

What is wanted from the participants is to get deep learning and new knowledge. By looking at Kolb's or Jarvis' model a picture of how the participants learn can be painted. Kolb's cyclic process of learning is implemented in the course where the adult learner has experience, then reflects, then formulates generalizations to eventually test these generalizations. This is used throughout the course and an example would be when the participant enters with some knowledge from the first course, reflects on a new problem and formulates a generalization and understanding to implement it. The participant will learn and then a new problem comes up making the fourth step the first step.

Peter Alheit describes how adult learning and life construction and reconstruction are bound to our biographies. Our biographies, with new meaning in life, are created from reflection, experiences, knowledge and lessons in our life stories. It is when we adapt the knowledge to ourselves that learning takes place. Since the course participants all have a lot of different experiences from life, it is crucial to consider that they all have different ways to learn.

Adults have an important role in the learning process and it is important to take advantage of the adults' experience of learning. It is important to interact with each other in the group and for the teacher to listen to what experiences the participants have had in life. This is also a reason for why the participants will be given the possibility to tell about their own experiences and to discuss problems with each other. This is also a reason for the teacher to be responsive and listen to the participants throughout the course.

It is important to let the participants take their own responsibility gradually from the first assignment where the purpose is to create a positive learning spiral. They need to feel secure and have support. It is also important for the teacher to build a relation with the participants and to work in group. Therefore it will be a small group and everybody will have a chance to tell about their experience. It is important to let every participant take up space.

5.1.5 Motivation

By using the strategy to first give the participants easier assignments and build up their knowledge they will experience positive emotions and feel competent about what they are doing. By giving feedback on the assignments and tests the participants will also feel that their actions lead to achievement. Since the participants will be able to share their experience and since the course is designed from interviews and questionnaires from employees at SKF the subject should be valued and the participants should be able to see the relevance. The course has clear learning objectives for the whole course, for each day and for each activity. The environment where the course is held is created in a way to inspire the participants. The equipment is similar to what they use in their own work and by simulating reality the environment should enhance learning.

5.1.6 Cognitive Perspective on Learning

By letting the participants build up their knowledge from less complicated assignments with less components to more complicated assignments with more components the learning is organized in a hierarchical way. The teacher will also listen to the participants' interests and goals and take prior knowledge into account. Taking the cognitive perspective into account together with motivation and listening should inhance learning.

5.1.7 Spaced Learning

Spaced learning will be used prior to massing by alternating between different subjects during the course. The same subjects are brought up several times individually but there is always a space in between the occasions. The subjects are combined in some exercises and in this case the participants will alternate between for example working with the PLC and working with the robot. To create a more dynamic environment the methods for teaching will alternate between for example practical and theoretical education, working in groups and individual work.

5.1.8 Formative Assessment

The course will not result in a grade for the participants. They either pass or fail. Formative assessment will be used during the learning process, not only at the end of the course. The reason for this is to make the participants used to assessment and to provide as much feedback as possible during the course to move the participants forward. By answering the three questions "Where am I going?" "How am I going?" and "Where to next?", the feedback will help the participants reflect on their work and help them improve. Depending on the type of assignment the teacher will focus on either feedback about the task, feedback about the process or feedback about self regulation. The teacher will focus on more immediate feedback about the task and process in the beginning and more delayed feedback, which makes the participants reflect more, later on in the course. As the participants become more independent and develop their reflective way of thinking they will also be able to handle a different type of feedback. Formative assessment will be used both in group and individually throughout the course.

Direct feedback on task performance will also be given to the participants from the PLC and the robot.

5.1.9 Cooperative Learning

There will be both individual and cooperative learning during the course. Many of the exercises will be completed in groups. The participants will work both in pairs and together in a group of four to create, read and troubleshoot programs. Student Team Learning will be used in the course. The focus will be on learning rather than doing and on team reward rather than individual reward. It is important that the participants help each other to learn. Each member will be given equal opportunities and individual accountability by doing different work with responsibility for learning and help the team. The participants will only be compared with themselves and not with the other participants. Some of the assignments will be individual but the assignments performed in a team won't be finished until the team has finished and questions regarding work done in a team can be directed to any of the group members. Therefore the participants won't benefit from learning by themselves rather than helping the group members.

5.1.10 The 5E Model

The 5E model was used when designing the course content and the activities. The teacher engages the participants by showing pictures, programs and the robot in action. The participants will have a great chance to explore throughout the course in assignments where they will experiment with the equipment in different exercises and practice troubleshooting. There can be different approaches for the same assignment and some of them does not have only one correct answer. There will always be a chance to discuss the result, ask questions and let the teacher explain when they have explored something new. Since the course is held in a small group the participants can have a great part of the explanation phase. The participants will have a good chance to elaborate since the same subjects reoccur during the course. PLC, robot and logic are examples of subjects which the participants will be able to work with several times during the course. The participants will be able to evaluate their knowledge through several assignments and tests. The evaluation phase will give each course participant the opportunity to demonstrate their knowledge for both their teacher and themselves.

5.2 Questionnaires and Interviews

This section describes how the results from the interviews and questionnaires regarding learning methods, assessment and common problems have affected the design.

5.2.1 Questionnaires - Learning Methods and Assessment

The answers from the operators and the technicians regarding learning methods and assessment showed for example if they prefer theoretical or practical education and if they learn best individually or in group. The questionnaires showed that most of the respondents prefer practical education while approximately half of the respondents learn best individually and half of them in group. Therefore there are more practical exercises than there are theoretical lectures and the exercises are divided so that some of them are individual and some of them are done in group.

5.2.2 Interviews - Learning Methods and Assessment

The answers from the interviews with the managers and the teacher gave more specific suggestions. Things brought up were for example that different individuals learn at a different pace, that some individuals are not used to ”being in school” and that it is important to use equipment similar to the equipment used in the factories. The exercises are made to fit different students by adding extra exercises for the participants who are fast and by making the participants more comfortable as students with simpler exercises in the beginning of the course. The equipment used in the course is the same as in many places in the factories. When the same equipment used in the factories is not accessible, such as HMI and sensors, they are replaced with other equipment. The sensors are for example replaced with buttons.

When it comes to assessment, the majority of the interviewees and managers said that it is important to have a test. The reason was both that it can increase the participants' knowledge and to get a receipt on it. The problem with having a test was brought up by the teacher who said that participants could be afraid of a test. There is not only one test in the course but many. The reason for that is to increase the knowledge and get a receipt but also to make the tests less dramatic. The participants will get used to doing tests with formative feedback.

5.2.3 Interviews - Common Problems

The second round of interviews was held with maintenance personnel specifically for the course activities. The interviewees were asked about common faults in the automation cell to get information about what activities to include. They were also asked who should handle the problems and when it comes to what the operators should be able to do, handling the robot, understanding communication between the different components and understanding their own cell were things that came up. Troubleshooting a program, controlling the robot with the PLC and jogging the robot to a safe position in the automation cell are exercises corresponding to these requests. These results made the activities more similar to the reality.

5.3 Learning Objectives

All activities and tests are created to give the course participants opportunity to reach the learning objectives and to show that they have reached them. The tests are created so that each participant has the opportunity to show both themselves and the teacher that they have reached the learning objectives. The test is practical or theoretical depending on what the objective is. The activities are created to support the participants' learning and understanding.

Knowing how the communication between the components work and being able to troubleshoot are two examples of learning objectives. To first create programs in the PLC and the robot and then control the robot with the PLC is an example of an activity that meets the course objective about communication between the components. To troubleshoot a program in different cases is an example of an activity that meets the course objective about being able to troubleshoot.

6
Evaluation

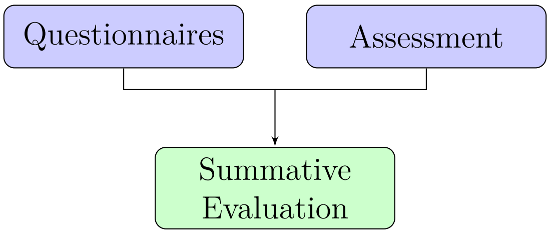


Figure 6.1: Flow chart of the evaluation

This chapter contains the results from the questionnaire filled in by the course participants after Automation course level 2. The questions and the answers to each question from the four participants are presented. The questionnaire is presented in Swedish in Appendix D. This chapter does not include results from the test since the test was not performed in the pilot course. Figure 6.1 shows how the questionnaires and the assessment would have resulted in a summative evaluation.

What do you think about the theory lectures?
- "*Good*".
- "*Good*".
- "*So so, no previous knowledge about PLC programming. Just right. More examples on how you think like a programmer*".
- "*5/10*".

What do you think about the group exercises?
- "*Good*".
- "*Too little time, there must be time for reflection over what you do*".
- "*Pretty hard, easy to jump to conclusions so that you have to go back and fix it later*".
- "*6/10*".

What do you think about the individual assignments/tests?
- "*Good*".
- "*Good*".
- "*OK*".
- "*5/10*".

What do you think about the time division between the different areas in the course?
- "*Good, troubleshooting*".
- "*I wish for more troubleshooting (with more time)*".
- "*OK*".
- "*4/10, More PLC*".

What would you like to change in the course?
- "*Nothing*".
- "*N/A*".
- "*Add one more day and have more examples*".
- "*More exercises*".

What would you absolutely like to keep in the course?
- "*Troubleshooting*".
- "*Everything*".
- "*Everything*".
- "*N/A*".

Do you feel that the course has been rewarding and do you feel that you will be able to use the knowledge you received in your daily work?
- "*Yes*".
- "*Yes*".
- "*Good and interesting*".
- "*3/10*".

Summarizing these answers showed that the course was too short for the content. An additional day with troubleshooting and more exercises would have helped the participants reach the learning objectives. The course participants do not want to remove anything from the course to be able to fit the missing parts in. Therefore more time is the only solution.

The last question was a multiple choice grid question. 20 short yes or no questions which represented the learning objectives were asked. The results are presented in Figure 6.2 and Figure 6.3. The answers showed that the participants felt that they could for example handle the robot, explain what a cell is and how it is controlled by the PLC, give examples on things that may go wrong and when they should contact maintenance. Figure 6.2 and Figure 6.3 show that the participants gained a good overview knowledge, but that IT, PLC and PLC code were difficult areas.

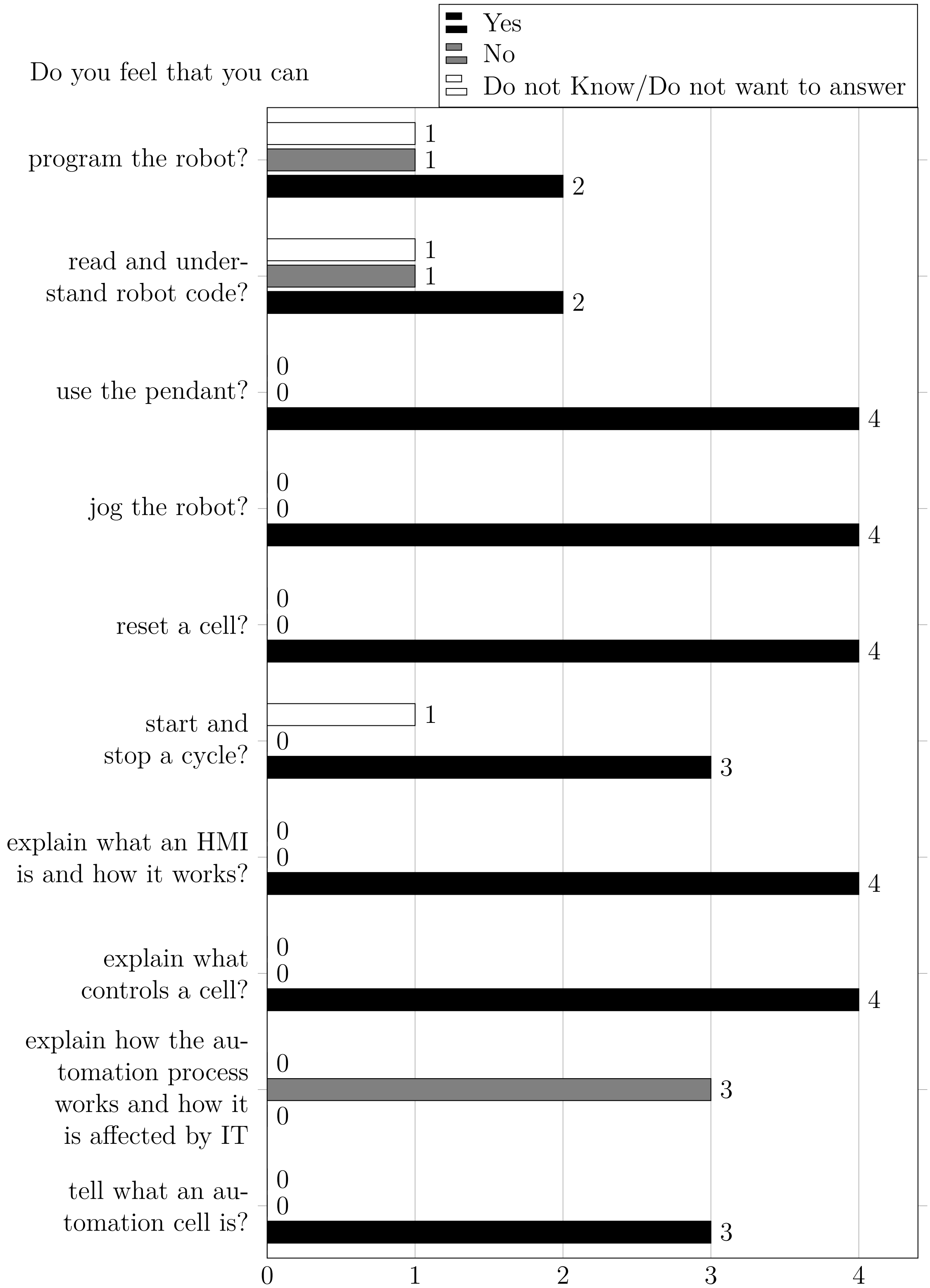


Figure 6.2: Bar chart of what course participants feel that they master after Automation course level 2, part 1

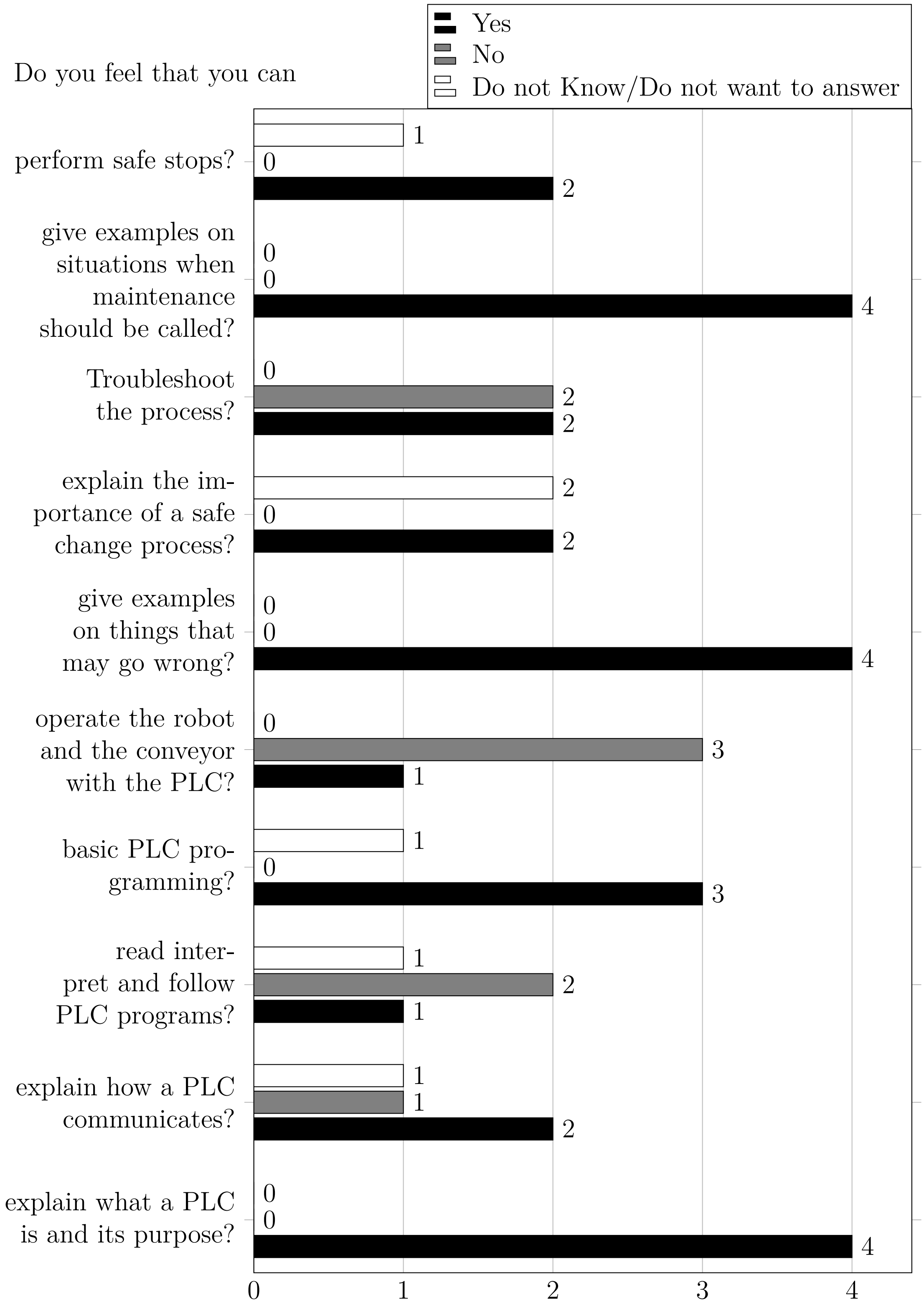


Figure 6.3: Bar chart of what course participants feel that they master after Automation course level 2, part 2.

7

Reflection

This thesis could have been completed using either only empirical or theoretical methods but we have chosen to combine the two. Empirical methods were used to gain information about the products, the development at SKF, wanted knowledge and previous knowledge of the employees. Empirical methods were also used for finding out how industry 4.0 affects the production at SKF. Theoretical methods, such as literature study, could have been used to receive this information but it would have given a more general view and not specifically how it affects SKF, which was interesting in this thesis.

Information about how automation is best taught could also have been collected using empirical methods. Questionnaires and interviews with teachers in the subject could have been arranged to find out how they teach and how they run their courses. However theoretical methods were used to bring in a wider perspective on learning. Various learning theories and learning methods were studied during this thesis.

One difficulty with using both empirical and theoretical methods were to combine them. Brainstorming was first used in this thesis to combine different types of analyzed data into learning objectives and then to create the course. Brainstorming is a creative method that worked very well in this case since all information gathered from empirical and theoretical methods could be used. The brainstorming led to finished products in this project. If the brainstorming had given hints and ideas rather than finished products the brainstorming would have been required to be supplemented with a systematic method.

During the analysis step of this project we had the possibility to participate in Robotics course level 1 and to experiment with the equipment around the automation cell. The same cell was also used in Automation course level 2. This gave us good knowledge about the equipment and made it possible for us to test the exercises that we created. Being familiar with the equipment and its limits might also have affected the creation of the course in a negative way. Having equipment with limitations such as not being top modern nor the most advanced led to limitations in the course. For example, there might be exercises that we did not think of because of these limitations. Another positive thing with learning about the equipment is that we gained some perspective on what it takes to learn, such as how much time it takes and what prior knowledge is needed.

Collecting data together with the data analysis was a time consuming part of this project. A substantial part of the result is gained from interviews and questionnaires. Analyzing qualitative and quantitative data was new for both of us when this project started. A thorough investigation of data analysis methods was performed and the data analysis methods for the qualitative data, where quotes were used in coding to obtain results, ended up being a time consuming but good way to obtain results. We learned how to handle a large amount of qualitative data and to obtain clear results from it.

Eight interviews with nine interviewees were conducted during the data collection phase together with the administration of 95 conducted questionnaires. What we learned from this data collection was how the face to face meetings with the possibility to discuss and ask further questions lead to more detailed answers. We also realized that it was very helpful to face the people that we wanted help from. A face to face meeting where we made people realize the importance of our work benefited the distribution of the questionnaires. Questionnaires which were sent out to people via e-mail and where we had no help with the distribution did not give as many responses.

The evaluations have been crucial for this project. The learning objectives and the course have been evaluated by an expert who is also a teacher in the subject. The teacher's view on the products created in our brainstorming has been the final piece of the puzzle in this project. We have used the teacher's experiences when it comes to the subject but also for difficult situations that might occur. An example is how operators may react to different learning situations.

The pilot course together with the evaluation questionnaire were also very beneficial. We got feedback on our work that would have been hard to get without testing the course in practice. One example of feedback from the course was that the time was not sufficient and that some of the assignments were too difficult.

8 Conclusions

Industry 4.0 is the fourth era of industry. It changes how products are produced which also changes the expectations on the industrial workers. Everything in the production should now be automated and connected via IT. So how does this change the work for the industrial workers? This thesis shows that skill development is getting more and more important. It becomes crucial for all the industrial workers connected to the production to have understanding of the automation cells and their components. This thesis particularly highlights the importance of an operator's understanding of the automation cell and its components. It also shows the importance of an operator's ability to troubleshoot the cell when something goes wrong. This changes with the new era of industry where a fully automated production demands a new level of understanding for new technology. To help the operators develop their skills in these areas it is important that they get training. It is important for them to get practical education with similar equipment as they use in their everyday work and that they get to see many examples of what can go wrong and how to fix it.

Assessment is important in skill development courses for the managers, the teacher and the course participants. Assessment can increase learning, help the teacher to evaluate the course and give managers a receipt on the participants' knowledge.

The evaluation of the pilot test of the Automation course level 2 showed that more time was needed for the course participants to reach all the learning objectives. The current content was appreciated, especially the troubleshooting, and the participants felt that they learned a lot. However more time is needed to give the course participants the possibility to reach all learning objectives and deepen their knowledge further.

There are many different learning methods and theories to take into account when an automation course for operators is created. One important thing is to motivate the course participants and to keep them motivated throughout the course. To do this we have used research about adult learning, cooperative learning, the 5E model and motivation strategies. Practical education, which has support from for example John Dewey and the 5E model, has been a big part of the course. Having practical education was also important for both the industrial workers and their managers.

Bibliography

ABB (2014). Irb 140. https://library.e.abb.com/public/98ba43a906331fec48257c6f00374818/PR10031EN%20R15_En.pdf.

Boekaerts, M. (2010). The crucial role of motivation and emotion in classroom learning. In Dumont, H., Istance, D., and Benavides, F., editors, *The Nature of Learning - Using Research to Inspire Practice*, chapter 4, pages 91–112. OECD Publishing.

Brace, I. (2008). *Questionnaire Design: How to Plan, Structure and Write Survey Material for Effective Market Reasearch*. Kogan Page Limited, second edition.

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer, New York.

Bron, A. (2005). Vuxnas förutsättningar för lärande. Technical report, Myndigheten för skolutveckling, Lärarhögskolan i Stockholm.

Cohen, L., Manion, L., and Morrison, K. (2011). *Research Methods in Education*. Routhledge, Abingdon, Oxon, seventh edition.

Elo, S. and Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62:107–115.

Guide, M. S. (2017). World class manufacturing. http://www.managementstudyguide.com/world-class-manufacturing.htm.

Hattie, J. and Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1):81–112.

Hultén, E.-L. (2013). Trygghet viktigt också för vuxnas lärande. *Pedagogiska Magasinet*.

Israel, M. and Hay, I. (2006). *Research Ethics for Social Scientists*. Sage Publications Ltd, London, Thousand Oaks, New Delhi.

Jackson, S. L. (2014). *Research Methods - A Modular Approach*. Cengage learning, Stamford, CT, third edition.

Johnson, B. and Turner, L. A. (2003). Data collection strategies in mixed methods research. In Tashakkori, A. and Teddlie, C., editors, *Handbook of Mixed Methods* *in Social & Behavioral Research*, chapter 11, pages 297–320. Sage Publications, Inc, Thousand Oaks, London and New Delhi.

Kitchener, K. S. and King, P. M. (1997). The reflective judgement model. In Arnold, K. and King, I. C., editors, *College Student Development and Academic Life - Psychological, Intellectual, Social and Moral Issues*, chapter 2, pages 141–159. Garland Publishing, Inc.

Kitzinger, J. (1995). Qualitative research. introducing focus groups. *BMJ*, 311:299–302.

Kornell, N. and Bjork, R. A. (2008). Learning concepts and categories - is spacing the "enemy of induction"? *Psychological Science*, 19(6):585–592.

Krippendorff, K. (2004). *Content analysis.* Sage Publications Inc, Thousand oaks, California, second edition.

Law, J., editor (2016). *A Dictionary of Business and Management - Brainstorming.* Oxford University Press, sixth edition.

Marr, B. (2016). What everyone must know about industry 4.0. *Forbes.*

Michalski, R. S. (1983). A theory and methodology of inductive learning. *Artificial Intelligence*, 20(2):111–214.

Miles, M. B., Huberman, A. M., and Saldaña, J. (2013). *Qualitative Data Analysis.* Sage Publications Inc, Thousand oaks, California, third edition.

Neuendorf, K. A. (2002). *The Content Analysis Guidebook.* Sage Publications Inc, Thousand oaks, California, second edition.

OECD (2007). *Understanding the Brain: The Birth of a Learning Science.* OECD Publishing.

Peterson, C. (2003). Bringing addie to life: Instructional design at its best. *Journal of Educational Multimedia and Hypermedia*, 12(3):227–241.

Phillips, D. and Soltis, J. F. (2012). *Perspektiv på lärande.* Studentlitteratur AB, Lund.

Porter, N., editor (1913). *Webster's 1913 Dictionary - Design.* C. & G. Merriam Co., Springfield, Mass.

Punch, K. F. and Oancea, A. (2014). *Introduction to Research Methods in Education.* Sage Publications, London, second edition.

RobotWorx. Industrial robot. https://www.robots.com/glossary.

Rothwell, W., Benscoter, B., King, M., and King, S. B. (2016). *Mastering the Instructional Design Process.* John Wiley & Sons, Inc, New Jersey, fifth edition.

Saldaña, J. (2009). *The coding manual for Qualitative Researchers.* SAGE publications Ltd, London.

Schneider, M. and Stern, E. (2010). The cognitive perspective on learning: ten cornerstone findings. In Dumont, H., Istance, D., and Benavides, F., editors, *The Nature of Learning - Using Research to Inspire Practice*, chapter 3, pages 69–90. OECD Publishing.

Shibley, I., Amaral, K. E., Shank, J. D., and Shibley, L. R. (2011). Designing a blended course: Using addie to guide instructional design. *Journal of College Science Teaching*, 40(6):80–85.

Slavin, R. E. (2010). Co-operative learning: what makes group-work work? In Dumont, H., Istance, D., and Benavides, F., editors, *The Nature of Learning - Using Research to Inspire Practice*, chapter 7, pages 161–178. OECD Publishing.

Smolen, P., Zhang, Y., and Byrne, J. H. (2016). The right time to learn: mechanisms and optimization of spaced learning. *Nature Reviews Neuroscience*, 17:77–88.

Stanford-University. Designing courses backwards. https://teachingcommons.stanford.edu/resources/course-preparation-resources/course-design-aids/designing-courses-backwards.

Tanner, K. D. (2010). Order matters: Using the 5e model to align teaching with how people learn. *CBE-Life Sciences Education*, 9:159–164.

Tierney, W. G. and Dilley, P. (2001). Interviewing in education. In Gubrium, J. F. and Holstein, J. A., editors, *Handbook of Interview Research*, chapter 22, pages 453–472. Sage Publications, Inc.

Tuckman, B. W. (1972). *Conducting Educational Research*. Harcourt Brace Jovanovich, San Diego.

Warren, C. A. B. (2001). Qualitative interviewing. In Gubrium, J. F. and Holstein, J. A., editors, *Handbook of Interview Research*, chapter 4, pages 83–102. Sage Publications, Inc.

Wetcher-Hendricks, D. (2011). *Analyzing Quantitative Data - An Introduction for Social Researchers*. John Wiley & sons, Inc, New Jersey.

Wiggins, G. and McTighe, J. (2005). *Understanding by Design - Expanded 2nd Edition*. Association for Supervision and Curriculum Development (ASCD), Alexandria, VA, second edition.

Wilhelmsson, L. (1998). Vuxenpedagogikens uppgift. Technical report, Pedagogiska Institutionen, Stockholms universitet.

Wiliam, D. (2010). The role of formative assessment in effective learning environments. In Dumont, H., Istance, D., and Benavides, F., editors, *The Nature of Learning - Using Research to Inspire Practice*, chapter 6, pages 135–160. OECD Publishing.

Wilson, C. (2013). *Brainstorming and Beyond*. Morgan Kaufmann is an imprint of Elsevier Inc, Oxford.

A

Questionnaires

Enkät för skapandet av Robotkurs steg 2

I dagsläget finns det en Robotkurs steg 1 på SKF kompetenscentrum. Denna enkät är till för att undersöka hur du som anställd på SKF ser på en Robotkurs steg 2. Svaren från enkäten skall ligga som grund för kursmål samt aktiviteter för en sådan kurs.

*Obligatorisk

1. **Vilken befattning har du?** *

   Markera endast en oval.

   - ◯ Operatör *Fortsätt till frågan 2.*
   - ◯ Tekniker *Fortsätt till frågan 14.*
   - ◯ Underhåll *Fortsätt till frågan 26.*
   - ◯ Underhållschef *Fortsätt till frågan 46.*
   - ◯ Driftchef *Fortsätt till frågan 39.*
   - ◯ Produktionschef *Fortsätt till frågan 53.*
   - ◯ Kanalgruppschef *Fortsätt till frågan 60.*

Operatörer

För att kunna skapa en bra kurs är det viktigt att få reda på vad du som operatör vill lära dig, vad du har för tidigare erfarenheter och hur du bäst lär dig.

2. **Vad gör dig motiverad till vidareutbildning?** *

   Markera alla som gäller.

   - ☐ Ökad personlig kompetens
   - ☐ Certifikation
   - ☐ Löneökning
   - ☐ Nyfikenhet
   - ☐ Roligare arbetsuppgifter
   - ☐ Att gynna företaget
   - ☐ Övrigt: ______________________

3. **Vilket/vilka av följande områden anser du är viktigt/viktiga att lära dig mer om?** *

   Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)	◯	◯	◯	◯
PLC-programmering	◯	◯	◯	◯
Robotprogrammering	◯	◯	◯	◯
Kommunikation mellan PLC, robot och transportbana	◯	◯	◯	◯

4. **Hur mycket erfarenhet har du från följande områden?** *
Markera endast en oval per rad.

	Ingen erfarenhet	Lite erfarenhet	God erfarenhet	Mycket god erfarenhet
PLC-konfigurering (hårdvara)	◯	◯	◯	◯
PLC-programmering	◯	◯	◯	◯
Robotprogrammering	◯	◯	◯	◯
Kommunikation mellan PLC, robot och transportbana	◯	◯	◯	◯

5. **Är förståelse kring logiken eller det praktiska användandet det viktigaste att få med sig från en robotkurs?** *
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Förståelse kring logik	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Praktiskt användande

6. **Inom vilka områden har du gått kurser tidigare?** *
Markera alla som gäller.

- [ ] PLC-konfigurering (hårdvara)
- [ ] PLC-programmering
- [ ] Robotprogrammering/Robothantering
- [ ] Robotkurs 1 på SKF kompetenscentrum
- [ ] Inget av de ovan nämnda

7. **Vilket upplägg skulle du föredra för en kurs inom robotteknik?** *
1=enbart teoretiskt, 5=hälften teori och hälften praktik, 10=enbart praktik
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Teoretiskt (Föreläsning, egen läsning, film m.m.)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Praktiskt (Testa och experimentera)

8. **Lär du dig bäst individuellt eller i grupp?** *
1=enbart individuellt, 5=hälften individuellt och hälften i grupp, 10=enbart i grupp
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Individuellt	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Grupp

9. **Kryssa i allt du känner att du behärskar** *
Markera alla som gäller.

- [ ] Joggning av robot
- [ ] moveL, moveJ & moveC
- [ ] Definiering av nytt verktyg
- [ ] Definiering av eget koordinatsystem
- [ ] Användning av sub-rutiner
- [ ] IF-satser
- [ ] Använding av IN- och UT-signaler
- [ ] Använding av IN- och UT-signaler mellan robot och extern PLC
- [ ] AND & OR
- [ ] XOR, NOT, NAND & NOR
- [ ] PLC-programmering
- [ ] Inget av det ovan nämnda ämnena

10. **Skulle du föredra att få något material innan kursen?** *
Markera alla som gäller.

- [ ] Ja, ett häfte för inläsning
- [ ] Ja, instruktionsvideor
- [ ] Ja, något annat
- [ ] Nej

11. **Om något annat, vad skulle det vara?**

12. **Skulle du vilja få med dig något material efter kursen?** *
Markera alla som gäller.

- [ ] Ja, en skriftlig sammanfattning
- [ ] Ja, häfte med ytterligare information
- [ ] Ja, instruktionvideor
- [ ] Ja, något annat
- [ ] Nej

13. **Om något annat, vad skulle det vara?**

Sluta fylla i det här formuläret.

Tekniker

För att kunna skapa en bra kurs är det viktigt att få reda på vad du som tekniker vill lära dig, vad du har för tidigare erfarenheter och hur du bäst lär dig.

14. **Vad gör dig motiverad till vidareutbildning?** *
Markera alla som gäller.

- [ ] Ökad personlig kompetens
- [ ] Certifikation
- [ ] Löneökning
- [ ] Nyfikenhet
- [ ] Roligare arbetsuppgifter
- [ ] Att gynna företaget
- [ ] Övrigt: ____________________

15. **Vilket/vilka av följande områden anser du är viktigt/viktiga att lära dig mer om?** *
Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

16. **Hur mycket erfarenhet har du från följande områden?** *
Markera endast en oval per rad.

	0 (Ingen erfarenhet)	1	2	3 (Mycket erfarenhet)
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

17. **Är förståelse kring logiken eller det praktiska användandet det viktigaste att få med sig från en robotkurs?** *
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Förståelse kring logik											Praktiskt användande

18. **Inom vilka områden har du gått kurser tidigare?** *
Markera alla som gäller.

- [ ] PLC-konfigurering (hårdvara)
- [ ] PLC-programmering
- [ ] Robotprogrammering/Robothantering
- [ ] Robotkurs 1 på SKF kompetenscentrum
- [ ] Inget av de ovan nämnda

19. **Vilket upplägg skulle du föredra för en kurs inom robotteknik?** *

1=enbart teoretiskt, 5=hälften teori och hälften praktik, 10=enbart praktik

Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Teoretiskt (Föreläsning, egen läsning, film m.m.)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Praktiskt (Testa och experimentera)

20. **Lär du dig bäst individuellt eller i grupp?** *

1=enbart individuellt, 5=hälften individuellt och hälften i grupp, 10=enbart i grupp

Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Individuellt	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Grupp

21. **Kryssa i allt du känner att du behärskar** *

Markera alla som gäller.

- ☐ Joggning av robot
- ☐ moveL, moveJ & moveC
- ☐ Definiering av nytt verktyg
- ☐ Definiering av eget koordinatsystem
- ☐ Användning av sub-rutiner
- ☐ IF-satser
- ☐ Användning av IN- och UT-signaler
- ☐ Användning av IN- och UT-signaler mellan robot och extern PLC
- ☐ AND & OR
- ☐ XOR, NOT, NAND & NOR
- ☐ PLC-programmering
- ☐ Inget av det ovan nämnda ämnena

22. **Skulle du föredra att få något material innan kursen?** *

Markera alla som gäller.

- ☐ Ja, ett häfte för inläsning
- ☐ Ja, instruktionsvideor
- ☐ Ja, något annat
- ☐ Nej

23. **Om något annat, vad skulle det vara?**

24. **Skulle du vilja få med dig något material efter kursen?** *
Markera alla som gäller.

- [ ] Ja, en skriftlig sammanfattning
- [ ] Ja, häfte med ytterligare information
- [ ] Ja, instruktionvideor
- [ ] Ja, något annat
- [ ] Nej

25. **Om något annat, vad skulle det vara?**

____
____
____
____
____

Sluta fylla i det här formuläret.

Underhåll

För att kunna skapa en bra kurs är det viktigt att få reda på vad du på SKF service vill lära dig, vad du har för tidigare erfarenheter och hur du bäst lär dig.

26. **Vad gör dig motiverad till vidareutbildning?** *
Markera alla som gäller.

- [ ] Ökad personlig kompetens
- [ ] Certifikation
- [ ] Löneökning
- [ ] Nyfikenhet
- [ ] Roligare arbetsuppgifter
- [ ] Att gynna företaget
- [ ] Övrigt: ______________________________

27. **Vilket/vilka av följande områden anser du är viktigt/viktiga att lära dig mer om?** *
Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)	○	○	○	○
PLC-programmering	○	○	○	○
Robotprogrammering	○	○	○	○
Kommunikation mellan PLC, robot och transportbana	○	○	○	○

28. **Hur mycket erfarenhet har du från följande områden?** *
Markera endast en oval per rad.

	0 (Ingen erfarenhet)	1	2	3 (Mycket erfarenhet)
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

29. **Är förståelse kring logiken eller det praktiska användandet det viktigaste att få med sig från en robotkurs?** *
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Förståelse kring logik											Praktiskt användande

30. **Inom vilka områden har du gått kurser tidigare?** *
Markera alla som gäller.

- [ ] PLC-konfigurering (hårdvara)
- [ ] PLC-programmering
- [ ] Robotprogrammering/Robothantering
- [ ] Robotkurs 1 på SKF kompetenscentrum
- [ ] Inget av de ovan nämnda

31. **Vilket upplägg skulle du föredra för en kurs inom robotteknik?** *
1=enbart teoretiskt, 5=hälften teori och hälften praktik, 10=enbart praktik
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Teoretiskt (Föreläsning, egen läsning, film m.m.)											Praktiskt (Testa och experimentera)

32. **Lär du dig bäst individuellt eller i grupp?** *
1=enbart individuellt, 5=hälften individuellt och hälften i grupp, 10=enbart i grupp
Markera endast en oval.

	1	2	3	4	5	6	7	8	9	10	
Individuellt											Grupp

33. **Kryssa i allt du känner att du behärskar** *
Markera alla som gäller.

- [ ] Joggning av robot
- [ ] moveL, moveJ & moveC
- [ ] Definiering av nytt verktyg
- [ ] Definiering av eget koordinatsystem
- [ ] Användning av sub-rutiner
- [ ] IF-satser
- [ ] Använding av IN- och UT-signaler
- [ ] Använding av IN- och UT-signaler mellan robot och extern PLC
- [ ] AND & OR
- [ ] XOR, NOT, NAND & NOR
- [ ] PLC-programmering
- [ ] Inget av det ovan nämnda ämnena

34. **Skulle du föredra att få något material innan kursen?** *
Markera alla som gäller.

- [ ] Ja, ett häfte för inläsning
- [ ] Ja, instruktionsvideor
- [ ] Ja, något annat
- [ ] Nej

35. **Om något annat, vad skulle det vara?**

36. **Skulle du vilja få med dig något material efter kursen?** *
Markera alla som gäller.

- [ ] Ja, en skriftlig sammanfattning
- [ ] Ja, häfte med ytterligare information
- [ ] Ja, instruktionvideor
- [ ] Ja, något annat
- [ ] Nej

37. **Om något annat, vad skulle det vara?**

38. **Av det som nämnts tidigare i enkäten, vad anser du att operatörerna ska lära sig mer om?** *

Sluta fylla i det här formuläret.

Driftchef

För att kunna skapa en bra kurs för operatörer är det viktigt att få reda på vad du som chef tycker är viktigt att lära sig samt vad kursen bör innehålla.

39. **Vilket/vilka av följande områden anser du är viktigt/viktiga att operatörer lär sig mer om?** *

Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

40. **Finns det någonting specifikt inom dessa områden som du anser är viktigt för operatörer att lära sig mer om?** *

41. **Finns det någonting annat som du anser är viktigt för operatörer att lära sig mer om?** *

42. **Vad har företaget för nytta av en kurs inom robotteknik enligt dig?** *

43. **Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens?** *

Markera endast en oval.

- Ja
- Nej

44. **Varför anser du det vara viktigt/oviktigt?** *

45. **Är det någonting mer du vill nämna eller tillägga?**

Sluta fylla i det här formuläret.

Underhållschef

För att kunna skapa en bra kurs för SKF Service-anställda är det viktigt att få reda på vad du som chef tycker är viktigt att lära sig samt vad kursen bör innehålla.

46. **Vilket/vilka av följande områden anser du är viktigt/viktiga att Underhålls-anställda lär sig mer om?** *

Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

47. **Finns det någonting specifikt inom dessa områden som du anser är viktigt för Underhålls-anställda att lära sig mer om?** *

48. **Finns det någonting annat som du anser är viktigt för Underhålls-anställda att lära sig mer om? ***

49. **Vad har företaget för nytta av en kurs inom robotteknik enligt dig? ***

50. **Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens? ***
Markera endast en oval.

- Ja
- Nej

51. **Varför anser du det vara viktigt/oviktigt? ***

52. **Är det någonting mer du vill nämna eller tillägga?**

Sluta fylla i det här formuläret.

Produktionschef

För att kunna skapa en bra kurs för tekniker är det viktigt att få reda på vad du som chef tycker är viktigt att lära sig samt vad kursen bör innehålla.

53. **Vilket/vilka av följande områden anser du är viktigt/viktiga att tekniker lär sig mer om?** *
Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

54. **Finns det någonting specifikt inom dessa områden som du anser är viktigt för tekniker att lära sig mer om?** *

55. **Finns det någonting annat som du anser är viktigt för tekniker att lära sig mer om?** *

56. **Vad har företaget för nytta av en kurs inom robotteknik enligt dig?** *

57. **Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens?** *
Markera endast en oval.

- Ja
- Nej

58. **Varför anser du det vara viktigt/oviktigt?** *

59. **Är det någonting mer du vill nämna eller tillägga?**

Sluta fylla i det här formuläret.

Kanalgruppschef

För att kunna skapa en bra kurs för tekniker är det viktigt att få reda på vad du som chef tycker är viktigt att lära sig samt vad kursen bör innehålla.

60. **Vilket/vilka av följande områden anser du är viktigt/viktiga att tekniker lär sig mer om?** *

Markera endast en oval per rad.

	Oviktigt	Mindre viktigt	Viktigt	Mycket Viktigt
PLC-konfigurering (hårdvara)				
PLC-programmering				
Robotprogrammering				
Kommunikation mellan PLC, robot och transportbana				

61. **Finns det någonting specifikt inom dessa områden som du anser är viktigt för tekniker att lära sig mer om?** *

62. **Finns det någonting annat som du anser är viktigt för tekniker att lära sig mer om?** *

63. **Vad har företaget för nytta av en kurs inom robotteknik enligt dig?** *

64. **Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens?** *

Markera endast en oval.

- Ja
- Nej

65. **Varför anser du det vara viktigt/oviktigt?** *

66. **Är det någonting mer du vill nämna eller tillägga?**

B

Interview Questions

B.1 Interview Questions - Middle Management

Swedish
Titel:
Ansvarsområde:

- Tycker du att kompetensutveckling är viktigt? Varför?
- Hur kommer World Class och industri 4.0 att påverka kompetensutvecklingen i företaget?
- Med företaget i åtanke. Vilka områden anser du är viktiga att tekniker/SKF Service-anställda/operatörer lär sig mer om?
  Vilka av dessa områden anser du passa i en robotkurs?
  Är det någonting specifikt inom dessa områden som bör tas upp?
- Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens?
  Varför anser du det vara viktigt/oviktigt?
- Är det någonting mer du vill nämna eller tillägga?

English
Title:
Responsibility:

- Do you consider skill development important? Why?
- How will "World Class" and "Industry 4.0" influence the skill development in the company?
- With the company in mind, what areas do you consider important for technicians/maintenance/operators to learn more about?
  Which of these areas do you consider appropriate in a robotics course?
  Is there anything specific in these areas that should be brought up?
- Do you want the course participants to take a test as evidence of increased competence?
  Why do you consider it important/unimportant?
- Is there anything else you would like to add?

B.2 Interview Questions - Teacher

Swedish
Titel:
Ansvarsområde:

- Utifrån dina erfarenheter från robotkurser. Vilka områden ser du att tekniker/ SKF Service-anställda/operatörer saknar kompetens inom?
- Vilka aktiviteter har du tidigare använt i robotkurser som fungerat bra respektive dåligt? Vilka aktiviteter har du använt i följande områden?
  Individuellt/grupp
  Teoretiskt/praktiskt
  Utdelning av material innan/efter kursen
- Vill du att kursdeltagarna avlägger ett prov som bevis på ökad kompetens?
  Varför anser du det vara viktigt/oviktigt?
  Vilka examinationsformer har du använt tidigare i robotkurser? Vad har de för fördelar/nackdelar?
- Är det någonting mer du vill nämna eller tillägga?

English
Title:
Responsibility:

- Based on your experience from robotics courses. In what areas do you see that technicians/Maintenance-personnel/operators lack competence?
- What activities have you previously used in robotics courses that worked well and bad? What activities have you used in the following areas?
  Individual/group
  Theoretical/practical
  Distribution of material before/after the course
- Do you want the course participants to take a test as evidence of increased competence?
  Why do you consider it important/unimportant?
  What examination methods have you previously used in robotics courses? What are their advantages/disadvantages?
- Is there anything else you would like to add?

B.3 Interview Questions - Common Problems and Faults

Swedish

- Vilka fel och problem är vanlig förekommande i företagets automationsceller?
- Vilka av dessa fel och problem ska operatörerna åtgärda själva och när ska det överlåtas till Underhåll?
- Är det någonting mer du vill tillägga kring det vi talat om?

English

- What common problems and faults exist in the automation cell at the company?
- Which of these faults and problems should the operators fix themselves and when should they contact Maintenance?
- Is there anything else you would like to add about what we have talked about?

C

Automation Course Level 2

Kurspaket - Automationskurs 2

Christian Andersson & Niklas Liljegren

April 2017

Sammanfattning

Automationskurs 2 är en fortsättningskurs på kursen Robotkurs 1 som erbjuds av SKF kompetenscentrum. Kursen innehåller lärande kring bland annat automationscellen, robot, PLC och felsökning. Kursen är framtagen efter ett ökat behov av kompetensutveckling i fabriken i och med SKF:s satsning på industri 4.0 och World Class. Kursen skall ge kursdeltagarna en övergripande förståelse för automationscellen samt kunskap som kan appliceras dagligen i fabriken, exempelvis felsökning.

Innehåll

1 Kursmål Automationskurs 2

En undersökning kring vad som anses viktigt för operatörerna att kunna, samt vad som bör inkluderas i en automationskurs har utförts. Utifrån resultaten har kursmål för en automationskurs 2 skapats. Under undersökningen framkom även syften med kursen.

1.1 Syfte med kursen

Kursdeltagaren skall efter avslutad kurs med gott självförtroende kunna utföra sina arbetsuppgifter i den befintliga miljön på arbetsplatsen. Kursen skall även leda till utveckling av företagets processer, samt ett mer tillfredsställande arbete för företagets produktionsmedarbetare.

Kursdeltagaren skall efter avslutad kurs

- ha djupare förståelse för automationsprocessen
- med gott självförtroende kunna utföra sina arbetsuppgifter
- känna sig bekväm och trygg i sitt arbete kring robotcellen.

För företaget skall kursen även leda till

- optimering av processen
- spridning av kompetens på företaget
- utveckling av de robotsystem som finns idag
- inspirerande arbetsuppgifter för produktionsmedarbetarna
- ökad kompetens hos produktionsmedarbetarna.

1.2 Mål med kursen

Kursdeltagaren skall efter avslutad kurs ha arbetat med de olika system och funktioner kring automation- och produktionsprocessen som SKF använder. Beroende på systemets eller processens vikt i produktionsprocessen samt dess komplexitet skall kursdeltagaren antingen ha sett, veta om eller kunna hantera dem.

1.2.1 Automationscellen/Processförståelse

Kursdeltagaren skall efter avslutad kurs ha förståelse för vad cellen består av, hur cellen fungerar samt hur samverkan mellan olika komponenter och system sker i och utanför cellen. Kursdeltagaren skall

- kunna nämna vad som inkluderas i en automationscell
- kunna förklara hur processen fungerar och hur den påverkas av IT
- kunna förklara vad som styr cellen

- kunna förklara vad ett HMI är och hur det används
- kunna förklara hur kommunikationen sker mellan cellens olika komponenter
- kunna starta och stoppa en cykel
- kunna återställa cellen.

1.2.2 Robot

Kursdeltagaren skall efter avslutad kurs kunna handha roboten samt ha förståelse för robotens program och kommandon. Kursdeltagaren skall

- kunna köra tillbaka roboten från alla lägen på ett säkert sätt
- kunna hantera pendanten och manövrera i dess olika menyer
- kunna läsa och förstå program med de vanligaste kommandona som används i fabriken idag
- kunna programmera roboten med hjälp av de vanligaste kommandona som används i fabriken idag.

1.2.3 PLC

Kursdeltagaren skall efter avslutad kurs veta veta vad en PLC är, vad den fyller för funktion i processen samt kunna programmera en PLC i den utsträckning att kursdeltagaren förstår kod. Kursdeltagaren skall

- kunna förklara vad en PLC är och vilket syfte den tjänar i cellen
- kunna förklara hur en PLC kommunicerar
- kunna läsa, tolka och följa PLC-program som används i fabriken idag
- kunna grundläggande PLC-programmering
- kunna styra roboten och andra komponenter med PLC:n.

1.2.4 Felsökning

Kursdeltagaren skall efter avslutad kurs kunna hantera felsökning samt precisera vad som är fel för att underlätta kommunikationen med underhåll. Kursdeltagaren skall

- i viss mån kunna felsöka processen samt precisera vad som är fel
- ha sett exempel på vad som kan gå fel.

1.2.5 Säkerhet

Kursdeltagaren skall efter avslutad kurs förstå vikten av en säker förändringsprocess samt vilka befogenheter kursdeltagaren har i förhållande till de andra verksamma yrkesgrupper såsom underhåll och konstruktion. Kursdeltagaren skall

- ha sett exempel på vad som kan gå fel och dess konsekvenser
- kunna förklara vikten av en säker förändringsprocess
- kunna ge exempel vilka befogenheter kursdeltagaren har till att göra förändringar och reparationer samt när arbetet skall överlåtas till underhåll/konstruktion
- kunna förklara säkra stopp.

1.2.6 Olika system

Kursdeltagaren skall efter avslutad kurs kunna applicera de erhållna kunskaperna på sin egen arbetsplats. Kursdeltagaren skall

- ha sett skillnaderna mellan de olika system som används på SKF
- kunna applicera sina kunskaper på sin arbetsplats i fabriken.

2 Undervisning

Undervisningen är uppdelad i åtta pass. Vardera pass är en halvdag med cirka 3 timmar undervisning exklusive raster. Varje utbildningsdag har ett mål och syfte, både för att stötta läraren och för att motivera kursdeltagarna. Varje dag har även minst en uppgift där kursdeltagarna får formativ feedback från läraren.

	Dag 1	Dag 2	Dag 3	Dag 4
FM	Introduktion & Repetition	Säker Hemkörning & If-satser	Kommunikation	Felsökning & Cases
EM	Erfarenheter & Robot	PLC & Logik	IT, HMI & Säkra Stopp	Tolka Kod & Test

2.1 Dag 1

	Dag 1	Dag 2	Dag 3	Dag 4
FM	Introduktion & Repetition	Säker Hemkörning & If-satser	Kommunikation	Felsökning & Cases
EM	Erfarenheter & Robot	PLC & Logik	IT, HMI & Säkra Stopp	Tolka Kod & Test

2.1.1 Syfte & Mål

Syftet med dag 1 är att kursdeltagarna skall få repetera de kunskaper de fått vid tidigare kurstillfällen, få en helhetsbild av cellen och få dela med sig av egna erfarenheter och motivatorer som har med automation att göra.

Målet med dagen är att kursdeltagarna kan tolka robotkod som består av de vanligaste kommandona som används i fabriken idag. De kursmål som berörs under dagen är att kursdeltagaren skall

- veta vad som inkluderas i en automationscell
- kunna hantera pendanten och manövrera i dess olika menyer
- kunna läsa och förstå program med de vanligaste kommandona som används i fabriken idag
- kunna programmera roboten med hjälp av de vanligaste kommandona som används i fabriken idag.

2.1.2 Innehåll

Tid	Innehåll
8:00-9:20	• Syfte och mål för kursen • Syfte och mål för dagen • Upplägg och innehåll för kursen • Automationscellen och dess innehåll (Föreläsning) • Uppstart robot, joggning och ställa in varvräknare
9:40-11:30	• Joggning av robot i olika koordinatsystem • MoveL, MoveJ och MoveC • Definiering av verktyg • Definiering av koordinatsystem • Fine och z • Subrutiner • For-satser

Tid	Innehåll
12:30-14:00	• Samla erfarenheter och motivatorer • Uppgift - tolka programkod • Extrauppgift - gör förändringar i koden (om tid finns)
14:20-16:00	• Prov - kör den förprogrammerade och ge feedback till deltagarna • Prov - extrauppgift, kör även den förändrade koden • Skapa ett program för hemläge och kör hem

2.1.3 Uppgifter, Material och Prov

Nedan följer uppgifter, material och prov för dag 1.

Genomgång

Presentation av kursens syfte och vad kursen ska leda till för individerna på kursen. Fortsatt presentation av dagens mål och syfte och hur de kopplar mot kursens mål.

Presentation av schemat med fok på hur de olika aktiviteterna kommer hjälpa kursdeltagarna att nå de mål som är uppsatta.

Presentation de olika delarna som är uppkopplade i automationscellen i lärosalen (PLC, Robot, transportband). Presentation även av de delar som ej finns i lärosalens cell, men som finns i fabriken (givare/sensorer, olika verktyg m.m.).

Ställ in roboten

Läraren ber kursdeltagarna ställa roboten i ursprungsposition, både för att se om de minns hur de ska göra från kurs 1 och för att kursdeltagarna ska få komma igång med joggning av roboten.

Repetition

Presentation på tavlan av de kommandon som kursdeltagarna lärde sig i kurs 1 (MoveL, MoveJ, MoveC, For, offset). Läraren känner av, genom dialog med kursdeltagarna, vilka delar som behövs repeteras mycket respektive lite. Roboten kan användas för att visa skillnaderna mellan MoveL, MoveJ och MoveC och skillnaderna mellan fine och zxx.

Presentation av definiering av nytt verktyg och nytt work object.

Kursdeltagarna använder kunskapen från repetitionen i uppgift 1.

Erfarenheter och Motivatorer

Läraren leder en diskussion med kursdeltagarna kring vilka erfarenheter kursdeltagarna har och vad som motiverar dem till att lära sig mer. Det som kommer fram under diskussionen kommer kunna användas senare i kursen. Exempelvis kan erfarenheter av händelser i fabriken göra diskussionen kring felsökning ännu mer aktuell.

Uppgift - Tolka programkod

Kursdeltagarna får kod utskrivet på papper och ska försöka tolka vad roboten kommer att göra/rita.

Extrauppgift - Om kursdeltagarna blir klara väldigt tidigt. Ge dem uppgift att fundera på vad som bör ändras i koden för att ge ett visst resultat.

Prov - Tolka programkod

Körning med roboten av de rutiner kursdeltagarna tolkat i sin uppgift. Läraren ber dem först presentera vad de tror kommer hända och ber dem diskutera med varandra om de har olika tankar. Visa sedan med roboten. Läraren försöker upptäcka eventuella feltolkningar hos kursdeltagarna och ger feedback i syfte att rätta till feltolkningarna.

Om kursdeltagarna gjort extrauppgiften, ber läraren kursdeltagarna att testa koden de skapat.

Hemkörning

Kursdeltagarna ska skapa en rutin som kör roboten till dess hemmaläge med moveJ.

2.2 Dag 2

	Dag 1	Dag 2	Dag 3	Dag 4
FM	Introduktion & Repetition	Säker Hemkörning & If-satser	Kommunikation	Felsökning & Cases
EM	Erfarenheter & Robot	PLC & Logik	IT, HMI & Säkra Stopp	Tolka Kod & Test

2.2.1 Syfte & Mål

Syftet med förmiddagen dag 2 är att kursdeltagarna skall bli säkrare på att köra hem roboten på ett säkert sätt och få ännu djupare kunskaper i robotkod. Syftet med eftermiddagen är att introducera PLC och den logik som krävs för att förstå och skriva PLC-kod.

Målet med Dag två är att kursdeltagarna skall kunna skriva och tolka enkla program från både PLC och Robot. De skall även ha sett exempel på vad som kan gå fel vid en felaktig hemkörning och förstå vikten av en säker förändringsprocess. De kursmål som berörs under dagen är att kursdeltagaren skall

- kunna köra tillbaka roboten från alla lägen på ett säkert sätt
- kunna läsa och förstå program med de vanligaste kommandona som används i fabriken idag
- kunna programmera roboten med hjälp av de vanligaste kommandona som används i fabriken idag
- veta vad en PLC är och vilket syfte den tjänar i cellen
- veta hur en PLC kommunicerar
- kunna läsa, tolka och följa PLC-program som används i fabriken idag
- kunna grundläggande PLC-programmering
- ha sett exempel på vad som kan gå fel och dess konsekvenser
- veta vikten av en säker förändringsprocess.

2.2.2 Innehåll

Tid	Innehåll
8:00-9:20	• Syfte och mål för dagen • Visa olycka i E-fabriken efter misslyckad hemkörning • Demonstration av olycka vid hemkörning (krocka med ett okänsligt föremål)
9:40-11:30	• Säker förändringsprocess • Repetition Robot dag 1 och If-satser • Användning av switchar (röd/grön/gul) i robotprogram från dag 1 för att demonstrera If-satser

Tid	Innehåll
12:30-14:00	• PLC - funktion med in och utsignaler • PLC - vanligaste blocken • PLC - hur den bearbetar koden (exempel på ett program på tavlan) • Uppgift - skapa enkla PLC-program i par
14:20-16:00	• Uppgift - skapa enkla PLC-program i par • Prov - kursdeltagarna visar upp sina program och får feedback • Extrauppgift - fundera över kommunikationen mellan PLC och robot

2.2.3 Uppgifter, Material och Prov

Nedan följer uppgifter, material och prov för dag 2.

Uppstart och konsekvenser vid misslyckad hemkörning

Presentation av syfte och mål för dagen följt av en demonstration av vad som kan hända då en robot krockar. Här visas en bild från E-fabriken då en robot krockade när den kördes till sitt hemläge. Här skall läraren tillsammans med deltagarna diskutera kring vad som kan ha gjort att detta gått fel, såsom att roboten inte bryr sig om vad som står i dess väg. Här skall det även framgå hur man åstadkommer en säker hemkörning genom att första ställa roboten i ett läge där den fritt kan gå till sitt hemläge.

Demonstration av olycka vid hemkörning

Vid denna demonstration skall det befintliga programmet ”säker hemkörning” användas. Detta program simulerar en robot som arbetar i en maskin gjord av kartong. Roboten skall köras till sitt hemläge och krocka med maskinen gjord i kartong för att demonstrera vad som kan hända. För att demonstrera hur en säker hemkörning går till skall roboten köras till sitt hemläge ytterligare en gång, med skillnaden att roboten denna gång manuellt har körts ur maskinen till ett säkert läge.

Säker förändringsprocess

Genomgång av hur en förändringsprocess skall ske på ett säkert sätt. Här presenteras vikten av att förändringen sker på ett standardiserat sätt av rätt personer.

Repetition Robot dag 1 och If-satser

Här repeteras det som gicks igenom vad gäller roboten under dag 1. Teori kring vad en If-sats är samt hur man använder den i robotprogram skall även gås igenom.

Användning av switchar

Här skall switcharna som finns tillgängliga utanpå cellen användas som ingångar. Villkor skall ställas med hjälp av If-satser där olika program från dag 1 körs beroende på vilken switch som är tillslagen.

Genomgång PLC

Under denna genomgång skall grunden till vad en PLC är och hur den arbetar med signaler ges. De vanligaste blocken som används vid PLC-programmering skall demonstreras och på tavlan skall det även gås igenom hur PLC:n läser koden uppifrån och ner.

Uppgift PLC

Deltagarna skapar enkla PLC-program i par för att öva på att skapa program samt öka förståelsen för funktionen.

Prov

Deltagarna får nu möjligheten att visa upp sina program och läraren ger deltagarna feedback.

Extrauppgift

Om tid finns så skall grupperna, utifrån den kunskap de skaffat sig om hur PLC:n använder in- och utsignaler, få i uppgift att fundera kring hur kommunikationen nu kan ske mellan PLC:n och roboten.

2.3 Dag 3

	Dag 1	Dag 2	Dag 3	Dag 4
FM	Introduktion & Repetition	Säker Hemkörning & If-satser	Kommunikation	Felsökning & Cases
EM	Erfarenheter & Robot	PLC & Logik	IT, HMI & Säkra Stopp	Tolka Kod & Test

2.3.1 Syfte & Mål

Syftet med dag 3 är att kursdeltagarna skall få ökad förståelse kring hur PLC:n styr Roboten och andra komponenter. Syftet är också att öka förståelse kring hur IT påverkar och hur HMI:t kan hjälpa dem i fabrikerna.

Målet med dag 3 är att kursdeltagarna kan skicka och ta emot signaler mellan roboten och PLC:n. De skall även kunna hur IT påverkar, både positivt och negativt. Kursdeltagarna skall också veta vad ett HMI är och hur den kan underlätta deras arbete och felsökning ute i fabriken. De kursmål som berörs under dagen är att kursdeltagaren skall

- veta hur processen fungerar och hur den påverkas av IT
- veta vad som styr cellen
- veta vad ett HMI är och hur det används
- veta hur kommunikationen sker mellan cellens olika komponenter
- veta vad en PLC är och vilket syfte den tjänar i cellen
- veta hur en PLC kommunicerar
- kunna läsa, tolka och följa PLC-program som används i fabriken idag
- kunna grundläggande PLC-programmering
- kunna styra roboten och andra komponenter med PLC:n
- förstå säkra stopp
- kunna applicera sina kunskaper på sin arbetsplats i fabriken.

2.3.2 Innehåll

Tid	Innehåll
8:00-9:20	• Syfte och mål för dagen • Styra automationscellen med PLC (föreläsning) • Skapa PLC-program och robot-program parallellt och styr roboten med PLC
9:40-11:30	• Skapa PLC-program och robot-program parallellt och styr roboten med • HMI - vad är ett HMI och hur fungerar det?

Tid	Innehåll
12:30-14:00	• Skapa PLC-program och robot-program parallellt och styr roboten med PLC
14:20-16:00	• Demonstration av skapat program (3 produkter och 3 maskiner) • Hur IT påverkar produktionen idag • Demonstration av hur IT påverkar produktionen (praktiskt i skapat program)

2.3.3 Uppgifter, Material och Prov

Nedan följer uppgifter, material och prov för dag 3.

Uppstart och genomgång

Presentation av syfte och mål för dagen. Sedan följer en föreläsning kring hur PLC:n är kopplad till roboten och transportbanan i lärosalen. Föreläsningen presenterar även hur signaler skickas och tas emot av roboten och PLC:n.

Uppgift - Skapa större program i par

Kursdeltagarna delas upp i två grupper. Ena gruppen programmerar robot och den andra gruppen programmerar PLC. Sedan byter de efter en stund. Programmen ska kommunicera med varandra. Se uppgift 8.

Genomgång HMI

Genomgång av vad ett HMI är och hur det används i fabriken idag. Visa vilka funktioner HMI:t har och hur det kan användas för att styra cellen och kontrollera att allting stämmer, exempelvis antal ringar på pallen.

Demonstration av program skapat av Niklas och Christian

Demonstration över vad programmet gör (Cellens syfte). Sedan presenteras koden av läraren och kursdeltagarna får gå igenom den för att tolka och ställa frågor.

IT

Genomgång kring att all information som cellen använder lagras i ”molnet”. När en pall anländer till en cell läses en streckkod av, först då vet cellen vad den ska genomföra. För att simulera detta i exempelprogrammet finns det inlagt hur många objekt som finns på ”pallen”. Om antalet inte stämmer, är det stor risk att roboten/cellen gör fel/stannar.

Visa demonstrativt vad som händer om cellen tror att det befinner sig fler eller färre produkter än vad som faktiskt befinner sig på plattan. Det som skiljer fabriken från lärosalen är bland annat att fabriken har sensorer, därför stannar cellen snarare än kör vidare utan produkt.

2.4 Dag 4

	Dag 1	Dag 2	Dag 3	Dag 4
FM	Introduktion & Repetition	Säker Hemkörning & If-satser	Kommunikation	Felsökning & Cases
EM	Erfarenheter & Robot	PLC & Logik	IT, HMI & Säkra Stopp	Tolka Kod & Test

2.4.1 Syfte & Mål

Syftet med dag 4 är att kursdeltagarna skall få använda och förstärka sina kunskaper i automation. Syftet är också att kursdeltagarna skall bli bättre på att läsa kod, tolka kod och felsöka en cell.

Målet är att kursdeltagaren skall kunna flertalet vanliga fel på cellen och hur de skall lösas. Kursdeltagaren skall kunna tolka kod för att se vart i programmet det gått fel och vad som bör ske härnäst. De kursmål som berörs under dagen är att kursdeltagaren skall

- kunna läsa och förstå program med de vanligaste kommandona som används i fabriken idag
- i viss mån kunna felsöka processen samt precisera vad som är fel
- ha sett exempel på vad som kan gå fel
- veta vilka befogenheter kursdeltagaren har till att göra förändringar och reparationer samt när arbetet skall överlåtas till underhåll/konstruktion
- ha sett skillnaderna mellan de olika system som används på SKF

2.4.2 Innehåll

Tid	Innehåll
8:00-9:20	• Syfte och mål för dagen • Se och tolka kod • Exempel på vad som kan gå fel och hur felen bör lösas
9:40-11:30	• Cases - Felsökning

Tid	Innehåll
12:30-14:00	• Se och tolka SKF-kod • Poängtera vad som är viktigt att förstå och inte • Visa på vilka befogenheter de olika befattningarna i fabriken har • Visa de viktiga skillnaderna mellan KUKA & ABB och mellan Siemens & ABB
14:20-16:00	• Prov - Tolka kod, skriva kod, teoretiska frågor • Låt kursdeltagarna sammanfatta vad de lärt sig och fått med sig av kursen

2.4.3 Uppgifter, Material och Prov

Nedan följer uppgifter, material och prov för dag 4.

Uppgift - se och tolka kod

Läraren går först igenom syfte och mål för dagen för att sedan dela ut en uppgift som går ut på att deltagarna skall tolka PLC- och robot-kod. De skall förstå vad roboten gör och när.

Genomgång

Under en genomgång skall exempel på vad som kan gå fel i en cell som gör att programmet inte fungerar. Exempel på sådana fel är att roboten inte står i rätt läge, någon givare är påverkad, det har blivit något fel vid scanning eller avkännande av antal etc.

Övning - cases kring felsökning

I denna övning så skall deltagarna få olika case där fel har lagts in i ett redan befintligt program. De ska ta reda på vad som är fel samt åtgärda felet.

Se och tolka SKF-kod

Läraren delar ut PLC- och robotkod som används i SKF:s fabriker idag. Deltagarna får nu möjlighet att tolka denna kod och jämföra med den enklare kod som de själva skapat. Här demonstreras komplexiteten i programmet samtidigt som deltagarna får en känsla för hur programmen är uppbyggda ute i fabrikerna. De skall även få med sig vad de bör fokusera på om de någon gång skall gå in och titta på programmet.

Befogenheter

Efter att deltagarna uppfattat komplexiteten i programmen skall läraren förklara vilka befogenheter de olika befattningarna har. Deltagarna skall veta vad de får göra och vem de skall kontakta om de ser behov av förändring.

Skillnader ABB och KUKA

Eftersom det finns olika system i fabriken är det viktigt att veta vad som skiljer dem åt. Under kursen används en ABB-robot men i E-fabriken finns det KUKA-robotar. Det är därför viktigt att demonstrera vad som skiljer dem åt.

Prov

Ett lite längre avslutande prov där deltagarna skall tolka kod, skriva kod samt svara på teoretiska frågor kring robot och PLC.

Sammanfattning

När provet är avslutat skall deltagarna få möjlighet att i grupp sammanfatta vad de fått med sig från kursen. Detta är en möjlighet för repetition samt en möjlighet för läraren att få feedback inför kommande kurstillfällen.

3 Uppgiftsbeskrivningar

3.1 Uppgift 1 - Repetitionsprogram

Denna uppgift går ut på att skapa ett program som ritar en figur på ett papper med pennan som verktyg.

1. Skapa ett program med namn Uppgift1.

2. Skapa en rutin för att hämta pennan (var observant när det kommer till användandet av MoveL, MoveJ och MoveC samt fine/zxx).

3. Skapa en rutin som går ner i pappret och ritar en enkel figur. Figuren skall innehålla 6 linjer. Fine och zxx skall användas 3 gånger vardera.

4. Skapa en rutin för att lämna pennan.

3.2 Uppgift 2 - Tolka programkod Robot

Nedan följer 3 rutiner som ritar någonting. Rita till höger om koden vad roboten kommer att rita, så noggrant som möjligt. r20 är en punkt på pappret. Fundera dessutom på om resultatet blir olika ifall programmet stegas igenom eller körs i sin helhet.

```
PROC tolkaKod1()
FOR i FROM 1 TO 3 DO
MoveJ Offs(r20,0,0,30), v2500, fine, penna;
MoveL r20, v200, fine, penna;
MoveL Offs(r20,-50,15,0), v2500, fine, penna;
MoveL Offs(r20,-30,30,0), v2500, fine, penna;
MoveL Offs(r20,-50,45,0), v2500, fine, penna;
MoveL Offs(r20,0,60,0), v2500, fine, penna;
MoveL Offs(r20,0,60,30), v2500, fine, penna;
ENDFOR
ENDPROC

PROC tolkaKod2()
FOR i FROM 1 TO 6 DO
MoveJ Offs(r20,0,0,30), v2500, fine, penna;
MoveL r20, v200, fine, penna;
MoveL Offs(r20,-50,15,0), v2500, z5, penna;
MoveL Offs(r20,-30,30,0), v2500, z5, penna;
MoveL Offs(r20,-50,45,0), v2500, z10, penna;
MoveL Offs(r20,0,60,0), v2500, fine, penna;
MoveC Offs(r20,30,30,0), r20, v2500, fine, penna;
MoveL Offs(r20,0,0,30), v2500, fine, penna;
ENDFOR
ENDPROC

PROC tolkaKod3()
FOR i FROM 1 TO 7 DO
MoveJ Offs(r20,0,0,30), v2500, fine, penna;
MoveL r20, v200, fine, penna;
MoveL Offs(r20,-50,0,0), v2500, z5, penna;
MoveL Offs(r20,-50,30,0), v2500, z5, penna;
MoveL Offs(r20,-50,30,30), v200, fine, penna;
MoveL Offs(r20,-25,30,30), v1500, fine, penna;
MoveL Offs(r20,-25,30,0), v200, fine, penna;
MoveL Offs(r20,0,10,0), v1000, fine, penna;
MoveL Offs(r20,0,10,30), v2500, fine, penna;
ENDFOR
ENDPROC
```

3.3 Uppgift 3 - Extrauppgift Ändra Kod

1. Skriv en rutin som ritar en cirkel med en radie på 30 mm och som har r20 som mittpunkt i cirkeln.

3.4 Uppgift 4 - Hemläge

Denna uppgift går ut på att skapa en rutin för robotens hemläge. I en produktionscell är detta hemläge en punkt som roboten ofta utgår ifrån i sina rutiner.

1. Skapa en rutin med namnet hemläge.

2. Använd MoveJ och lämpligt värde på zxx för att köra till denna position.

3.5 Uppgift 5 - Switchar

Syftet med denna uppgift är att lära sig styra roboten med hjälp av signaler som skickas till den. I denna uppgift används de tre switcharna för att styra vilken rutin roboten skall göra.

1. Öppna main

2. Använd if-sats för att köra tolkaKod1() om grön switch är påslagen, vilket innebär att diGrönKnapp är 1.

3. Gör likadant för tolkaKod2() och tolkaKod3() med gul respektive röd switch.

4. Vad händer om flera switchar är påslagna?

5. Programmera så att ingenting händer om flera switchar är påslagna.

3.6 Uppgift 6 - PLC

Denna uppgift går ut på att skapa enklare PLC-program i par. Diskutera sinsemellan vad de olika funktionerna som ni använder gör.

1. Öppna programmet PLC_1_grupp1 alternativt PLC_1_grupp2 beroende på vilken grupp du blir tilldelad.

2. Skapa ett nytt FC-block och kalla det för FC10.

3. I Network 1 i detta FC, skapa ett program där en valfri lampa tänds med en valfri knapp och släcks när man släpper knappen.

4. Skapa ytterligare ett Network. I detta Network 2, skapa ett program där en annan valfri knapp tänder en annan valfri lampa så att den förblir tänd med hjälp av en en SR-funktion (ett minne). Släck lampan med ytterligare en valfri knapp.

5. Fortsätt att arbeta i Network 2. Använd en &-funktion för att sätta villkoret att två valfria knappar måste tryckas in för att lampan skall tändas.

6. Fortsätt att arbeta i Network 2. Använd en Eller-funktion för att sätta villkoret att ytterligare en valfri knapp kan hållas intryckt för att lampan skall lysa.

7. Återgå till Network 1. Finn ett sätt att få lampan att lysa konstant utan att använda en SR-funktion.

8. Skapa ett nytt FC-block och kalla det för FC20. I Network 1 i FC20, skapa ett program som får ytterligare en lampa att lysa då någon av lamporna i FC10 lyser.

9. Fortsätt att arbeta i FC20 och Network 1. Lägg in en timer som gör att lampan i FC20 och Network 1 lyser först 3 sekunder efter det att någon av lamporna i FC10 lyser.

10. Gå till FC10 och Network 2. Lägg in en counter som gör att du måste trycka 3 gånger på en av knapparna för att lampan skall lysa.

3.7 Uppgift 7 - Extrauppgift PLC

Denna extrauppgift finns till förfogande då det blir tid över. Hittills har du använt lampor som utgångar. Fundera nu på hur denna lampa skulle kunna ersättas med en funktion i roboten. Hur skickas denna signalen från PLC:n och hur tar roboten upp denna signal?

3.8 Uppgift 8 - PLC/Robot Kommunikation

Syftet med uppgiften är att ni ska lära er hur kommunikation sker mellan PLC och Robot. Grupp 1 kommer att genomföra PLC-del 1 och Robot-del 2. Grupp 2 kommer att genomföra Robot-del 1 och PLC-del 2. Avsluta gemensamt med den gemensamma delen.

Robot-del 1

1. Skapa ett nytt program.
2. Skapa en rutin som hämtar pennan, ritar någonting och sedan lämnar pennan. Passa på att testa olika kommandon och att jogga roboten mycket.
3. Avsluta rutinen med att pulsa signalen DO10_13.
4. Lägg in i main att rutinen skall köras om signalen DI10_12 = 1.

Robot-del 2

1. Skapa en rutin som hämtar pennan, ritar någonting och sedan lämnar pennan. Passa på att testa olika kommandon och att jogga roboten mycket.
2. Avsluta rutinen med att pulsa signalen DO10_14.
3. Lägg in i main att rutinen skall köras om signalen DI10_13 = 1.

Gemensam del

1. Testa programmet.
2. Diskutera med varandra, vad skulle förbättra programmet?
3. Implementera era förbättringar.

PLC-del 1

1. Öppna programmet PLC_2
2. Skapa ett nytt FC-block och kalla det för FC10.
3. Programmera grundförutsättningar för drift.
   (a) I Network 1 i FC10, programmera så att ett minne(%M1.0) blir aktivt om nyckeln är omvriden och PLC:n står i auto.
   (b) Ändra "tag" på minnet till lämpligt namn.
4. Skapa ett nytt FC-block och kalla det för FC16.
5. Sätt signal Q0.0 till aktiv om (%M1.0) är aktiv och den blå knappen längst till vänster trycks in. Då ska även den blå knappen lysa.
6. Om (%M1.0) blir inaktiv eller om (%i2.0) blir aktiv ska utgång Q0.0 bli inaktiv och knappen slockna.

PLC-del 2

1. Öppna FC10 och tolka koden. Vid oklarheter, fråga grupp 1.
2. Öppna FC16 och tolka koden. Vid oklarheter, fråga grupp 1.
3. I FC16, sätt signal Q0.1 till aktiv om (%M1.0) är aktiv och den blå knappen längst till höger trycks in. Då ska även den blå knappen lysa.
4. Om (%M1.0) blir inaktiv eller om (%i2.1) blir aktiv ska utgång Q0.1 bli inaktiv och knappen slockna.

3.9 Uppgift 9 - Tolka Kod PLC/Robot

Använd häftet med koden och svara på följande frågor

1. Kolla i robotkoden: Vad krävs för att rutinen HamtaObject1Maskin1() skall köras?

2. Kolla i "FC16 Uppdrag Robot": Vad krävs för att %M10.3 "HämtaObjekt1Maskin1" skall aktiveras?

3. Följ dessa minnen för att ta reda på allt som krävs för att HamtaObjekt1Maskin1 skall kunna köras

4. Kolla i "FC10 Maskinstyrning": Vilka olika händelser skulle kunna stoppa automatdriften, alltså sätta %M1.2 "Stoppa_Automatdrift" till 1.

5. Bana1 (Inbanan) kan startas på två olika sätt och även stoppas på två olika sätt. Vilka är dessa?

3.10 Uppgift 10 - Cases

3.11 Prov

Nedan följer provet som skall hållas sista dagen på kursen.

Fråga 1

Namnge de markerade föremålen

1.________________________________
2.________________________________
3.________________________________
4.________________________________

Fråga 2

I World Class-kanalen i D-fabriken bär varje komponent information från varje steg i tillverkningsprocessen. Denna information består exempelvis av typinformation och toleranser, men även information om vilka delar av processen som produkten gått igenom. Om registreringen av en process inte sker, vad leder då detta till i nästkommande process? Nämn även minst en för- och en nackdel med detta system.

Fråga 3

Vilken komponent i cellen styr cellen?
Hur kommunicerar den med de andra komponenterna?

Fråga 4

Varför är en säker förändringsprocess viktig?

Fråga 5

Förklara hur ett HMI kan användas vid felsökning av en cell, ge gärna flera exempel.

Fråga 6

Vad innebär ett säkert stopp?

Fråga 7

Ge exempel på fel du kan åtgärda själv. Ge även exempel på fel som du ej bör åtgärda själv och då du istället bör tillkalla underhåll.

Fråga 8

Nedan följer en rutin som ritar någonting. Rita till höger om koden vad roboten kommer att rita, så noggrant som möjligt. r20 är en punkt på pappret. Förklara varför skissen ser ut som den gör.

```
PROC tolkaKod()
FOR i FROM 1 TO 3 DO
MoveJ Offs(r20,0,0,30), v2500, fine, penna;
MoveL r20, v200, fine, penna;
MoveL Offs(r20,-50,0,0), v2500, z5, penna;
MoveL Offs(r20,-30,-30,0), v2500, z10, penna;
MoveL Offs(r20,-30,30,0), v2500, fine, penna;
MoveC r20, Offs(r20,-30,-30,0), v2500, fine, penna;
MoveL Offs(r20,-30,-30,30), v2500, fine, penna;
ENDFOR
ENDPROC
```

Fråga 9

Använd häftet med koden och svara på följande frågor

1. Kolla i robotkoden: Vad krävs för att rutinen HamtaObject3Maskin3() skall köras?

2. Ta reda på allt som krävs för att HamtaObjekt3Maskin3 skall kunna köras.

3. Kolla i ”FC20 Simulering maskinkörning”: Vad krävs för att maskinen ska startas(Cykeltid maskin 1 aktiveras)? Vad krävs för att Maskinen ska resetas?

D

Evaluation - Questionnaire

Utvärdering Automationskurs 2

Denna enkät har till syfte att ta reda på vad du som kursdeltagare tycker om kursen och vad du lärt dig. Som hjälp på traven, om tankarna står stilla, så har vi även ställt ett antal hjälpfrågor i varje huvudfråga.

1. **Vad tycker du om teorigenomgångarna i kursen?**
   Skriv vad du tycker om teorigenomgångarna. Exempel på frågor att svara på: Var innehållet lätt att förstå? Var genomgångarna lagom långa? Vad kunde gjorts annorlunda?

2. **Vad tycker du om gruppövningarna?**
   Skriv vad du tycker om gruppövningarna. Exempel på frågor att svara på: Var övningarna lätta att förstå? Var övningarna lagom långa? Var det lagom stora grupper vid övningarna? Vad kunde gjorts annorlunda?

3. **Vad tycker du om de individuella uppgifterna/Proven?**
   Skriv vad du tycker om uppgifterna/Proven. Var uppgifterna/proven lagom utmanande? Var det givande att göra individuella uppgifter/prov? Vad kunde gjorts annorlunda?

4. **Vad tycker du om uppdelningen mellan de olika områdena i kursen?**
   Var det rätt fokus på respektive område, såsom PLC, robot, IT, kommunikation, felsökning etc.? Var det någonting som kursen bör fokusera mer eller mindre på?

5. **Vad skulle du vilja förändra med kursen?**

6. **Vad bör absolut behållas i kursen?**

7. **Tycker du att kursen har varit givande och känner du att du kommer att kunna använda kunskapen du fått i ditt dagliga arbete?**

8. **Känner du att du kan**

Markera endast en oval per rad.

	Ja	Nej	Vet ej/Vill inte svara
Berätta vad en automationscell är och vad den innehåller?			
Förklara hur automationsprocessen fungerar och hur den påverkas av IT?			
Förklara hur och vad som styr en cell?			
Förklara vad ett HMI är och hur det används?			
Starta och stoppa en cykel?			
Återställa en cell?			
Jogga roboten på ett säkert sätt?			
Hantera pendanten och manövrera i dess menyer?			
Läsa och förstå Robot-kod?			
Programmera roboten?			
Förklara vad är en PLC är och vilket syfte den har i cellen?			
Förklara hur en PLC kommunicerar?			
Läsa, tolka och följa PLC-program?			
Grundläggande PLC-programmering?			
Styra roboten och transportbanan med PLC:n?			
Felsöka processen och i viss mån precisera vad som är fel?			
Ge exempel på vad som kan gå fel?			
Förklara vikten av en säker förändringsprocess?			
Ge exempel på situationer när du bör tillkalla underhåll/konstruktion?			
Genomföra säkra stopp?			