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Development of educational activity based on learning factory in order to enhance learning experience

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Preface

This Master Thesis was written during the Spring semester 2016 at NTNU Gjøvik. The work was done in cooperation with IDT Solutions AS. The company kindly helped and provided all the necessary equipment in order to set up the learning factory in the building laboratory of NTNU Gjøvik at Mustad Næringspark, which was used as a basis for educational activity development described in this work. NTNU Gjøvik, in its turn, allocated financial resources necessary to complete the project.

Gjøvik, June 6, 2016

Olga Ogorodnyk

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Olga Ogorodnyk, Gjøvik, 06-06-2016.

Abstract

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<p>Purpose: The following thesis describes development of educational activity in order to enhance students' practical and theoretical knowledge on topics of kaizen, waste types, efficiency, push/pull production systems, in addition to this, it gives suggestions/guidelines for creation of similar activities.</p> <p>Approach: Such methods as literature review and group interview were used in order to conduct the study and evaluate developed educational activity. Practical case study approach was also applied.</p> <p>Findings: Educational activities based on learning factories are a valuable part of the learning process, since they significantly enhance practical and theoretical knowledge of participants. Combination of use of such concepts as learning factories, experience based learning, experiential learning cycle, game based learning, serious games and sensemaking leads to enhancement of learning experience gained during educational activities.</p> <p>Value: Thesis can be used as instruction for application of the developed educational activity. In addition to this, it includes list of suggestions and example for those willing to create similar activities, especially in the field of engineering and manufacturing education.</p>		

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Background

After completion of the project work¹, dedicated to improvement of manual assembly line for roller skis used at IDT Solutions AS, an idea of building a learning factory based on the assembly line appeared. However, the factory could bring even more educational benefits if students' interaction with it was structured with help of a certain learning activity. As a result of this idea the topic of master thesis was formulated and the work on it began.

The activity, designed during the work on the thesis, will bring possibilities to gain practical knowledge of operating with production lines and processes through interaction with copy of the real assembly line. It will also provide students with practical examples of application of such concepts as *kaizen*, *waste types*, *efficiency* and *push/pull production systems*, as well as theoretical knowledge on the listed topics. Activity is based on such concepts and theories as: *learning factories*, *experience based learning*, *experiential learning cycle*, *game based learning*, *serious games* and *sensemaking*. In manufacturing education, serious games, for example, can be very useful while teaching engineers, as they increase possibility of gaining not only technical, but also soft skills (collaboration, creativity, communication) (Tehran, Taisch and Fradinho, 2013). In addition to this, it will also be possible to use the activity and the factory in order to improve skills of people that are already working in the manufacturing industry. This will bring opportunity to have students and employees to learn together, thus receiving more useful knowledge and strengthening link between the industry and education. It might open new possibilities for future employment of students and bring undeniable benefits to companies, as students, that they will hire, will already have knowledge of working on the production line in environment imitating the real work situation. All of the above mentioned can also be stated as a first motivation to conduct the study. It is also important to notice that application of such activities is extremely useful in engineering and manufacturing education. These fields are known for having one of the highest dropout rates, because of high complexity and use of ineffective teaching methods.

As it will be more broadly shown further in the paper, activities based on serious games are,

¹ Granheim, M and Ogorodnyk, O (2015) unpublished work "*Improvement of manual assembly line for roller skis*"

unfortunately, rarely used as educational tools in field of manufacturing and engineering, as teachers and professors often lack extensive guidelines and effective examples on the topic of their design. This became an additional motivation for conducting the study, as it may serve as an example of similar educational activities development. The next section presents introduction of the paper.

1. Introduction

1.1. Problem statement

“We learn all the time, inside but also outside of classrooms, from books written by scholars but also from conversations with casual strangers, from watching an instructional video but also from watching a wave roll in and out at the beach” (Ruben, 1999, p. 499). Knowledge can be created everywhere, however, the most common places are schools and higher educational institutions. This master thesis offers to take a closer look at educational activities based on serious games, game and experience based learning as a source of knowledge and sense creation. Game based learning can be defined as *“activities that have a game at their core, either as the main activity or as a stimulus for other related activities, and have learning as a desired or incidental outcome”* (Kirriemuir and McFarlane, 2004, p. 7). Serious games, in their turn, *“have proven to support learners in acquiring new and complex knowledge and are ideally creating engaging experiences around a contextual problem where users must apply competences to solve these presented challenges”* (Cerinsek et al., 2012, p. 194). In other words, games are often chosen as means to learn, in order to excite the pupil or student, instead of making him or her to sit and try to perceive material that is presented by teacher through conventional learning techniques. Here learning by doing concept also comes into place. Use of passive learning methods leads to decrease of interest and amount of people willing to receive higher education in all the fields, especially in engineering and manufacturing (Oliveira et al., 2013). STEM (Science, Technology, Engineering and Mathematics) educational programs face the problems of attracting the students to proceed with their studies in these fields, even though they are ones of the most important for the industry and innovation.

At the same time, it is becoming more and more popular to use games and activities based on them as tools for teaching adults as well as children. However, if the game or activity is easy, related to artificial situations and doesn't have a link to the real world it might bring certain theoretical knowledge, but not practical knowledge and competence. This might be enough in case of school education, but the higher education should bring practical learning outcomes as well as theoretical ones.

Taking into account the above mentioned remarks, this master thesis is going to present an

educational activity based on the learning factory which is a copy of a real assembly line of roller skis used at IDT Solutions AS, thus combining the features of the game and experience based learning. The activity is focused on application of such concepts as *kaizen*, *waste types*, *efficiency* and *push and pull production systems* on the line in order to increase its performance. Running the activity on the copy of the real assembly line makes educational process being held in the real world brought into the class room (Abele et al., 2015). Moreover, the skis assembled by students during the learning activity will be sold by IDT to the customers; this makes the process even closer to the actual work experience. *“Learning Factories pursue an action-oriented approach with participants acquiring competencies through structured self-learning processes in a production-technological learning environment”* (Tisch et al., 2013, p. 580). In addition to use of the learning factory, the activity, developed within the master thesis, gives students opportunity to look on the possible challenges and problems that might appear on the assembly line implemented in the real company. In order to do this, the concept of experiential learning is used within the work. This type of learning process is stated to be a key factor that allows students to gain knowledge through experiencing things (Efstratia, 2014). At the same time, use of combination of the educational activity, together with the learning factory, might lead to development of the new knowledge used further for improvement of production processes in the real companies. In this case, as mentioned by Abele et al. (2015) one of the aims is to transfer the knowledge from academia to the industry.

This work is dedicated to answering the main research question, which is ***how to design an educational activity based on the learning factory in order to enhance the learning outcomes (experience) in the field of engineering and manufacturing education?*** However, in order to answer it, the next sub questions will also be covered:

- *How the activity was designed in the thesis?*
- *What are the learning outcomes gained by students from it?*
- *What are the benefits of using educational activity based on the learning factory versus use of learning factory or activity on their own?*
- *What is relation between developed educational activity and sensemaking?*

To sum up, this master thesis includes theory layout of related topics, description of the learning

factory, educational activity and its development, as well as description of the learning outcomes, results of use of the activity and answers to the above mentioned research questions. The paper also provides information about testing and running of the activity, as well as analysis of the interview with participants. Suggestions for further research and development of the activity will be also provided. The following subsections will give an overview of IDT Solutions AS, learning factory used as the base for the activity development and shortly describe the boundaries of the study.

1.2. Overview of IDT Solutions AS and the learning factory

IDT is a Norwegian company, which is manufacturing roller skis in addition to other products. The name of the company stands for Industrial Design and Technology AS and it was founded by Svein Iversbakken in 1995 (IDT, 2015). IDT helped to build the learning factory, which is used as one of the basic components for development of the educational activity described in this thesis. As mentioned before, the factory is a copy of the assembly line for roller skis implemented at IDT. Roller skis are used in order to train skiing skills when there is no snow.

The learning factory can be used to produce two main models of roller skis – *classical* and *skate*. The main difference between the models is the way wheel rolls. In the classical model wheels can roll only forward, while in the skate model they can go both ways (forward and backward). This adds a difference to the assembly process of the ski pairs, since there is different amount of parts needed to assemble different models. During the assembly process all the parts are put together in order to receive a ready product. The learning factory consists of the four work stations. The first station is used to assemble the *wheels*, the second one to connect the wheels with *a frame* and add *stickers*. The third station is needed to put on *mudguards*, *plates* and *ski bindings* on the frame, while the fourth one is used for *quality check* and *packaging* purposes. The short theory layout on the topic of learning factories will be given further in the thesis, as well as more detailed description of the factory at NTNU Gjøvik.

The educational activity is based on the previously mentioned learning factory. Its main purpose is to teach students what is kaizen/continuous improvements, what are the main waste types that appear during the manufacturing process, what is efficiency, what is the difference and use of push and pull production systems and how these concepts can be implemented in the

manufacturing industry during the work on the production line. The activity consists of two assembly rounds and of three discussion rounds during which students work on increase of efficiency, minimization of waste, change from push to pull production system with help of continuous improvements. Further description of details related to the activity and its development is provided later in the paper. In order to proceed to the theory section, it is also necessary to describe the boundaries of the study.

1.3. Boundaries of the study

The following study contains several boundaries that appeared mainly because of the time limits given to conduct it. It is necessary to describe them in order to give the readers a clear picture of the study and to make it easier to understand what the further research and development possibilities are.

The first boundary is focus of the activity on topics of kaizen, waste types, efficiency and push and pull production systems and not on other tools possible to be used for improvement of a production line. It was hard to develop an educational activity that would be interesting, had logical links between the parts and easy to go through within the given time boundaries. Adding more topics to the activity or expanding it to the set of educational games/activities based on the learning factory at NTNU Gjøvik can be one of possibilities for further development of the topic highlighted in the thesis. The second limitation is connected to amount of people that can take part in the activity simultaneously. For the moment of thesis completion this number is from five to six, as the activity is designed for four students, each being busy with tasks at one of the work stations of the line, and one or two students being dedicated to manager's activities. The number can be increased with making changes to the process of running the activity stages and adding more tasks. The third limitation is time needed to run the activity. It is necessary to remember that all the participants should be ready to spend at least three hours learning with help of the educational activity, otherwise, the process won't be completed and the learning outcomes might decrease. The next boundary is possibility to apply the activity. As it was developed specifically for the above mentioned learning factory, it is possible to run it only with the assembly line at NTNU Gjøvik or with a similar one. However, this can also be changed in future through generalizing the activity for bigger amount of situations and places. Among others, the limitation of technology is present in the study. Since the assembly line used during the activity is manual,

it doesn't include technological appliances such as screens showing time used for a certain stage of the activity or operation within it. However, this can be added in future during expansion of the learning factory and activity based on it. It is also important to know that the focus of the study was on interaction with students from Technology, Economy and Leadership faculty at NTNU Gjøvik. This limitation doesn't mean that activity cannot be ran with students from other faculties or programs. However, the study was easier to conduct with testing the activity with help of students from the same department. Altogether, there was one test run of the learning activity with four participants and two more runs with six participants in the first and five in the second. These are the main limitations of the study that can be improved or removed during its further development and research.

This section introduced the topic of the thesis, it also gave description of the company in collaboration with which the thesis work was completed, introduced the learning factory which was the base for the activity development and presented boundaries of the study. The next section will go deeper into the topic of the work and introduce all the main theoretical aspects of it.

2. Theory

This section will give an overview of the theory used as a basis for conducting the study. It presents all the main theoretical topics touched in the work in order to make the reader familiar with them and to understand the logics behind the research method used in the thesis. The section starts with a paragraph explaining the concept of learning factory and is logically moving towards the other topics that need to be highlighted.

2.1. Learning Factories

Learning factories concept is presented first, as establishment of NTNU's factory was the basis for the educational activity development described in this thesis. In other words, there would be no possibility to write the work if the learning factory did not exist. Nowadays learning factories term is becoming more and more popular as there appear more companies and universities that try to apply it. The reasons for this are multiple, starting with shorter life cycles of manufactured goods and ending with increasing variety of products (Tisch et al., 2013). *“Learning factories can be used by any company facing the challenge of remaining competitive and efficient in the face of continuous change and expanding product variety”* (Wagner et al., 2012, p. 114).

Even though the amount of learning factories established is rising (Abele et al., 2015), it is complicated to define the concept in a simple way. *“The term has 2 words: “learning” and “factory” and therefore should be used for systems that have elements of both”* (Wagner et al., 2012, p. 110). At the same time, the learning environment of the factory should include realistic production processes and be possible to be used for different target groups and teaching purposes (Wagner et al., 2012). *“The concept of the learning factory offers a well suited approach to meet the industries requirements: the continuous improvement philosophy is facilitated by individual actions and participants' active involvement as a genuine part of the overall learning conception”* (Tisch et al., 2013, p. 580). In other words, possibility to study within the environment, designed in a way that is as much as possible near to the real production line, leads to opportunities of gaining both theoretical knowledge and practical skills. It also gives an opportunity to understand that continuous improvement is an important part of the manufacturing process, which should be not only a tool, but an adapted philosophy followed every single day. *“By using a learning factory for teaching, theoretical knowledge can be more effectively*

communicated and tested for practical applications, and learning results can be transferred to industry” (Wagner et al., 2012, p. 110).

In addition, Bender et al. (2015) state that the learning factory is a suitable approach to be used in education of engineering students at the university as well as industrial participants. This point is especially important in case of the thesis, as the established learning factory, as well as the developed educational activity are going to be used mainly for teaching students from engineering programs.

The previous paragraphs have given an overview of some of definitions that can be found in the literature on the topic of learning factories, however, in order to increase understanding of the concept Abele et al. (2015) has proposed a model containing the key features of the factories shown in Figure 1.

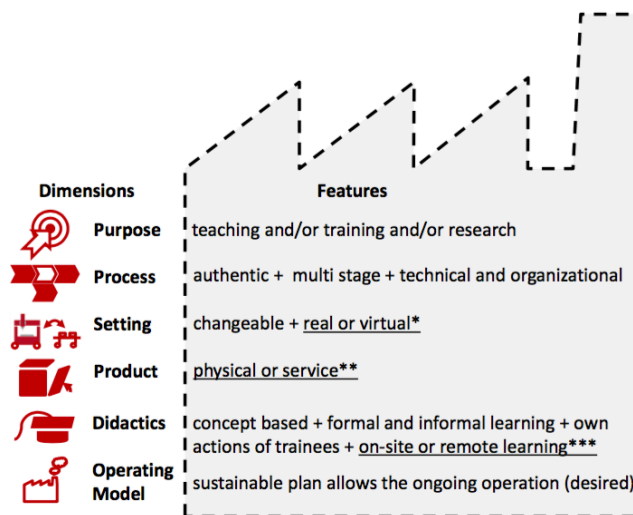


Figure 1. Key Features of Learning Factories (Abele et al., 2015)

The figure depicts that the learning factory has six main features:

- purpose – teaching and/or training and/or research;
- process – type of the process implemented as a part of a factory;
- setting – type of setting, which can be changeable, real or virtual;
- product – type of product manufactured at the factory (physical or service);
- didactics – what, how and by whom should be learnt;

- operating model – nature of operating institution, staff, funding (Abele et al., 2015).

It also displays what exactly is meant by each of them. So, the learning factory might be a combination of any of mentioned in the figure possibilities. At the same time, it is extremely important to remember that the learning factory is not only a duplicate or a copy of the industrial factory (Wagner et al., 2012). The factory necessarily contains the educational and/or research component, while the usual one is often dedicated only to the manufacturing purposes and is not taking into account the other peculiarities of the learning case.

Furthermore, one of the important goals of the learning factory use is either technological or organizational innovation. This aim is desirable to be achieved in both cases of using it as research or educational tool. In case of using it as the research tool it is important to have it linked closer with innovations such as new prototypes, product technologies, production technologies and processes (Abele et al., 2015). On the other hand, if it is used as educational or training tool it should be capable of increasing students' competence in certain topics (Abele et al., 2015). One of important topics in case of the competence building is boost of sustainable productivity and application of continuous improvements.

It is important to remember that the learning factories are similar to usual factories in a sense that copying of one doesn't guarantee its successful work, as there are too many disturbing factors present during its use. *“No learning factory usually resembles another or is used in the same way”* (Abele et al., 2015, p. 4). The reasons for this can be multiple, however, the most important is difference in the environment factories are created and used in.

In addition to all above mentioned possibilities to apply the factory, there is another one, which was briefly mentioned previously – opportunity to use it in order to educate the future workers of the companies and shorten time of their education of working within the particular production system or line. *“Learning factories represent an effective and efficient concept for the transfer of knowledge and conveying competences”* (Nöhring et al., 2015, p. 110).

All described features of the concept make it extremely attractive for higher educational institutions and companies to be used as an effective tool for educational and research properties,

as it brings possibility to go into the real world while physically staying in the classroom. This thesis used the learning factory as the basis, however, it is not concentrating on the questions of its development. Never the less, more detailed description of the factory and its structure will be given in the results section of the paper in order to simplify readers understanding of the educational activity developed on its basis. The following subsection will explain the role of experience based learning and experiential learning cycle in the thesis.

2.2. Experience based learning and Experiential learning cycle

This master thesis is describing development of the educational activity based on the learning factory, however, the main aim of creation of both the factory and the activity is to make students more interested and eager to learn, thus bringing them more *knowledge* and *learning outcomes*. These two terms are being mentioned several times in the paper, it is though important to clarify what do they mean in this context.

Here knowledge can be simply defined as *“information, understanding, or skill received from experience or education”* (Merriam-Webster, 2016). The learning outcomes, on the other hand, *“are the learning results desired from students. These results are demonstrations that occur after the end of a significant learning experience”* (Spady, 1994, p. 49). In addition, the outcomes are not an average or a collection of the previous learning experiences, but a manifestation of what are students capable of doing after experiencing all of the learning activities. It is also important not to confuse the learning outcomes with outcome aliases such as: attitudes, feelings, aptitudes, objectives, assignments, grades, values, beliefs, goals, activities, scores or averages (Spady, 1994).

These concepts are being often used in the paper and have a strong relation to the Didactic Relations Model applied for planning and reflection, allowing teachers and professors to define the key factors within the teaching situation and understand how are they interrelated (Skagen et al., 2009). During planning of the educational activity six didactic categories of the model were defined: learning conditions, settings, goals, content, learning process and assessment.

According to Nöhring et al. (2015, p. 110) *“the effectiveness of learning and learning outcomes strongly correlates with the teaching method. Students retain only 5% of knowledge taught by*

passive ex-cathedra teaching but up to 75% from active learning methods". One of the active learning methods is experiential learning, which is strongly connected to serious games and educational activities based on them. Among other advantages it should also be highlighted that this method is one of the most beneficial for manufacturing and engineering students, as here they get to work in the real situations. As a result, after their graduation they have knowledge and experience that can be easily applied.

"The theoretical foundations for simulations, games, and other forms of interactive, experience based learning had been in place at least since the writings of Aristotle and the practices of Socrates" (Ruben, 1999, p. 500). Unlike the traditional passive learning techniques, experiential learning is concentrating more on the process than on the outcome of an activity. It also doesn't perceive ideas expressed during the class as something fixed. Opposite to this, ideas are stated to be something that is constantly changing through experience (Kolb, D. A., 2014). *"Experiential learning stimulates original thinking and develops a wide range of thinking strategies and perceptual skills which are not called forth by books or lectures"* (Williams, 1986, p. 170) This is what is expected to be provided to students through giving them opportunity to work with the educational activity applied on the learning factory. It will lead to possibilities to try doing the real things related to the industry not leaving the walls of the educational institution.

Experiential learning accommodates diverse approaches to learning processes and outcomes, it allows interactivity, promotes collaboration and learning in groups, fosters active learning and is based on learning by doing (Ruben, 1999). These features are extremely important as their lack will return us to the same limitations as the passive learning methods have. Collaboration and learning in groups is a useful and important part of experiential learning, since, in this case, students learn not only the knowledge they discover on their own, but also share their experiences, thus gaining much more from the process. In addition to already mentioned advantages, such type of learning addresses possibility to apply the knowledge in the real problem situation (Cachay et al., 2012).

As one of examples of students' feedback about activity, based on experiential learning, in one of the classes in manufacturing study program Gray (2011, p. 87) mentioned that *"experiential*

learning of the managerial aspects of a production line opened student's eyes to what (in their own words) "were amazing ramifications of real-time problems"". He also described that when students went through the educational activity, where they could perform a hands-on manufacturing of the paper product on the fabrication line set up in the classroom, they experienced complexities of the real line with need to analyze and deal not only with soft-sided questions, but also with technical challenges.

According to Kolb, A. Y. and Kolb (2012) experiential learning has six main propositions which are mentioned in works of experience based learning scholars, these are:

- Learning is best conceived as a process, not an outcome;
- *"All learning is re-learning. Learning is best facilitated by a process that draws out the students' beliefs and ideas about a topic so that they can be examined, tested and integrated with new, more refined ideas"*;
- Learning requires resolution of conflicts between different modes of adaptation to the world. *"Conflict, differences, and disagreement are what drive the learning process. It is important to move between modes of reflection, action, feeling and thinking"*;
- Learning evolves from interaction between an individual and his/her environment;
- Learning is a result of holistic process of adaptation – it includes thinking, feeling, perceiving and behaving. None of these can be excluded;
- Learning is the process of knowledge creation (Kolb, A. Y. and Kolb, 2012).

All of above mentioned features and propositions of experiential learning can be used as a part of the framework for the educational activity development. These propositions show that experiential learning process is a complex activity, which includes not only changes from individual to group knowledge creation process, but also switching between feeling, action, reflection and thinking. This component is often excluded in the conventional learning techniques, thus limiting student's activity to only one of above mentioned modes. Such approach significantly decreases amount of information perceived and knowledge created, while experiential learning, on the other hand, enhances it. In addition, experiential learning cycle shown on the Figure 2 can also be a useful tool for the activity planning and development. It

perfectly depicts the idea that within experiential learning, the learning itself is defined as the process of creation of knowledge through transformation of experience (Kolb, A. Y. and Kolb, 2012). It also shows that in order to gain knowledge, repetition of learning actions is needed.

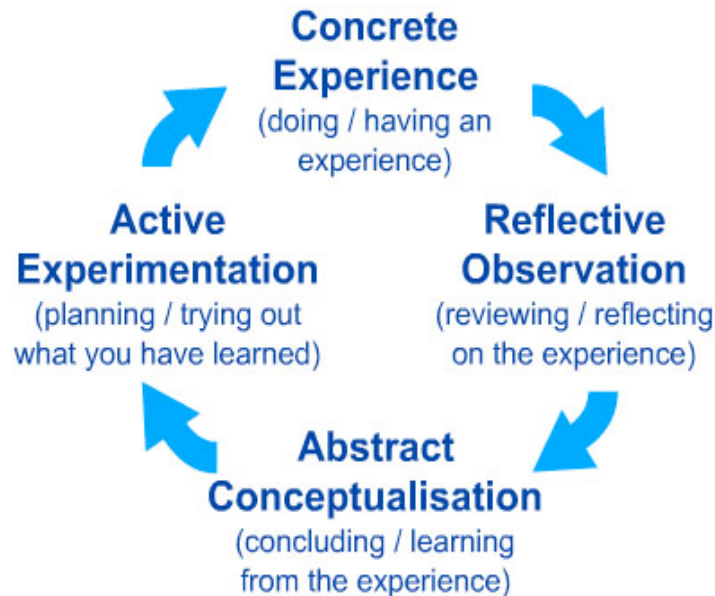


Figure 2. Experiential learning cycle (McLeod, 2010; Kolb, A. Y. and Kolb, 2012)

The learning cycle consist of four stages:

- *Concrete experience* means actually experiencing things and/or doing something in order to learn. This stage of the cycle is also a basis for observations and reflections that are following up in the cycle.
- *Reflective observation* means process of reflecting on the experience gained in the previous step. It is a very peculiar and interesting moment of the learning process, if a learner feels that the concrete experience doesn't correspond to the previous experience or understanding.
- *Abstract conceptualization* is entered after reflection on the new experience and means rise of a new idea, understanding or modification of the previous knowledge.
- *Active experimentation* is needed in order to test whether that, what was reflected upon and understood during the previous stages, fits into the world around the learner (McLeod, 2010). This learning cycle was chosen as a basis for the educational activity development and its practical application will be described in the section where the activity is presented.

After description of such concepts as experience based or experiential learning and experiential

learning cycle, the next section will present the theory related to game based learning and serious games themselves, as *“game-based learning is often experience-based or exploratory, and therefore relies upon experiential, problem-based or exploratory learning approaches”* (De Freitas, 2006, p. 6).

2.3. Game based learning and Serious games

Several decades ago it was hard to imagine possibility of using a game as an educational tool or even as a basis for learning activity at higher educational institutions, if it was not a war game for training soldiers (De Freitas, 2006). As mentioned before, active learning methods avoid limitations that are present during teaching with use of the old fashioned techniques. *“The science education literature indicates that science at educational institutions is often delivered in a conventional way, which is very similar across countries and includes transmissive pedagogy, un-engaging curricular content and in several cases is associated with difficulty”* (Oliveira et al., 2013, p. 131). Nöhring et al. (2015) state that such type of learning leads to 5% of knowledge being retained, which is obviously a very small amount, while use of learning techniques such as experiential learning gives a level of 75% of material perceived and remembered by learners. Among others, game based learning and serious games are a good way of implementation of active learning and a good combination together with experiential learning. Serious games can be defined as those that have as a purpose to provide learners with *“authentic learning experience where the entertainment and learning are seamlessly integrated”* (Charsky, 2010, p. 3).

The question of low level of retained knowledge is critically important in all spheres of education, especially in fields of engineering and manufacturing. This fields face challenge not only in making the learning process more engaging and interesting, but in attracting students to study on such programs in general, as mentioned in the introduction. Oliveira et al. (2013) is presenting a visual description of so-called STEM (Science, Technology, Engineering and Mathematics) pipeline depicted in the Figure 3. The pipeline metaphor is commonly used to highlight the fact that amount of students graduating from STEM programs is decreasing with students dropping out from them on different levels of education. This process starts on the level of primary education and continues up to tertiary education and employment. One of the main reasons for this is use of conventional passive learning techniques, which require unbelievable amount of concentration from students that want to memorize and understand more than 5% of

the proposed material.

Another big challenge in this field is extent to which the knowledge, gained during the learning on different study programs, is theoretical. The reason for this is that “*companies expect their employees therefore to utilize their knowledge but also to operationalize it in unimaginable situations. Therefore, production-related education requires new approaches that allows future and actual employees to act independently in real problem situations*” (Cachay et al., 2012, p. 1144). As stated before this is one of the reasons why the educational activity with serious game features was decided to be created.

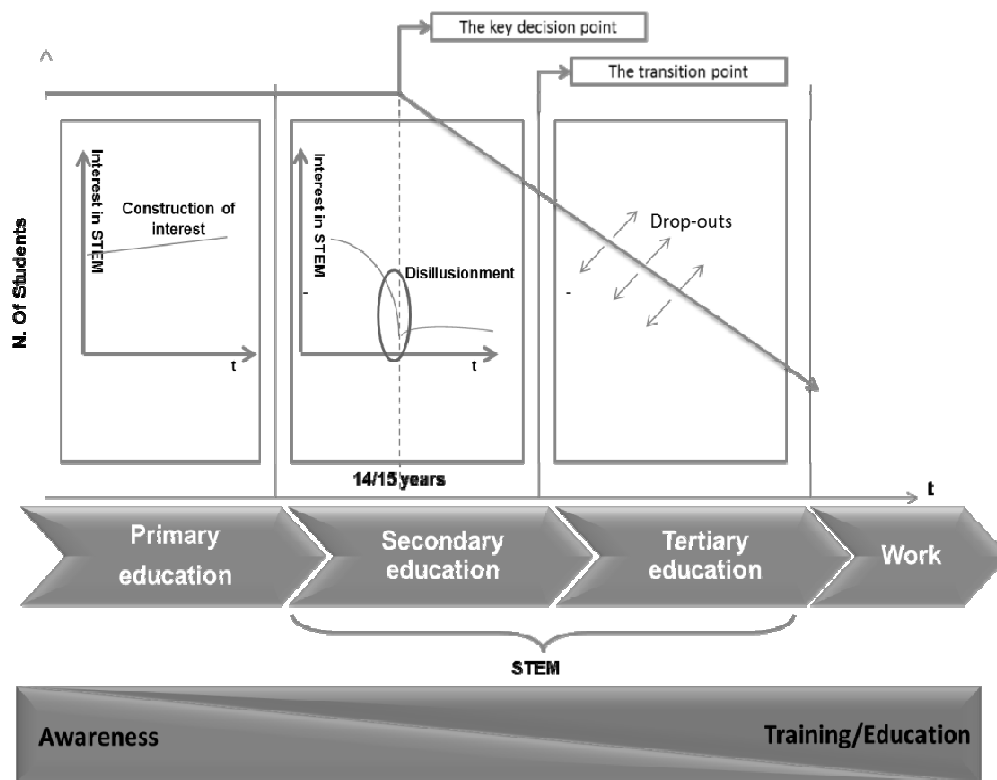


Figure 3. STEM pipeline (Oliveira et al., 2013)

Even though game based learning is a good solution to the above mentioned problems, it is not that often applied in the manufacturing and engineering education (Tehran, Taisch and Fradinho, 2013). The most valuable reason for this is lack of clear guidelines, case studies and examples for design and improvement of game based learning, serious games and activities that use them as a basis (De Freitas, 2006). “*In other words, teachers need assistance in developing the*

technological, pedagogical, and content knowledge needed to effectively use games for learning” (Denham, Mayben and Boman, 2016, p. 71).

As it was mentioned before, game based learning means all kinds of activities that are games at their core, but have learning as an outcome (Denham, Mayben and Boman, 2016). *“However, memorable educational experiences should not only be enriching and transformational but also enjoyable”* (Ebner and Holzinger, 2007, p. 874). As a result, there is another big difference between game based learning and traditional learning – games involve the play component, while schooling usually does not (Klopfer, Osterweil and Salen, 2009). Furthermore, Klopfer, Osterweil and Salen (2009) state that games frequently give player freedom along five different axes, that can be rarely found within any educational activity:

1. *Freedom to fail* – there is no fear of failure during the game, as you can either restart or redo an action. A game doesn’t end with unchangeable score (unlike a test with a grade), it might always be played one more time, the actions can be changed and desirable result reached. This feature is very important within education, as when you are not afraid to fail, you might start experimenting.

2. *Freedom to experiment* – this freedom is a straight outcome of the previous one. It allows player to act differently from what he or she is used to. This possibility may lead to new achievements both in the game and in the real life.

3. *Freedom to fashion identities* – this freedom means opportunity to try on different roles of different characters thus exploring the surrounding world under their cover.

4. *Freedom to effort* – it is absolutely up to the player how hard he or she is trying to do a certain action at the particular moment of time, as there always can be a second chance to try better and harder.

5. *Freedom to interpretation* – *“there is no “one” game”* (Klopfer, Osterweil and Salen, 2009, p. 5). Even though participants are playing the same game, their individual characteristics influence their experience.

These freedom axes are critically important for those working on development of the games or activities based on them, since they give a core understanding of why the difference between conventional learning and game based learning is so big.

As game based learning might mean different kinds of activities, according to De Freitas (2006), there are four main types of this learning: educational games, online games, serious games and simulations. “*A serious game is a game in which education is the primary goal, rather than entertainment*” (De Freitas, 2006, p. 10). Such definition leads to a conflict with the game definition by Huizinga (1967), as he stated that “*games as a free activity stand quite consciously outside ‘ordinary life’, as being ‘not serious’*” (De Freitas, 2006, p. 10). However, serious games exist and even though they are used for serious purposes, they still are not ordinary life as long as it is possible to play them.

“*Serious games are so-called because they integrate gaming elements with learning or training objectives. The name also refers to a movement of researchers and developers who are working towards developing games specifically aimed at educational audiences*” (De Freitas, 2006, p. 70). However, in order to understand deeper what an educational activity with serious game features should include, it is necessary to add list of attributes usual for this type of games. As this work is mainly dedicated to development of the activity used for manufacturing and/or engineering education, these attributes will be specified for this field. The list of the attributes and their performance indicators is presented in the following Table 1 adopted from the work by Tehran, Taisch and Fradinho (2013).

Performance indicator	Description
Rule and Goal	Identifying the rules and goals, identifying specific learning outcomes, providing various ways to achieve goals, providing constructive, clear and frequent feedback.
Sensory Stimuli	Providing a manufacturing and engineering processes through engaging students into interaction with learning factory.
Control	Provide a responsive learning environment, providing different level of choices and solutions, giving opportunity to experiment and act.
Challenge	Providing optimal level of information, provide positive feedback in order to promote feeling of competence.
Interactivity	Making the game neither boring or anxious.

Table 1. Attributes of serious games and their performance indicators (Tehran, Taisch and Fradinho, 2013)

Table 1 explains that the serious game should include such features as rule and goal, sensory stimuli, control, challenge and interactivity. It also shows what is meant by the attributes not to confuse the reader. This table one more time reflects on the difference between serious games and activities based on them and usual educational activities, since serious games include not only controlling and engaging features, but also interaction. Another important component of the serious game is motivation of students (Ebner and Holzinger, 2007). However, it should be quite easy to achieve, if the developed game is playful and enjoyable. These aims should be reached through application of the above described features of serious games and game based learning. Description of educational activity based on the serious games properties and its development, as well as application of above mentioned attributes, features and definitions will be provided in the following sections of the thesis. The next theoretical subsection will tell about the concept of sensemaking and its role in this work.

2.4. Sensemaking

As it was mentioned previously, learning is an active process, where the learner is the main actor and knowledge and understanding are the main results. However, they can be only constructed or produced by the learner him- or herself (Ebner and Holzinger, 2007). This is where the process of sensemaking takes place and that is why it is interesting in the context of educational activity. The main questions asked, by those interested in sensemaking, are what is constructed, why and with what effects (Weick, 1995). *“The concept is well named because, literally, it means the making of sense”* (Weick, 1995, p. 4) and there are no doubts that sensemaking is a natural process for everyone. The framework of making sense described by Weick is quite suitable here, as it is elaborated in a wide range of different fields (Klemsdal, 2008).

As many other concepts, sensemaking has different definitions according to different scholars. Louis (1980), for example, says that it can be viewed as a continuous cycle consisting of a sequence of events happening during certain period of time. In this case, the process begins as unconscious or conscious expectations or assumptions, regarding future events of an individual, and continues as the events are occurring and often are not the same as predicted. Such occurrences trigger the need for explanation of those things that are not answering the expected patterns. In the end of a sensemaking process, individual receives a meaning that was made up by him/her (Louis, 1980). This process is somehow similar to what is happening during the

experiential learning cycle, when the concrete experience of a learner doesn't correspond to the previous experience and understanding. Klemsdal (2008, p. 87) defines it as *"a process that is evoked when we are interrupted in our ongoing daily activities by our expectations not being met; it is about making sense of a situation, an event or a phenomenon that is new to us and experienced as ambiguous"*. Thomas, Clark and Gioia (1993, p. 240), on the other hand, define the sensemaking as *"interaction of information seeking, meaning ascription, and action"*. Here the environmental scanning and interpretation are also involved. It should also be remembered that sensemaking and interpretation are two different things and they are not to be used as synonyms, as interpretation might be defined as *"acceptable and approximate translation"* (Mailloux, 1990, p. 121) or *"a rendering in which one word is explained by another"* (Weick, 1995, p. 7), while sensemaking is clearly something different. At the same time, Feldman (1989) speaks about sensemaking as about an interpretative process. Here it is necessary to share opinions of members of a group about the functionality of a process all of them are involved into. She also states that sensemaking doesn't necessarily result in an action, but might equally result in creation of understanding or knowledge (Feldman, 1989).

Another important feature of making sense is that it can be both an individual and a group issue. Since *"sense may be in the eye of the beholder, but beholders vote and the majority rules"* (Weick, 1995, p. 6). This point is well fitting into the educational activities context, as here the learners are producing the knowledge mostly in the group with their colleagues, but also each individually.

In order to understand the sensemaking better Weick (1995) proposes to take into consideration the seven properties of the process, which distinguish it from other explanatory or knowledge creating mechanisms. In this case, sensemaking is proposed to be viewed as a process that is:

1. ***Grounded in identity construction.*** The first property means that an individual is always a set of 'selves' (Weick, 1995). The sense might change depending on how a sense maker perceives him- or herself. This feature is similar to the freedom to fashion identities as described in the game based learning theory, in a game a player has possibility to act in a different way depending on the character he is acting as. Identity construction also depends on which role has a sensemaker in it. For example, if a person looks at a situation as a manager in the company, there

is one type of sense made, however, if a person then makes sense as an operator worker – the sense will probably change.

2. **Retrospective.** This feature shows that sense is constructed through looking back at previous knowledge or “*meaningful lived experience*” (Weick, 1995, p. 24). Moreover, it is impossible to make sense without making that, what the sense is made of, a part of the past. “*Reality is always the moment of vision before intellectualization takes place*” (Winokur, 2005, p. 82).

3. **Enactive of sensible environments.** Here it is meant that depending on actions, environment, needed to be dealt with, is changing correspondingly. For example, if a child that is not a very good swimmer is asking his mother permission to go to swim, it is up to the mother what to answer and depending on her answer she will need or not need to go and watch a child swimming to help him in case something happens. The same can be viewed in games, when depending on actions of the player, he or she enters different scenarios in the game.

4. **Social.** “*Sensemaking is never solitary because what a person does internally is contingent on others. Even monologues and one-way communications presume an audience*” (Weick, 1995, p. 40). The process of sensemaking is in one or another way influenced by others, it might be influenced physically as well as metaphorically.

5. **Ongoing.** This property means that sensemaking never starts as it never ends. “*People are always in the middle of things, which become things, only when those same people focus on the past from some point beyond it*” (Weick, 1995, p. 43). An example of such situation is when the educational activity is over, however the students continue reflecting on that what they have experienced during it. Later in the class they might read something related to the activity topic and continue their process of making sense of it, afterwards their knowledge will be applied and rethought again. Here it is visible that it is hard to understand where the beginning and end of the process were.

6. **Focused on and by extracted cues.** “*Extracted cues are simple, familiar structures that are seeds from which people develop a larger sense of what may be occurring*” (Weick, 1995, p. 50). This feature means that individuals focus on such small, familiar structures in order to understand the surrounding environment. However, depending on this environment, extracted cues might evolve into different kind of sense. An example of this property is when there is a company embarking on a certain task. However, the workers are not sure how to reach

it. In this case, they rely on their leader or manager to explain them what they are supposed to do. Often it happens that those on the top are not sure themselves how to reach the desired goal. What they need to do is to lead the group into generally right direction, cheer them up and provide support. After doing so, the members of the group should start making sense of the surrounding situation, look for extracted cues and understand more and more how to reach the goal through increasing the sphere of their awareness (Weick, 1995).

7. ***Driven by plausibility rather than accuracy.*** By this property it is shown that in case of sensemaking, it is more important to create plausible sense than accurate. Here accuracy is nice, but not necessary. On the other hand, it is more important to have something that is *“reasonable and memorable, something that embodies past expectations, something that can be constructed retrospectively, but used prospectively”*, etc. (Weick, 1995, pp. 60-61). In other words, *“filtered information is less accurate but, if the filtering is effective, more understandable”* (Starbuck and Milliken, 1988, p. 41).

All of these properties together with different definitions of sensemaking are quite important for the study, as they give possibility to understand deeper how the sense is constructed and what is necessary to be added into the learning activity to give participants possibility to extract as much sense as possible from it and to make the activity of higher usefulness. It often occurs that educational activities are carefully planned by teachers, but they don't think about how students will make sense of them and, as a result, fail to bring all the necessary knowledge. It is also important to note, that not all aspects of sensemaking fit into the educational activity perspective, however, the links between the concepts will be shown more detailed in the discussion part of the thesis. After presentation of such concepts as learning factories, experience based learning, game based learning and the sensemaking, theory used *within* the educational activity is described in the following section.

3. Theory used within the educational activity

After giving an overview of the theory the educational activity development was based on, it is necessary to present theory which is taught with help of the activity. As it was stated before, the activity was planned in order to increase students' knowledge on topics of kaizen or continuous improvements, waste types, efficiency and, in particular, efficiency in manufacturing, as well as push and pull production systems. In this subsection these concepts will be briefly defined to give reader a deeper understanding of structure of the learning activity.

3.1. Kaizen or continuous improvements

The first concept to be explained is *kaizen*, which is usually translated from Japanese as “continuous improvements”. As mentioned before, in the work by Tisch et al. (2013) it is stated that kaizen is quite natural to be taught through interaction with learning factories and since the educational activity is based on the factory, it is easier to include this concept into those learnt during its run. Understanding of kaizen through its practical application during the activity brings students significant benefits, as continuous improvements philosophy is often used in the industry. *“The concept of kaizen is a mandate to constantly improve performance. At the root of kaizen is the idea that nothing is perfect and everything can be improved”* (Liker and Convis, 2011, p. 36). Kaizen is important to be applied in every company, because each worker should understand that there is always room for improvement and that the process is never perfect. *“No matter how many times it has been improved, every step in the production line is full of waste; even if it could be perfect today, conditions will change tomorrow, and more waste will creep in”* (Liker and Convis, 2011, p. 37). At the same time, there are always different aspects that can be improved within a company in general and not only in a particular process. For example, if the manufacturing process has been improved, it doesn't matter that packaging doesn't produce too much waste, or the other way around. It is necessary to understand that that there is no limit for perfection and there is always something that can be done better. This leads to conclusion that kaizen is not only a concept or a tool, moreover, it is a philosophy, that should be constantly followed, otherwise, there will be competitors that will follow it and conquer a market share. Students get possibility to use this philosophy throughout activity and experience its benefits, thus understanding its importance.

3.2. Waste types

The second topic of the activity is *waste types*. Necessity to learn it logically comes from the previous concept, as continuous improvements is often connected to elimination of waste. However, in order to be able to decrease amount of waste, it is necessary to understand which waste takes place. According to Ohno (1988) there may be three main groups of waste in the production systems: *muda*, *mura* and *muri*.

Muda is one of three waste types which can be defined as ‘wastefulness’ or non-value added activity performed for the end customer. Muda can be of two types, where the first means a non-value added activity, which is necessary, while the second one is defined as activity that is non value adding and not necessary, thus it can be eliminated (*Wikipedia*, 2008). In addition to this, Ohno (1988) was distinguishing seven types of waste belonging to muda category, which are shown in Table 2.

Type of waste	Explanation
1. Transportation	Moving products that are not actually required to perform the processing.
2. Inventory	Production and storage of products not ordered by the customer.
3. Motion	People or equipment moving or walking more than is required to perform the processing.
4. Waiting (delay)	Waiting for the next production step.
5. Overproduction	Production ahead of demand.
6. Over- or inappropriate processing	Adding extra values, when they are not requested by the customer.
7. Defects	The effort involved in inspecting for and fixing defects.

Table 2. Seven wastes (Ohno, 1988; Robinson et al., 2012)

Mura and muri, on the other hand, are separate categories of waste that are not part of muda. Mura is related to ‘unevenness’ or ‘imbalance’ – big difference in load of production processes or workers. Muri, on the other hand, can be translated as ‘overload’ or ‘excessive strain’, meaning that the work load should not be too big and the working conditions need to be good enough for a

worker to feel him/herself comfortable (Robinson et al., 2012). The following Figure 4 illustrates the difference between muda, mura and muri in a very simple way.

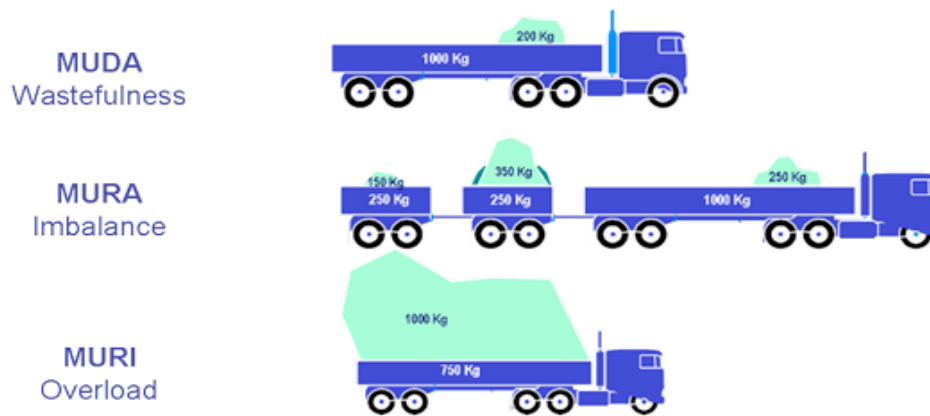


Figure 4. Muda, mura and muri (Pinterest, 2016)

It is easy to see the difference between the waste types from Figure 4, where muda is shown to be waste of different kind of resources, mura unbalanced use of them and muri – exploitation, which leads to nothing else except fast wearing out and failure. The participants of the learning activity interact with a copy of a real assembly line, this allows them to see what kinds of waste might appear in proposed assembly process and how they can be avoided.

3.3. Efficiency

The next concept is efficiency or manufacturing efficiency, in this case. *“The simple definition of manufacturing efficiency is to fulfill customer orders as quickly and reliably as possible using the least amount of inventory and work in progress”* (DBA Manufacturing, 2015, p. 5). The term is closely related to the previous ones, since elimination of waste and following the continuous improvements philosophy will undoubtedly lead to increase of manufacturing efficiency. The students experience need of increase of efficiency and work through the activity in order to improve their result.

3.4. Push and Pull

The last, but not the least topic touched in the educational activity is push and pull production systems and their difference. *“Push type means Make to Stock in which the production is not based on actual demand. Pull type means Make To Order in which the production is based on actual demand”* (Lean manufacturing - Japan, 2008). At first students experience work with push production system and are able to see which disadvantages are in use of it, later they have

possibility to switch to a pull system, thus assuming that they have an order that is supposed to be fulfilled on time and with as high as possible efficiency. In the end, participants are able to easily distinguish one system from another and understand advantages and disadvantages of use of both of them in the context of the activity and learning factory.

This section has presented the main theoretical topics taught during the activity. The following section describes and explains the research method used to conduct the master thesis.

4. Research Method

This section will describe methodological view and the research method of the thesis. It will start with explanation of research aims and go through other parts until validity and reliability subsection. As it was stated in the background section of the paper, there are two main components of the motivation to conduct the study. The first one is necessity to give students possibility to gain practical knowledge with good theoretical basis, this can be done through creation of an educational activity based on the copy of a real assembly line and having certain features of serious game as a core. Such activity will give opportunity to bring the real industrial world into the classroom, thus enhancing students' practical experience. The second part is need in creation of guidelines and solid examples of development and use of similar educational activities in manufacturing and engineering education, since application of them in this field is surprisingly low, while need in practical knowledge is extremely high.

The thesis is aiming to fulfill above mentioned needs through answering the main research question formulated as follows: ***how to design an educational activity based on the learning factory in order to enhance the learning outcomes (experience) in the field of engineering and manufacturing education?*** However, in order to make it clearer several sub questions will also be answered: *how the activity was designed in the thesis?* The answer to this sub question will give readers deeper understanding of the process of the educational activity creation in particular case of the thesis and in general. *What are the learning outcomes gained by students from it?* Here it will be explained which knowledge students gained through participation in the activity through analyzing the group interviews held after running the activity. *What are the benefits of using educational activity based on the learning factory versus use of learning factory or activity on their own?* The answer will explain why it is better to use an educational activity together with learning factory instead of application of only one of them. And *what is relation between developed educational activity and sensemaking?* This question will help to understand how the educational activity needs to be designed in order to enhance the learning experience. The following subsection will present research aims of the study based on motivation and research questions.

4.1. Research Aims

Research aims of the study can be listed as follows:

1. Develop an educational activity based on the learning factory and implement it.
2. Run the activity in order to conduct a case study, where the learning outcomes of participants are revealed.
3. Provide description of the learning activity development and application in order to facilitate creation and implementation of similar activities.
4. Find the links between educational activities, learning factories and sensemaking.

As it is easy to see, all the research aims have a strong connection to motivation and research question and sub questions of the thesis and can be covered if the answers to them are given. The next subsection describes which methodological view was used in the thesis.

4.2. Methodological view within the study

Depending on the character of the study and views of its author there might be different methodological approaches applied. These approaches often differ significantly and, as a result, outcomes might not only vary, but contradict with each other. However, this gives possibility to percept the same question from different angles, thus receiving more and better results. This work uses actors methodological view, which is described in more details in the following paragraphs.

While presenting certain view on knowledge creation it is important to take into account such points as:

- conception of reality;
- what knowledge depends on;
- which goal is chased – understanding, explanation or both;
- nature of result;
- prerequisites for continuing.

Conception of reality. Reality in the actors approach is claimed to be socially constructed and consist of finite provinces of meaning shared by different number of people, who have their own sociocultural significances. These parts of reality can be perceived as objectified, but not

objective, since they are created by actors that have different backgrounds. In this case reality depends on its observers, just as knowledge created by students taking part in the educational activity differs from individual to individual. Here reality is grounded in identity construction, as described in the theory related to sensemaking. Depending on who the actor is, his/her reality is created, and also the actor is changing depending on surrounding reality (Arbnor and Bjerke, 2008).

Knowledge depends on individuals and knowledge creator. As it was already mentioned before, reality is dependent on individuals, so is knowledge that is created. In the framework of objectified reality established with help of world views, beliefs and behavior of one or another individual, new knowledge is seriously subordinated to the individuals that are involved in the process of creation and their perception, actions and interpretations of environment.

Understanding. The view is trying to develop understanding of dialectic relations that are continuously changed and reinterpreted. To achieve this, it is necessary to understand finite provinces in which individuals are acting, after this researcher can proceed to understanding actions in the social world and dialectic relations directly (Arbnor and Bjerke, 2008). It can also carry internal or external character, where internal character is related to understanding of the concrete situation that actors are involved in, while external means creation of new way of thinking and acting.

Nature of result. Knowledge creation is resulted in appearance of new forms of descriptive language in its various forms (Arbnor and Bjerke, 2008). Important thing to take into account is that result is created through interactive development of understanding. Here the result appears, first of all, as a product of actor's perception of surrounded and created by him/herself reality, which, never the less, depends also on those around the actor bringing in the social component.

Prerequisites for continuing. This view is strongly connected to the personal development of knowledge by individuals themselves, so, previous experiences and knowledge can be involved in the process both for actors and researchers. Previously established by investigators of knowledge theories are encouraged to be used. After shortly describing the methodological view

used in the study, the following section will describe the methods applied within the thesis.

4.3. Methods used to conduct the study

In order to receive desired results of the study there were several methods used. At first the literature review was conducted in order to go deeper into the topic of the thesis and gain a better understanding of theoretical concepts used within it. This step gave opportunity to gather information about some of existing serious games and educational activities related to them, their development and application processes. For example, here it was defined that such activities tend to be more effective if they contain of several rounds.

At the same time, two ways of presenting the theory to students during the learning activities were discovered. The first method is ‘push’, here students get the theory before being introduced to the problem, while ‘pull’ method contains of presentation of the problem first and later the theory (Tisch et al., 2013). It was decided to use the ‘push’ method in the activity, as then students have a better understanding of how to categorize information during its run.

Later it was necessary to choose a method for evaluation of the educational activity and the learning outcomes. It was decided to have one pretest of the activity in order to increase reliability and validity of the study, where four people participated and to hold two more runs of the activity with six participants the first time and five in the second. As a result, a method of group interview also was chosen, since it is qualified as a qualitative research method, which evaluates *“characteristics, or qualities, that cannot be entirely reduced to numerical values”* (Leedy and Ormrod, 2013, p. 97). It was necessary to choose a qualitative method rather than quantitative, as learning outcomes and educational activity effectiveness are hardly quantitative values. In case of choosing the qualitative method, validity of the study could be easily questioned. However, in addition to conducting the interview right after the activity it was decided to have one more interview session with participants in a week. Such approach increases sufficiency of gained results as the knowledge gained through activity will be tested not only straight after taking part in it, but also significantly later. This will help to understand if participants have really learnt something or not. For this purpose, the interview questioner for both sessions was created, if the further information about the questioner is needed, it can be found under the Appendix B part of the thesis. The following section will explain in more details

how validity and reliability were dealt with in the study.

4.4. Validity and Reliability

Reliability and validity are crucially important for any study, since they are the main characteristics showing whether the scientific work is worth taking into consideration. According to Golafshani (2003) reliability can be defined as extent to which results are consistent in means of time passing, evaluation and accurate representation of the examined phenomena/population. If results of the study can be reproduced following similar methodology, the study can be considered reliable. Validity, on the other hand, is stated to be determining if the study is measuring that what it was intended to (Golafshani, 2003). In addition to this there are several criteria proposed by Guba and Lincoln (1989), which show how good is validity of the qualitative work; they will be now presented and explained in the context of the master thesis.

The first criterion is *prolonged engagement*, according to Guba and Lincoln (1989) it means involvement into the corresponding case or field. As it was mentioned before, the master thesis was carried out in cooperation with IDT during the Spring semester 2016, the time of engagement was thus limited to one study semester. However, the author of the thesis was familiar with the company and roller skis production line the learning factory is based on from Autumn semester 2015, when the project work mentioned in the background section was carried out with the same partners.

The second criterion is *persistent observation*, which provides depth of the study scope. In case of the master thesis, the production system within IDT was studied in order to understand better how the learning factory and educational activity should be built, in order to bring practical as well as theoretical knowledge to students. In addition to this, literature review was carried out to study cases of similar educational activities.

Peer debriefing means discussing the study with those not involved into it directly, but by implication. In this case, two professors from NTNU Gjøvik were helping, as well as one professor from Hedmark University College. In addition to this, case of the master thesis was discussed with friends and relatives. During these discussions, certain improvements of the work appeared and were afterwards used.

The next criterion is *negative case analysis*, it means refining conclusions until they correspond to all similar cases. Here further research is necessary in order to make conclusions of the study more solid, as educational activity developed during the work was tested on four students and then ran two times with 11 people participating. The reason for having few runs of the activity is limited time to conduct the study, as time of work on the master thesis is limited to one semester. To increase validity of the study according to this criterion, it is necessary to run the activity with more students and have participants from different study programs, higher educational institutions or companies.

Progressive subjectivity is about change in expectations for the study of the one conducting it. In this case, author's observations were becoming more subjective during work on the thesis. At first, the outcome seemed to be rather transparent and expected, however, the further study was moving, the more expectations were questioned. It was coming naturally from discussion of the work with supervisor and other people, as more results were received and more literature on the topic studied.

Member checks are used to test data, interpretations, reports, etc. with members of the community of the study. Construction of the learning factory and the way processes are supposed to function there were checked by IDT. Also, the skis assembled by students were reviewed by the company representative in the end of the work on the thesis, as one of employees came to see the results of the project. Questions and results related to scientific part of the work were checked, first of all, by supervisor of the master thesis, Halvor Holtskog, and also with professor from Hedmark University College, Tone Vold.

Transferability (external validity) of the study needs to be increased, as amount of runs of the activity is rather small, as said previously. This makes it hard to say whether it is possible to fully generalize results, however, in case of the master thesis, conclusions are considered as being valid. In order to check further transferability, more runs of the activity are necessary.

Dependability is another criterion needed to be considered, as it is about trustworthiness of results over time. Conclusions of the study are related to educational activity, its efficiency and development. The study was conducted in the regular environment, with usual students; this gives possibility to state that results of the study won't change over time, as they were not received in special circumstances that will change later.

Confirmability implies that information and outcomes of the study are embedded into the proper context and can be confirmed by others, this criterion is somehow related to peer debriefing and member checks and thus was already discussed. As it was mentioned previously, results of the study were discussed with IDT representatives and professors from NTNU and Hedmark University College.

Authenticity, in its turn, brings the fairness component in to the picture, meaning that there should be different points of view presented and discussed. This master thesis is mostly concentrated on showing one sided view on the case, suggesting that use of similar educational activities and combination of above mentioned theoretical concepts leads to gaining of both practical and theoretical knowledge, in this case, it might be necessary to add point of view that is contradicting with the present one in future research and development.

Even though both reliability and validity were attempted to be increased through holding the pretest of the educational activity and choosing suitable evaluation methods, it is still necessary to have more runs of it and conduct interview with bigger amount of participants to make more solid conclusions. However, this was a limitation stated in the very beginning of the study described in the boundaries subsection of the paper. As a result, most of criterions described were tried to be met, but some of the points were hard to complete as the time to work on the master thesis is limited. After presentation of two sections of the paper such as theory and research methods, results of the thesis will be described.

5. Results

This section will present all the results received during the work on the master thesis project. First it will describe in more details the learning factory, afterwards the educational activity, development of which was one of the main aims within the work.

5.1. Description of the learning factory

In order to simplify readers understanding of the educational activity developed within the thesis, more detailed description of NTNU's learning factory (the base for the activity) is described in this subsection. It is necessary to mention that the learning factory establishment was also part of this thesis, however, not its main focus. More information on the factory setting up can be found in master thesis on the topic of *"Norway's First Learning Factory – A Learning Outcome Case Study"* by Malin Victoria Granheim (Granheim, 2016).

The learning factory was planned as a copy of an assembly line for roller skis used for skis production at IDT AS with minor changes necessary for enhancement of the learning process. As mentioned before, the factory is situated at the building laboratory of NTNU Gjøvik at Mustad Næringspark. The line at the factory contains of four stations corresponding to four processes as parts of the overall process of the ski assembly. The first station is dedicated to the wheels' assembly process and contains of the press and a drawing of the wheel assembly as shown on Figure 5.



Figure 5. Station 1

The second station includes the ski frame holder, two drawings to help the worker and an example of half assembled ski. This station is used in order to put stickers and wheels, assembled on the previous station, onto the frame, as well as poking the wholes for the rivets that are holding the binding plates on the ski frame. The station is depicted in Figure 6.

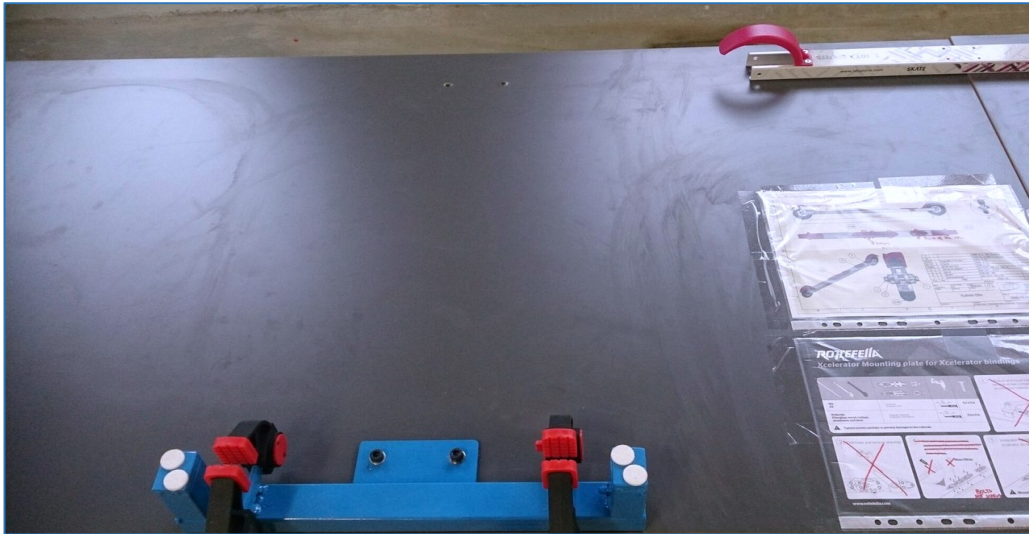


Figure 6. Station 2

The third station is used in order to add the mudguards and the binding plates onto the frame with wheels and stickers from the previous step of the assembly process. This station includes a ski frame holder, a compressor, a bolt-riveter, an illustration for putting on the mudguards and the binding plates, the station also shares an example of a half assembled roller ski with the previous station. The station can be seen in Figure 7.

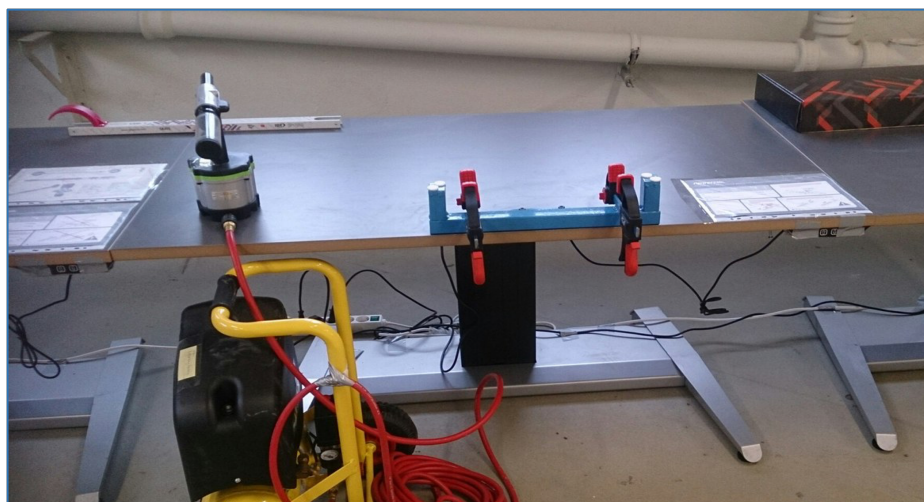


Figure 7. Station 3

The last station is dedicated to quality check and packaging purposes. It contains of examples of packaging units and is shown in Figure 8.



Figure 8. Station 4

Such setting of the stations is done in order for students to think about optimization of the production process. For example, not having the assembly parts on the stations leads to increase of time wasted for each operation, here students need to understand that it would be much easier to work if all the corresponding parts were stored next to them. In addition to four work stations, there is also a place containing the cardboards for packaging of the skis (Figure 9) and two separate tables with all the necessary parts showed in Figures 10 and 11.

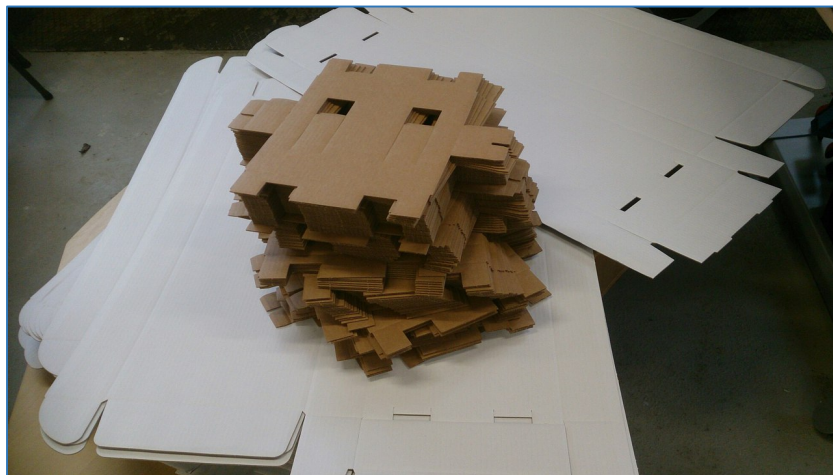


Figure 9. Packaging cardboards



Figure 10. Assembly parts, table 1

From Figure 10 it is possible to see that the first table with assembly parts contains the ski frames (black and white), stickers for black and white frames, as well as the binding plates of black and pink color.



Figure 11. Assembly parts, table 2

The second table, on the other hand, has on it boxes with not assembled wheels, rivets, the nut keys, all the parts for the wheels' assembly (colorful boxes) and mudguards. All the stations, including the storage tables, are situated in a sequence logical for the ski assembly process. Also,

the tables height can be adjusted if necessary, however, the students are not aware of this in the very beginning, since this should be one of their suggestions of improvements. Next to the work station number four, a storage for assembled skis is situated (Figure 12), where the boxes with ready products are stored until IDT representative comes to pick them up in order to sell to customers afterwards.



Figure 12. A box for assembled skis

The learning factory has been described in this part of the paper in order to make the following subsections easier to understand. The next subsection will give a broad explanation of the educational activity created within the thesis.

5.2. Description of the educational activity

The following activity is based on theoretical topics and concepts mentioned previously in the thesis and, the most important, on the learning factory presented in the previous subsection. It will be described in the subsection “Answers to research questions” how the activity is linked to the theory, while here the procedure of the educational activity will be explained.

Activity’s main aim is to increase practical skills and theoretical knowledge on such topics as kaizen, waste reduction, efficiency and push/pull production systems through use of the learning

factory, which is a copy of manual assembly line for roller skis. Students need to use their skills, theoretical topics presented in the beginning of the activity and knowledge in order to decrease the assembly time of the roller skis. Activity's theoretical base contains of elements of such topics as: experiential learning, experiential learning cycle, game based learning, serious games and sensemaking. It is also possible to say that educational activity has features of serious games as a core. The learning factory setting corresponds to unbalanced line, which has a lot of improvements to be done. In order to run the activity, it is necessary to have from five to six participants. The time used for running of the activity is approximately three hours.

In the very beginning of the activity the stations have the setting as described in the previous subsection, meaning that they do not have anything else on except that mentioned in the learning factory description. However, among other imperfections, students are supposed to understand that it is much more convenient to have all the necessary materials on the station, instead of running for them every time. Table 3 contains lists of what should be *eventually* present on each of the stations (the papers with instructions, illustrations, drawings and examples of half assembled skis are not mentioned).

<i>The first station:</i>	<i>The second station:</i>
<ul style="list-style-type: none"> - Wheels; - Nuts; - Nut washers; - Bearings; - Screws; - Bearing press (present in the very beginning). 	<ul style="list-style-type: none"> - Ski frames; - Stickers; - Ski frame holder (trigger clamps) (present in the very beginning); - 2 spanners; - Nuts; - Nut washers; - Hexagonal screws; - A pen.
<i>The third station:</i>	<i>The fourth station:</i>
<ul style="list-style-type: none"> - Binding plates; - Ski frame holder (trigger clamps) (present in the very beginning); - Mudguards; - Air hydraulic riveter (present in the very beginning); - Compressor; - Bolts. 	<ul style="list-style-type: none"> - Black pieces of cardboard. - White pieces of cardboard.

Table 3. Lists of necessary parts on different stations

In the beginning of the process the students receive pamphlets, which include schedule, short theoretical layout, process description according to their role (four participants are occupied at the workstations and one or two are managers) and two blank pages that will be used by participants during the activity in order to take notes and make changes to the process descriptions, since they are on purpose not perfect. The theoretical layout and process descriptions can be found in the Appendix A. Next, the theory in the pamphlets is presented by the guiding teacher or trainer of the group, participants also are given the time they can use in order to look through the layout themselves and ask questions. Afterwards participants are getting familiar with their role (one of the four workstations worker or a manager) and are explained how the assembly process goes in general and which tools and parts are available for their use. The four workstations correspond to the next processes: assembly of wheels; putting on stickers and wheels onto the ski frame; putting on mudguards and binding plates onto the frame; quality check and packaging. The manager(s) is(are) helping any of the workers that need it, control the overall process and actively think about disadvantages and advantages of the line's work, as well as about improvements that can be done.

After getting all the necessary information students are starting the first assembly round, where they put together one roller ski following the given process description, the time needed is noted. Next is a discussion round, all the students reflect on their own and overall process, they discuss improvements and implement them, afterwards the second assembly stage starts. Students can produce as many skis as they want according to assumptions they do about the customers' order; the time is measured again. After finishing the second assembly round, students one more time discuss process run and decide on future improvements that can be made. At this point the educational activity is over and an interview with participants takes place. During the interview students reflect on the activity process and link the theory learnt to the practice. The interview questions can be found in Appendix B. Participants are notified that there will be one more interview session in a week that is used in order to understand whether the knowledge was really gained during the activity.

In the end of the activity process students receive certificates of accomplishment, an example of group of students that went through the educational activity process can be seen in the Figure 13.

As a result, the activity contains of three theoretical rounds (theory and processes presentation and two discussion rounds) and two practical assembly rounds. Initially it was planned to have three assembly rounds, however, it was decided to have two not to increase the time needed for the activity run. It is also important to note that before start of the second assembly round it is necessary to notify students that they can make an assumption about customers' order of roller skis pairs, this will push them to think about change of one type of production system to another.



Figure 13. Students after the completion of educational activity

During the above described educational process participants are supposed to come up with the following list of improvements:

- Students get the process description which is not completely right, they need to rewrite it to make it better.
- Boxes with necessary parts are put away from the stations, as mentioned. Students should decide to rearrange this.
- The box for the used bolts on the third station is not on the table, so, they might start falling on the floor and cause inconvenience. However, it is necessary to notice this and suggest to have a trash bin.

- Students don't know that the height of the work stations might be adjusted, they need to figure this out to make their working place more comfortable.
- The assembly process on the next station cannot start before the previous stage on the station is completed. It is necessary to change the push system to pull system to make the process go faster.
- Any other meaningful suggestions are welcome.

As a result of improvements' application participants will experience use of continuous improvements (kaizen), increase of efficiency, elimination of different kinds of waste and use of pull and push production systems. This will lead to increase of their practical and theoretical knowledge in the list of above mentioned topics.

During the work on this master thesis there was one test group with four participants working on the learning factory before the educational activity runs, this experience was used in order to check whether the activity and the factory function according to the described plan. As a result, there were several issues uncovered, they were related to imperfection of tools and parts; this led to need of getting another tools for future runs of activity and looking through the ski frames in order to sort out those that had some imperfections which made the assembly process very long and inefficient. During the following two runs everything functioned well and there were six students taking part in the first and five in the second run, as mentioned previously in the paper. The interviews were held only with participants of the usual runs and not of the test run. The next section presents discussion of the thesis.

6. Discussion

This section, at first, presents analysis of interviews with the students right after participation in the educational activity and in a week after that, later it gives answers and discusses research sub questions and, in the end, the main research question.

6.1. Interview analysis

In order to answer research questions of the paper and make conclusions about efficiency of above described educational activity interview sessions with participants were held. As mentioned before there were 11 students that took part in the interview and four more that were testing the activity before the following runs, who were not interviewed. This subsection is, thus, presenting results of interview sessions with 11 students. At first the groups were interviewed straight after educational activity and then a week after. The questions of straight away session and in a week session are different and contain of 14 and six questions correspondingly. The list of all interview questions can be seen in the Appendix B.

Depending on what was extracted from the interview questions it is possible to divide them in three main groups:

- Related to efficiency of the educational activity (showing how well did students gain theoretical and practical knowledge) – questions number 1, 2, 4, 6, 7, 8 from the list asked right after the activity and number 1, 2 from the list asked in a week;
- Related to group learning and sensmaking (what was learnt individually and in the group, where is it possible to learn more in a group or individually, how the sense was made) – questions number 3, 9, 10, 11 from the list asked right after the activity;
- Related to quality of the educational activity (value, advantages, disadvantages and suggestions of improvements) – questions number 5, 12, 13, 14 from the list asked right after the activity and number 3, 4, 5, 6 from the list asked in a week.

Table 4 will present students' answers to different groups of questions during the interview held right after the activity.

<u>Questions group</u>	Efficiency of the educational activity	Group learning and sensemaking	Quality of the educational activity
<u>Answers of group 1</u>	<ul style="list-style-type: none"> - Kaizen was used in order to improve the process, everyone took part in it; - Three types of waste in the processes were identified and distinguished; - Worked on increase of efficiency, decreased time for one ski assembly from 25 to 13 minutes; - Correct definitions of push and pull systems were given, and their difference, it is better to use combination of push and pull on the assembly line; - Group work is essential; - Activity fully covered the theory in the theory layout. 	<ul style="list-style-type: none"> - Improvements were based on the knowledge and improvements from the previous rounds and previous experience; - Individually the separate processes are learnt; - Group work gives a holistic view of the line; - In group you learn more, as you work on improvement of the process and reflections on the theory; - During the sensemaking process doing, acting, practice and reflection on previous experience were used. 	<ul style="list-style-type: none"> - Such activity is a valuable educational experience as it gives practical knowledge in addition to theoretical; - It is good to have the theory in the beginning of the activity, then you have categories in which to sort your knowledge; - The big advantage that you receive are practical examples of theory application; - No disadvantages; - It would be good to add 5S into the theory layout.
<u>Answers of group 2</u>	<ul style="list-style-type: none"> - Kaizen was actively used during the activity run, it is never-ending and it is a philosophy; - Gave explanation of where were the waste types present in the process; - Increased efficiency, decreased the assembly time of one ski from 34 minutes to 6; - Reflected on what is the difference between push and pull, pull is better to be used on the assembly line, changed production from push to pull (made assumption about customer's order); - Work in a group is important; - Theory from the theory layout was covered during the activity. 	<ul style="list-style-type: none"> - Improvements were based on previous knowledge and experience gained during the activity; - During individual work the individual processes are learnt; - During the group work you see the whole picture of the line, the theoretical knowledge is also sorted out; - Four students said that they learn more during the group work, one student said that individual and group work are equally important; - During the sensemaking trial and error method was used, as well as previous experience and knowledge. 	<ul style="list-style-type: none"> - You get both practical and theoretical knowledge from such activity, you also receive a better understanding; - It is good to have the theory in the beginning of the activity, since it decreases time for theory sorting; - It might be better to have theory explained one more time after the end of the assembly rounds; - Advantage of such activity is gaining of practical experience in addition to theoretical; - No disadvantages; - Add 5S and poka yoke to the theory layout.

Table 4. Interview answers of students after the educational activity

Table 4 presents students' opinions about the value of the educational activity, their suggestions of its improvements, explains what they learnt on their own and in a group and shows that their understanding of theoretical topics was quite high. Both of the groups came up with improvements mentioned in the previous subsection, however, the first group didn't change the system from push to pull, even though while asked theoretical questions on this topic they have shown a deep understanding of the concepts. The second group, on the other hand, at first didn't notice possibility to adjust the height of the tables. Nevertheless, students have mentioned all the improvements mentioned in the paper before and in addition suggested to divide the second station into two and did it using the additional ski frame holder. In order to increase the efficiency students also hired their managers to help at the station two, which was previously divided. In addition to this, both groups suggested to use protection glasses during the activity run and fire one person since, in their opinion, they had too many workers (they were mostly meaning to fire the person working on the packaging station as there was a lot of waiting time and a small work load). In a week participants of both runs of the activity were gathered together one more time to check whether they still remembered something that they have learnt and ask for more advantages and improvements of the activity. Table 5 present results of this interview.

<u>Questions group</u>	Efficiency of the educational activity	Quality of the educational activity
<u>Participants' answers</u>	<ul style="list-style-type: none"> - Students still remembered theoretical concepts (kaizen, waste types, efficiency, push/pull production systems) that were learnt during the activity and could define all of them and give examples of their use during the activity; - Participants stated that in case of need they can apply the gained knowledge as they understand how and where it can be used. 	<ul style="list-style-type: none"> - Educational activity was stated to be a valuable experience; - In addition to advantages mentioned in the previous interview, participants added possibility of remembering of what you have learnt for a long time and ability to explain the theory to others in case of need; - No disadvantages; - Students suggested to increase competitiveness during the activity through adding a parallel line for a second team to work on it; - Increase quality of drawings used as instructions aid.

Table 5. Interview answers of students in a week after the educational activity

As it is easy to see from Table 5, the second interview session has shown that after a week time students still remembered most of the theory taught through the learning activity, in addition to this they added more advantages of taking part in it and gave more suggestions of improvements. After presentation of the interview results, the answers to the research questions raised in the thesis will be given.

6.2. Answers to research sub questions

This subsection will answer the secondary research questions stated in the introduction to the paper. The answers will be based on theoretical topics presented earlier, description of the learning factory, description of the educational activity and interview results. In order to cover the main research question as fully as possible, the answers to the sub questions are given at first.

6.2.1. The first research sub question – How the activity was designed in the thesis?

The answer to the first research sub question will explain how the educational activity was developed as without understanding of this, it will be impossible to answer the final question.

In order to start the activity's development a broad literature review was carried out, as mentioned in the research method of the study. This was done in order to get familiar with necessary theoretical topics and understand which of them can be used. As a result, such tools and concepts as experiential learning and experience learning cycle, game based learning, serious games and sensemaking were decided to be applied. In addition to this, learning factory was planned to be used as a basis of the activity.

Each of above mentioned concepts played an important role during the activity development process. The factory was a basis, without it the learning activity would be of no use as it was started to be planned specifically for application together with the learning factory. It was essential to include it, as the knowledge brought to the students was supposed to be practical and useful. *“In terms of enhancing employees' improvement abilities with the use of learning factories, existing education and training programs are remodeled by the means of competency-oriented, scientific-founded didactic concept”* (Tisch et al., 2013, p. 580).

As students were going to work on the copy of the real assembly line with products that will be

later sold to the customers, experiential learning was clearly applied to further plan the activity. Experience based learning gives students opportunity to apply their theoretical knowledge in practical situations gaining skills and knowledge that cannot be received from reading books (Williams, 1986; Efstratia, 2014). According to Kolb, A. Y. and Kolb (2012) experiential learning follows six important propositions described in the theoretical part of the paper, activity was also created following these principles. For example, one of the principles states that learning is always better if it is ‘re-learning’, that is why educational activity contains of several practical and theoretical rounds, in this case, students get a chance to remember that, what they are learning, better. According to this principle it was decided to have three theoretical and two practical (assembly) rounds.

In addition, it was decided to plan the activity according to experiential learning cycle described previously in the thesis. This cycle contains of four phases starting with actually doing things (*concrete experience*), switching to reflection on that what was done (*reflective observation*) and later to updating the previous knowledge according to newly gained (*abstract conceptualization*), the last phase is called *active experimenting* and means fitting that what was learnt to the world of the learner (McLeod, 2010). In the activity students start with introduction of the theory and the problem and then move to concrete experience (they assemble one ski), afterwards they have a discussion session, where they reflect on the theory and assembly process (reflective observation) and decide on improvements needed (abstract conceptualization), later they apply improvements and look at how the process has changed (active experimenting and concrete experience), at this point the cycle starts again. Two assembly rounds and three theoretical rounds, which correspond to different phases of the experiential learning cycle are used to give students opportunity to learn more and remember it better. Introduction of the theory before introduction of the problem is called a ‘push’ method (Tisch et al., 2013) and was chosen to be used as students might not be familiar with theoretical topics that they need to use, learn and experience on practice and thus the efficiency of the learning process might decrease.

In order to further increase learning outcomes, elements of game based learning and serious games were applied. In case of learning through games, five freedoms described by Klopfer, Osterweil and Salen (2009) were attempted to be embedded into the activity. Freedoms to fail

(students have possibilities to make mistakes that won't harm anything), to experiment (participants can use everything they have access to, meaning tools, parts, theory, their own knowledge and skills in order to reach the goal of decreasing the time of roller skis assembly), to fashion identities (students can try different roles) and to interpret (every participant perceives the activity they want to and gain that knowledge they need and want) are fully present within the activity, while the fifth freedom to effort is present partly, as student doesn't have to put a lot of effort into the learning process if he/she doesn't want to, but there might not be a chance to try the activity again with more effort.

Serious games are games at their core, but their preliminary goal is education, rather than entertainment (De Freitas, 2006), this makes them to be an attractive tool within educational activities development. Their possibility to combine serious aims and playfulness is a crucial feature, which often is missed within the learning process. Engagement and amusement of students is important, especially in such fields as engineering and manufacturing, as topics might be difficult and boring, while taught. However, application of serious games or their features within educational activities would make students more interested in what is going on during the classes. Serious games are stated to have the following performance indicators: rule and goal, sensory stimuli, control, challenge and interactivity (Tehran, Taisch and Fradinho, 2013). They were tried to be used to improve the activity, however, rules are not present as such here, it is allowed to do more or less everything that is possible. Control, in its turn, is missing the component of providing different levels, however, possibility to experiment, act and use different solutions is possible, challenge is present partly as there is no competing team in the activity, the group of participants competes only with themselves (trying to decrease the time of the ski assembly through improving the process). The activity was tried to be developed as the one making it interesting and joyful to learn, instead of having the boring and unengaging process.

The activity also used sensemaking in order to connect activity to the process of making sense and producing the knowledge. In the theoretical subsection dedicated to sensemaking seven features of sensemaking were presented and explained, the activity doesn't concentrate on all of them, but clearly uses most of them. Now it will be explained where and which of them were used. All people are different, this leads to students perceiving and learning material in different

ways, depending on who they are and which role they have, the sense that is created is different (*grounded in identity construction* feature of sensemaking). During the interview participants mentioned several times that they used their previous knowledge to make sense and that new improvements were build up on the ones from the previous rounds (*retrospective*), students were responding to problems occurring during the assembly process through implementing improvements thus being *enactive of sensible environments*. They were learning both individually and in the group making the process *social*, in addition they were engaged in the learning in several rounds and continued rethinking of what they have learnt even after the activity was over (*ongoing* feature of sensemaking). In order to learn, act and make sense, students had to *focus on and by extracted cues*, as then it is possible to divide the happening around into small and familiar portions of information that are easier to make sense of. Accuracy of *driven by plausibility rather than accuracy* feature of sensemaking use within the learning process can be argued, as during the knowledge creation it is important to have the knowledge that is accurate and correct. In addition to use of sensemaking and its features within the activity, it is also possible to find more links, which will be shown in the answer to the third research question.

After explaining the process of educational activity development the answer to the second research question will be given.

6.2.2. The second research sub question – What are the learning outcomes gained by students from the activity?

The answer to this question will be given with help of the interview results presented previously. According to the goal of the activity it was planned to increase students' theoretical and practical knowledge in such topics as kaizen, waste types, efficiency and push/pull production systems through making improvements to the assembly process of roller skis and, as a result, decreasing the assembly time. However, understanding of whether students really have learnt something was possible only through running the activity and holding interviews with participants afterwards.

According to answers to the interview sessions students have gained learning outcomes in form of both theoretical and practical knowledge on the aimed topics, participants also emphasized that all the theory from the short theory layout was fully covered. They could define the major

concepts (kaizen, efficiency, waste types, push/pull production systems) and were able to distinguish different types of waste and production systems.

In a week after the activity, they still remembered the terms and claimed to be able to use them on practice. In their opinion, such activity is quite valuable for the learning process, as it gave them possibility to gain practical knowledge of application of the above mentioned topics and examples of their use in the real life. After participation in such activity, according to their own opinion, they were able to explain the above listed concepts to others through use of this experience. In addition to this, they emphasized importance of group work and most of the students stated that they have learnt more in the group than individually, as group work allows to see a holistic picture in addition to limited to one process or one workstation, however, one of the students said that both types of learning are equally important. Students said that during the individual learning they mostly were studying their own processes according to the role, while in the group they have got to understand how the overall assembly process works, what are the problems and reflect on the theory.

In order to make sense of activity, participants were using “*doing, acting, practice, reflection on previous experience*” and “*trial and error*” method. This shows that most of the sensemaking features were indeed present during the process and that this concept is very important for the learning activities, as it helps to understand the way students learn things. Now the answer to the third research sub question will be given.

6.2.3. The third research sub question – What are the benefits of using educational activity based on the learning factory versus use of learning factory or activity on their own?

This question explains why it is important to use combination of the learning factory and educational activity, instead of using them separately. Educational activity described in this master thesis is impossible to be applied on its own, as it uses learning factory as a base and in order to learn something, students need to work on the factory, however, in general, it is possible to have such learning activities that are designed in order to be used together with the factory, but still work on their own. However, it won't be as beneficial as use of their combination.

The answer contains of two main points. First of all, effectiveness of educational activities based

on serious games and experience based learning, among other topics, is often questioned, even though some of them “*obviously pinpoint the importance of considering not only engineering knowledge, but also professional skills*” (Tehran, Taisch and Fradinho, 2013, p. 100). Nevertheless, it is always harder to say whether students have gained practical knowledge if they were *not doing* real things. Educational activities that are computer based, contain only simulations or use toys instead of real tools and parts give a glimpse of how things are done in the real world, instead of allowing to try and experience it. That is why combination of above described concepts (experience based learning, game based learning, sensemaking and learning factory) together is so important. Although, it is understandable that in some spheres it is impossible to use real things instead of use of simulators (patients in medical education), however, in such fields as engineering, it is usually possible to bring the real world into the class room, so, why not to do it?

Secondly, learning factories, which are set up without adding any scenario to be followed do not give enough theoretical knowledge, as they show how the things work, but do not *explain* it. To sum up, educational activities that are supposed to be used without learning factories do not have enough practical knowledge component, while learning factories on their own lack the theoretical one. However, if combination of two is used, it is possible to find a point of perfect balance, where students gain enough of practical and theoretical knowledge and skills. After responding to the third research sub question, the fourth will be answered.

6.2.4. The fourth research sub question – What is relation between developed educational activity and the sensemaking?

“*Sensemaking is what it says it is, namely, making something sensible*” (Weick, 1995, p. 16), while educational activity is part of the learning process that is used in order to help students to make something sensible. In case of this paper, educational activity described in it was based on several different learning techniques, it involves use of the learning factory, experience based learning and game based learning, but what about understanding of how students make sense of such activities? In the first research sub question relation between the educational activity and sensemaking was somehow described, however, there are even more links.

Experiential learning cycle contains of four phases, it is possible to say that the cycle itself is also

partly a sensemaking cycle, as learning activities based on experiential learning and serious games “are used for sensemaking: a process by which people give meaning to experience. The outcome of this process is knowledge” (Harteveld, 2012, p. 15). More precisely, phases called *reflective observation* and *active experimentation* include moments of trying to fit newly discovered into the framework of the learner’s world and then attempt to live in the world with changed knowledge, this is something sensemaking is also used for by individuals.

In case of game based learning, here is how Harteveld (2012, p. 374) links them: “*When sensemaking is provided within the medium of a game, the game provides a structure to create order, enables the (re-)construction of knowledge by discovery and trial-and-error learning, and challenges the player with game elements that need to be made sense of. The game experiences and results may not be completely similar because players differ from one another. Players’ history, culture, identity, and other factors play a role in how knowledge is (re)constructed*”. Here links between freedoms of games and features of sensemaking become more visible. It is now possible to see, that *freedom to fail* can be linked to *feature driven by plausibility rather than accuracy*, *freedom to experiment* partly corresponds to *enactment of sensible environments*, *freedom to fashion identities* to *feature grounded in identity* and *freedom to interpret* to *focused on and by extracted cues*. Freedom to effort is not looked at since it is present in the activity only partly.

So, it is allowed to say that learning in general and educational activities (especially in case of the activity developed during the master thesis project) in particular are closely linked to sensemaking, as there are clearly present those features that are common or close to each other. The following subsection sums up answers to the research sub questions.

6.2.5. Summary of answers to the research sub questions

The first research sub question explained how the educational activity was designed within the master thesis. It not only said that concepts of learning factories, experience based learning, experiential learning cycle, game based learning, serious games and sensemaking were used, but also showed why each of them was important to be implemented. It was also shown that some of ideas of the activity’s structure were evolving as above mentioned theoretical frameworks were coming into the picture.

The second sub question described learning outcomes gained by students from participation in the activity. As a result, it became visible that students received theoretical and practical knowledge on the topics of kaizen or continuous improvements, waste types, efficiency and pull/push production systems. In addition to this, students claimed to be using their previous experience, learning by doing and trial and error method. It was also stated by participants that now they are able to apply their knowledge on practice, explain the theory to others through their practical experience and remember everything for the long time. They said that learning in group was giving holistic picture of the processes, while individual learning led to knowing only their own processes. In a week after the activity run, they were still able to remember and explain the learnt concepts.

The next sub question helped to understand why it is especially beneficial to use the learning factory in combination with educational activity instead of use of each of them separately. As a result, it was concluded that educational activities on their own do not bring enough practical knowledge, while learning factories lack theoretical one. However, if combination of both is used it is possible to find a balance for students to gain enough theoretical knowledge and practical skills.

The last research sub question explains how educational activity developed in the thesis is related to sensemaking. It shows links between features of the concept and phases of experiential learning cycle, as well as with freedoms of games within the game based learning. There are also other links shown in the answer to the first research sub question. The next subsection contains of the answer to the main research question and its discussion.

6.3. The main research question

The main research question of the thesis is *how to design an educational activity based on the learning factory in order to enhance the learning outcomes (experience) in the field of engineering and manufacturing education?* This question is very complex, so, there is no one right way of answering it and in addition to the answer given in the thesis, it is definitely possible to bring in something else. The answer is suggestion and authors vision embedded into discussion of it.

First of all, **in order to build an educational activity that enhances learning experience it is necessary to understand that all the components of the activity are equally important.** It is not possible to create a useful activity if one of the aspects is not taken into account. This statement is illustrated in Figure 14, which shows that for educational activity the following concepts should be paid attention to: learning factory, experience based learning, game based learning and sensemaking. Holistic application of these techniques can be a recipe for building a good learning activity in field of engineering and manufacturing educational programs.

In order to build anything, it is necessary to start from the foundation, as without it nothing will hold together. *A good foundation for educational activity for engineering and manufacturing students is a learning factory.* To connect the activity and the factory it is important to pay attention to key features of learning factories listed in the theoretical section of the paper, which are: purpose, process, setting, product, didactics and operating model. Defining of what these features are, in case of particular learning factory, will lead to further understanding of how the educational activity needs to be planned. After setting up the factory and in such a way building the foundation of the activity it is time to build the house's walls.

As it is shown in Figure 14, *the walls of the house are experience and game based learning techniques.* They are what the roof is holding on, since without their use the activity will lack some of its most important features. In order to have an educational activity, that is interesting and capable of bringing practical knowledge to engineering and/or manufacturing students, they are critically important, as one brings in the component of actually gaining experience and practice, while another makes it engaging, challenging and playful. Theoretical subsection describing experience based learning contains two main things that are important to pay attention to, these are: six propositions of experiential learning and experiential learning cycle. The first one helps to plan activity and to explain essential points of the learning process. In addition to this, experiential learning is extremely important if the educational activity is really supposed to be designed as the one bringing students competence and practical knowledge.

Game based learning, on the other hand, among others, includes such concepts as five freedoms

of games, serious games and their performance indicators. Of course, it might be necessary to look at other related terms, however, these are suggested to be extremely useful for the educational activity planning and development. *“For any activity to be challenging, it needs to have a goal with an uncertain outcome”* (Ebner and Holzinger, 2007, p. 875). This can be realized through defining values of performance indicators of serious games in context of the educational activity under development. Use of certain features of serious games within activity can *“provide the opportunity of situated learning, where the learner is emerged in the actual context and therefore increasing the retention rate whilst improving the potential for transformation of the learner”* (Tehran, Taisch and Fradinho, 2013, p. 99). In addition, if the educational activity developed will have at least some of five freedoms of games, this will increase activity’s interest for students, as *“members of the Game Based Learning community point to the native affordances of games as a more engaging and motivating alternative to traditional learning environments”* (Denham, Mayben and Boman, 2016, p. 70).

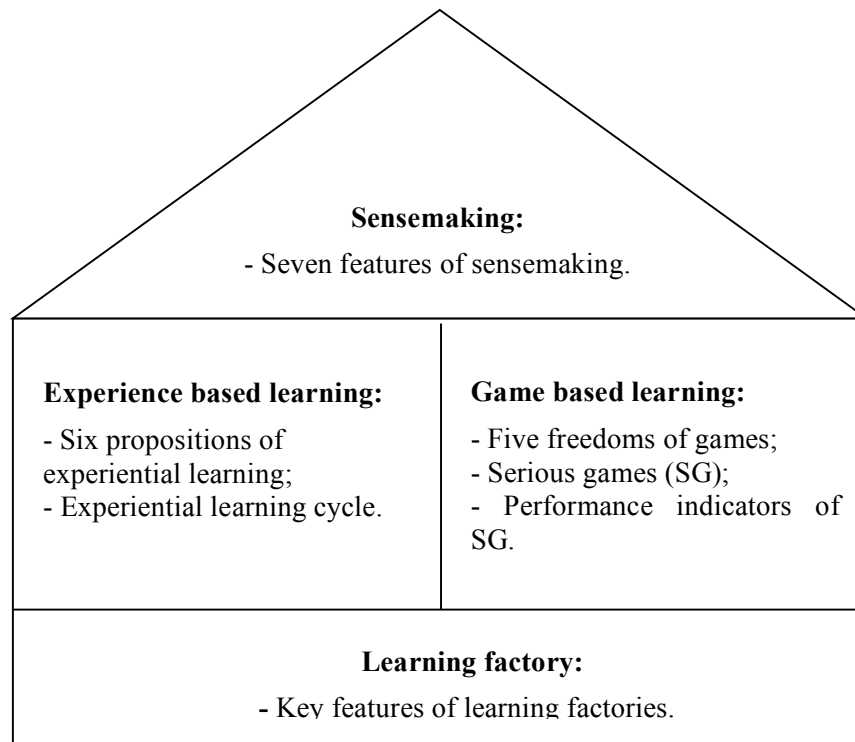


Figure 14. Educational activity house

However, *the house is not complete if there is no roof, for the educational activity it is sensemaking and its seven features: grounded in identity construction, retrospective, enactive of*

sensible environments, social, ongoing, focused on and by extracted cues, driven by plausibility rather than accuracy. The relation of sensemaking and other terms mentioned in Figure 14 was explained in the previous subsections. According to those connections its importance is hard to overestimate, having it in mind might help to understand how the students are learning and what it is necessary to add to the activity in order to enhance learning outcomes and experience. Sensemaking is in one or another way connected to other topics important to be taken into account for development of the educational activity, that is why it can play a role of the roof, as without it, the house of educational activity will be incomplete and not possible to be used.

Connection of all of these topics and their correspondence to parts of the house is showing that educational activities should be developed having a holistic picture of all the necessary concepts and theories. All of the parts are equally important, if one of them is not there or if it is not constructed the way it should be, the educational activity fails to be good enough to enhance the learning experience for engineering and/or manufacturing purposes.

After explaining the educational activity house, it is also necessary to say that **learning factory is a good tool to be used during the learning process, however, it needs experience based learning, game based learning and sensemaking to be applied together with it in order to enhance the learning outcomes/experience.** Lack of these concepts leads to inefficient learning process that doesn't bring students as much benefits as combination of the listed techniques. It is common to use these concepts to teach students, but it is not usual to combine them, while this study shows that it brings significant benefits for the students, as they gain theoretical knowledge and practical skills that are remembered for a long time and can be explained to others in case of need.

Another important point is that **teachers and professors often work on the content of educational activities, but barely think about the way students make sense of them,** even though it is just as important as to plan and develop activity's curricula. Such approach leads to failure to bring to students planned knowledge, as they might simply not perceive it the way it was expected, especially, when it wasn't thought about how will they do it. To avoid such sad results, it is strongly suggested to take into account sensemaking.

The above described house is designed for development of activities for engineering and manufacturing field of education, as it contains of the topics that are oriented on gaining practical experience and applying the theoretical one. This doesn't mean that suggestions described earlier are completely useless for other fields, on the opposite, it is highly recommended to make educational activities for other programs as highly connected to practice, as here. However, depending on the field of education there are certain features that need to be different during the learning process, this should also be taken into account. For example, in case of computer science programs related to software development, it is not necessary to work on the setting up of the learning factory as hard as in engineering programs case, since there the main tools are hardware (PCs, laptops) and software (program development programs), while engineers need much more complicated environment to gain practical experience.

Also, it is important to remember that **when it comes to activities, which involve people, it is impossible to plan everything in advance**. This doesn't necessarily mean bad results, but it might lead to unexpected issues, that is why it is good to have a test run and/or try it by yourself. However, even after that it won't necessarily lead to everything being as expected, this might mean both good and bad outcomes. For example, during the test run of the activity described in this master thesis there were some failures because of imperfection of tools and parts provided, however, discovery of them led to possibility to prevent future problems.

However, as said before, unexpected results might also be those of positive character. For example, educational activity described in the paper intended students to come up with five suggestions listed in the "Description of educational activity" subsection, but students went further and proposed more solutions than it was expected. Both groups of students decided to divide workstation number two into two in order to shorten the assembly time, to operate on the new station they hired their manager and in the last round of discussion suggested that it might be necessary to fire person working with packaging, as there is more waiting than working and that station can be operated by employee from station one, for example, as he/she doesn't have such a big workload. In addition to this, students suggested to add use of protection glasses during the process to make it safer and more comfortable.

When it comes to improvement of the activity, it is, of course, good to implement those improvements that cross minds of activity creators, however, another good way of doing it is asking participants about what should be changed, as engagement of participants is important to be present in learning environments (Dahlgren, 2014; Ogorodnyk, Granheim and Holtskog, 2016) in a sense that asking participants about improvements to learning environment or activity will lead to bigger and more efficient changes. The reason for this is that participants know this environment as those interacting with it from the inside.

During the interview with students, who took part in the educational activity, among other questions they were asked about advantages, disadvantages of taking part in the activity, its value for the learning process and improvements needed to be done. According to students' answers presented shortly in the "Interview results" subsection, there were no disadvantages and the value was high as advantages listed were: giving practical experience and knowledge in addition to theoretical, examples of practical application of theoretical concepts (kaizen or continuous improvements, waste types, efficiency, pull and push production systems), possibility of remembering material for a long time, capability of applying theoretical topics learnt on practice and ability to explain the theory to others in case of need.

In addition to this, students gave meaningful and useful suggestions about improvements needed to make activity better. It was suggested to add *kanban* as one of the topics taught, as the learning factory is constructed in a way that makes this concept possible to be learnt through interaction with it. It was also suggested to add *5S* and *poka yoke* to the short theoretical layout as their application is visible during the activity, but they are not mentioned in the list of learnt topics. In addition, students also advised to make process descriptions even worse, increase competitiveness, change order of the stations of the learning factory in the beginning of the activity to show how important it is to put them in the logical sequence for smooth assembly process and have explanation of the theory not only in the beginning, but also in the end to make students to understand it even better.

As it is easy to see, all of students' suggestions are quite useful and can easily improve the

activity, that is why receiving their feedback is important not only to be sure that they have gained the expected knowledge, but also to continue making the activity more interesting. After presenting theory used to conduct the study, describing research method, providing results of the thesis, answering research questions and discussing suggestions for development of the educational activity based on the learning factory for engineering and manufacturing students, it is necessary to move to conclusion of the master thesis.

7. Conclusion

There were two main components of the motivation for this work. Firstly, to give students possibility to gain practical knowledge in addition to theoretical through their participation in the educational activity based on the learning factory. Secondly, providing suggestions/guidelines for development of similar activities, since there is not much literature on this topic, especially in field of manufacturing and engineering education.

Research aims of the thesis were defined as follows: develop an educational activity based on the learning factory and implement it; run the activity in order to conduct a case study, where the learning outcomes of participants are revealed; provide description of the learning activity development and application in order to facilitate creation and implementation of similar activities and find the links between educational activities, learning factories and sensemaking. The aims were reached during work on the thesis and the following research sub questions were answered: *how the activity was designed in the thesis? What are the learning outcomes gained by students from it? What are the benefits of using educational activity based on the learning factory versus use of learning factory or activity on their own? And what is relation between developed educational activity and the sensemaking?* In addition to this the main research question “*how to design an educational activity based on the learning factory in order to enhance the learning outcomes (experience) in the field of engineering and manufacturing education?*” was discussed and answered. In order to create a valuable learning activity, it is suggested to use concepts depicted in Figure 14 and keep in mind their roles in the educational activity house.

Thesis contains of several parts:

- Background section explains preconditions for start of the work;
- Introduction presents the topic, gives short information about IDT AS and describes boundaries/limitations of the study;
- Theory section presents all theoretical concepts used in order to conduct the study and the next section all the topics taught during the activity;
- Research method introduces aims of the work, methodological view, methods used during work on the thesis (literature review, group interview, etc.) and explains how validity and reliability were dealt with;

- Results section provides description of learning factory and educational activity;
- Discussion section presents interview analysis, answers to research sub questions and suggestions regarding the main research question.

Educational activity developed during the work on the thesis is based on such concepts as learning factory, experience based learning, experiential learning cycle, game based learning, serious games and sensemaking. Each of them is equally important, as shown with help of the educational activity house presented in discussion section, and lack of one leads to failure in application of others. Learning factory might be a good educational tool, but application of it together with experiential and game based learning, as well as sensemaking, will increase value of the activity significantly. Such educational activities are important for the learning process, as use of conventional learning techniques leads to the problem that students do not think about material taught and often just passively write it down (DeNeve and Heppner, 1997). Application of such concepts as serious games, on the other hand, leads to strengthening ability of the activity *“to provide job like training environments which is very appreciated by trainees from manufacturing industry”* (Messaadia et al., 2012, p. 559). In addition to this, sensemaking concept is not less important than the others, as understanding of how students make sense of an activity is as important as planning of it.

Educational activity described in the thesis is concentrated on providing students with necessary theoretical and practical knowledge on the topics of kaizen or continuous improvements, waste types, efficiency and push/pull production systems. In the beginning of the activity students receive pamphlets with schedule, theoretical layout, project description and pages for notes. The short theoretical layout and project descriptions can be found in Appendix A of the thesis. The activity had one test run with four participants and two regular runs with six students participating in the first and five in the second. Participants of the regular runs were asked to take part in group interview sessions straight after the activity and in a week. Questioner used for the sessions can be found in Appendix B. Group interviews were also used in order to understand whether students gained expected knowledge and receive their feedback about the educational activity. The following section will summarize recommendations for further research.

8. Recommendations for Further Research and Development

Previously in the thesis suggestions of activity improvement from students were given, however, in this section recommendations for further research and development of the topic are provided. First of all, it is strongly advised to use the educational activity based on the learning factory in different courses of engineering and manufacturing programs, where students encounter such theoretical topics as kaizen or continuous improvements, waste types, efficiency and push/pull production systems. Simple application of the activity will lead to its technical improvement and enhancement of students' practical knowledge. In addition to this, it is possible to use educational activity as part of examinational process of students, where they would receive task to improve assembly line performance using certain theoretical methods.

Secondly, it is suggested to add other theoretical topics to the curriculum of the learning activity, such as *kanban*, for example, and artificially create different erroneous situations on the assembly line, such as lack of inventory. Implementation of this suggestion is connected to application of experience and game based learning techniques within the activity.

Thirdly, adding screens that would show time used for completing certain operations would improve the learning factory and educational activity, as it would increase motivation and competition among the participants, in addition to this it might trigger new improvements ideas in students' heads. This would make activity even closer to the serious game, thus making it more joyful and playful. Also, it would be good to improve the learning environment of the activity and factory, as now the building lab, where the factory is situated, is hard to be used for explaining the theory, there is no blackboard or projector to show presentations and not enough space to put desks for the students, just chairs.

Next, it is possible to create a workshop available for different companies focused on training their employees to apply above mentioned theoretical topics during the working process in manufacturing. This would increase potential of learning factory usage and bring more benefits from its creation. In addition, development of a whole course based on the educational activity and learning factory would be a possible and beneficial goal.

However, all of above mentioned points are related rather to development than to further research. In case of research it is necessary to conduct a study with bigger amount of participants. This would give possibility to receive more solid results and increase both reliability and validity of the study, as the procedure would become smoother and the bigger amount of population would be engaged. It would also be interesting to hold a separate research to analyze learning outcomes among those not having any previous knowledge on the theoretical topics and relation to them. This would give opportunity to make more conclusions of how effective such educational activities are. In addition, conduction of the study where different educational activities are used and their efficiency compared would bring valuable results, since it would give possibility to look at different views on the educational activity application and development.

Lastly, this master thesis can be a starting point for future development of guidelines for similar educational activities creation, as they are extremely important in all fields of education and especially for engineering and manufacturing programs. There is lack of such literature and, as a result, lack of such activities used during the learning process and practical knowledge among higher educational institutions graduates, even though demand for practical knowledge from higher educational graduates is huge.

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Appendices

Appendix A

Short theory layout

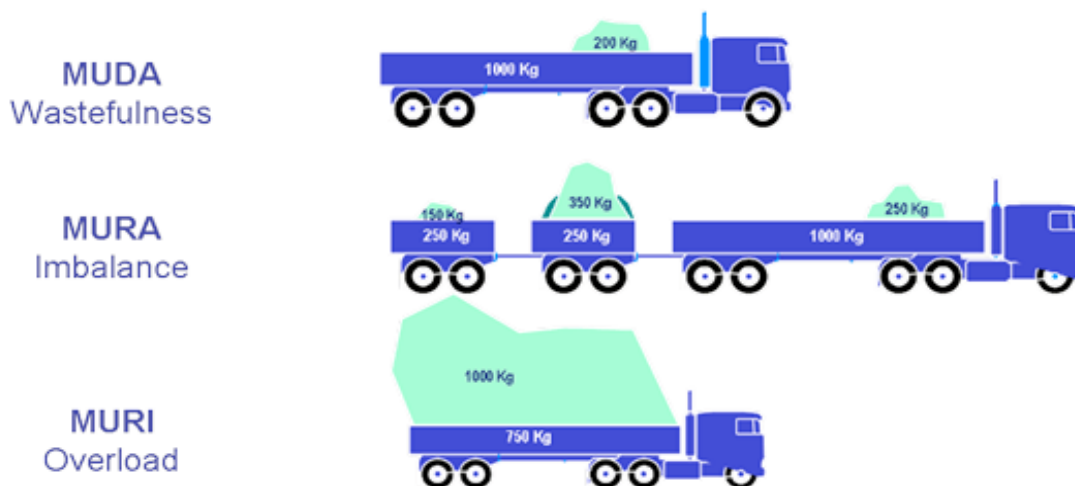
1. Kaizen or continuous improvements

The concept of kaizen is a mandate to constantly improve performance. At the root of kaizen is the idea that nothing is perfect and everything can be improved. This is critical to the company, as every leader is taught to remember that the process is never perfect and that the company has never achieved the perfect solution. No matter how many times it has been improved, every step in the production line is full of waste; even if it could be perfect today, conditions will change tomorrow, and more waste will creep in. Similarly, every aspect of the company can be improved, from the way products are designed to the way they are sold, to the way service parts are stored and shipped, to the performance of every team associate in the company (Taken from Liker, J & G. L. Convis (2011) *The Toyota way to lean leadership: Achieving and sustaining excellence through leadership development: McGraw Hill Professional*).

2. Efficiency

The simple definition of manufacturing efficiency is to fulfill customer orders as quickly and reliably as possible using the least amount of inventory and work in progress (Taken from: <http://www.dbamanufacturing.com/documents/ManufacturingEfficiencyGuide.pdf>).

3. Waste reduction



(Taken from <http://www.allwidewallpapers.com/muda-mura-muri/bXVkyS1tdXJhLW11cmk/>)

Muda - one of the three types of deviation from optimal allocation of resources. Waste reduction is an effective way to increase profitability.

Muda Type - I : The non value added activity for end costumer but it is necessary.

Muda Type - II : The non value added activity for end costumer which are not necessary. It is targeted to eliminate this type of wastage.

(Taken from: [https://en.wikipedia.org/wiki/Muda_\(Japanese_term\)](https://en.wikipedia.org/wiki/Muda_(Japanese_term)))

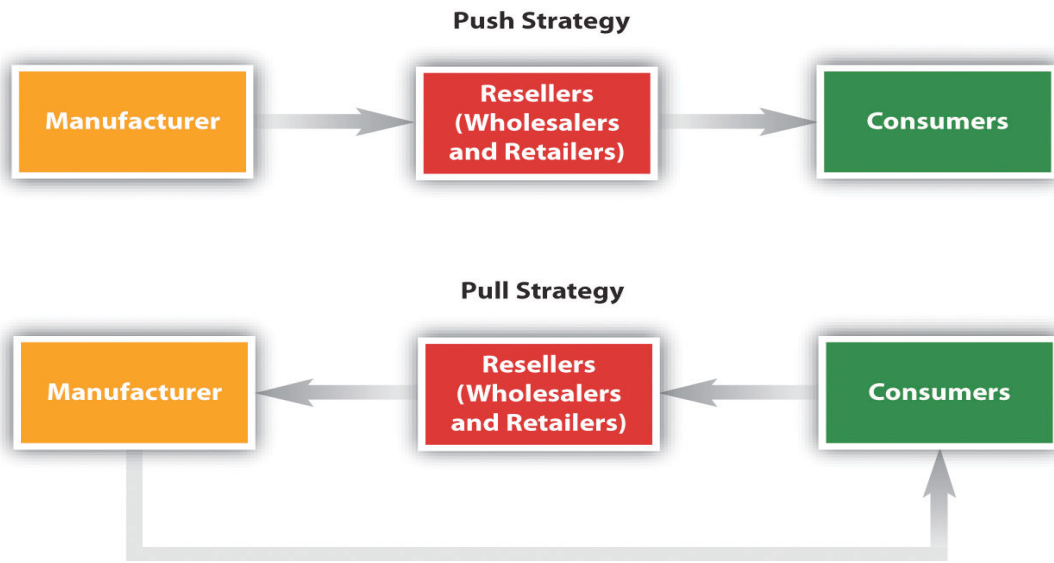


(Taken from: <https://www.linkedin.com/pulse/20140822051531-14147448-toyota-production-system>)

Mura - is a Japanese word meaning “unevenness; irregularity; lack of uniformity; nonuniformity; inequality”. Mura, in terms of business/process improvement, is avoided through Just-in-Time systems which are based on keeping little or no inventory. These systems supply the production process with the right part, at the right time, in the right amount, using first-in, first-out (FIFO) component flow. Just-In-Time systems create a “pull system” in which each sub-process withdraws its needs from the preceding sub-processes, and ultimately from an outside supplier. When a preceding process does not receive a request or withdrawal it does not make more parts. This type of system is designed to maximize productivity by minimizing storage overhead (Taken from: [https://en.wikipedia.org/wiki/Mura_\(Japanese_term\)](https://en.wikipedia.org/wiki/Mura_(Japanese_term))).

Muri - is a Japanese word meaning “unreasonableness; impossible; beyond one's power; too difficult; by force; perforce; forcibly; compulsorily; excessiveness; immoderation”. Muri can be avoided through *standardized work*. To achieve this a *standard condition* or output must be defined to assure effective judgment of quality. Then every process and function must be reduced to its simplest elements for examination and later recombination. The process must then be standardized to achieve the standard condition. This is done by taking simple work elements and combining them, one-by-one into standardized work sequences (Taken from: [https://en.wikipedia.org/wiki/Muri_\(Japanese_term\)](https://en.wikipedia.org/wiki/Muri_(Japanese_term))).

4. Push and Pull



(Taken from: http://catalog.flatworldknowledge.com/bookhub/reader/5229?e=e613.fwk-133234-ch11_s98)

Process Description

Station 1: Assembly of Skate Roller Ski Wheels

To assemble one roller ski it is needed:

- 2 Skate wheels
- 2 nuts
- 2 nut washers
- 2 bearings
- 1 screw
- Bearing press (at the station already)

Step 1: Press one bearing inside of the first wheel with the bearing press. Push it down so that it is leveled with the back of the wheel.

Step 2: Put one nut washer onto a screw and then insert the screw and nut washer through the bearing that you did in step 1.

Step 3: Put another bearing on the wheel and press it down with the bearing press. Push it so that the bearing is leveled with the front of the wheel (the part that faces you).

Step 4: Place the wheel (with both bearings) and place a nut washer and nut on the part that is the end of the screw tip. Make sure that it is not coming off when you do the next stage.

Step 5: Make sure that the wheel works, and that the wheel goes around smoothly.

- If the wheel makes a wired noise/ or is hard to roll the bearing is not inserted correctly. (If so, try to disassemble it and do the steps again).

Step 6: Put the ready wheel on the work station, so that the second station can reach it.

Repeat steps to make the other wheel.

Process Description

Station 2: Stickers and wheels onto Ski Frame

To add stickers and wheels onto one roller ski it is needed:

- 1 Ski frame (Labeled skate ski frame)
- 2 Spanners (either spanner wrench 10mm, or spanner wrench 13 mm)
- 2 Nuts (box labeled components skate wheels, pink box nr 5)
- 4 Nut Washers (box labeled components skate wheels, green box nr 3)
- 1 Trigger clamp (at the station already)
- Stickers (labeled Stickers for black/ white skis)
- 2 ready wheels from station 1
- 2 Octagonal screws (box labeled components skate wheels, green box nr 4)
- Illustration (at the station, use as guide!)
- Pen for poking the holes of the frame

Step 1: Collect the above mentioned parts and place them at your station. Read the process description carefully and also study the illustration before going to step 2.

Step 2: Take the ski frame and place it in the trigger clamp. Make sure that the clamp is fastened and that the ski is held steady. Place the ski so that the holes are facing you.

Step 3: Placing the stickers onto the ski frame:

1. Find the end of the ski, this is illustrated in the illustration placed in front of you.
2. Place wide sticker on the front of the ski frame (the one facing you with holes (see the first step). The IDT Sports Skate logo should be at the front of the roller ski. Use your hands to make the sticker be applied without air-bubbles. Also you must push hard enough so that you can see the holes from the frame through (this is important for the next step).
3. Take a pen and poke the holes (you see through the sticker - if not use the illustration in front of you as a guide).
4. Then take the ski out of the trigger clamp, turn the ski on one of the sides and place it in the trigger clamp and fasten. Then you can take the smaller sticker, where the flag represents the end of the ski, and apply it the same way as before.
5. Repeat stage 4 to apply sticker on the other side of the ski. If the sticker is not placed right it can be peeled off, but it must be done right away. And if the sticker is deformed you should take a new sticker. (The sticker should cover all holes in the frame).

Step 4: Pick up one wheel from station 1. Make sure that you don't drop the bearing cups as they are loose, don't worry it is supposed to be that way.

Step 5: Insert the wheel into the side of the roller ski frame and onto the correct place where there is a slit – you should use your muscles and just push it in, don't be scared!

Step 6: Then take one octagonal screw and put one nut washer onto the screw. Then insert it into the ski frame and the wheel you placed there in step 5. (Use illustration as guide if you are

unsure.) You should insert it wherever the octagonal screw goes in the frame. Then you take one nut washer and one nut onto the opposite side of the octagonal screw that's been inserted through the ski frame and wheel.

Step 7: Then fasten the parts from step 6 with spanners on each side. Make sure that it is fastened in a way that the wheel is inserted straight. This means that one spanner holds the nut tight and the other spanner is used as the fastener.

Step 8: Make sure that the roller ski looks nice and that the wheels are tightened properly.

Step 9: Repeat steps 4-8 to assemble the second wheel onto the ski frame.

Step 10: Place the ready roller ski (assembled with stickers and two wheels) on the station so that station 3 can reach it.

Process Description

Station 3: Plates and Mudguards

To add plates and mudguards onto one roller ski it is needed:

- 1 Mounting plate. (1 big and one small) (Box labeled black/pink mounting plate)
- 1 Trigger Clamp (At the station already)
- 1 Air Hydraulic Riveter (At the station already)
- 12 Bolts. (Box labeled Bolts)
- 1 Skate Roller ski from station 2
- 2 Mudguards (Box labeled Skate mudguards (select one color))
- Rottefella User manual and illustration (At the station)

Step 1: Go and get the above mentioned parts.

Step 2: Place the ski from station 2 into the trigger clamp. Make sure that the ski is secured properly there.

Step 3: Then place the mounting plates as the user manual states on to the ski frame.

Step 4: Take the Air Hydraulic Riveter and make sure that the compressor is plugged it in the socket at the back of the station. - If so take the red button of the compressor and push it up (It will make some noise, don't get scared), if the compressor stops making noise, it is because the compressor has enough air in it, so you can continue your work.

Step 5: Take a bolt into the nozzle of the Riveter and place it over the first hole of the mounting plate. When it is in the correct place, press the button of the riveter and the bolt should now fasten the mounting plate onto the ski frame. Remove the tip of the bolt that is left in the Riveter. Repeat the steps until the holes in the mounting plate are fastened with 8 bolts. (Use the manual in front of you as a guide if you are unsure).

Step 6: Place one mudguard over the two holes that are left at the end of the ski. (Use the illustration in front of you as a guide if you are unsure), take one bolt and place the long part in the nozzle of the Riveter. Put the Riveter with the bolt and place it over the hole of mudguard. Press the button. Mudguard should now have been mounted on the frame with one bolt. Then remove bolt that is left in Riveter. Repeat until both mudguards are fastened (Should be 4 bolts, 2 for each mudguard).

Step 7: Make sure that the ski looks nice and that all the bolts are secured.

Step 8: Place the ready ski on the station so that station 4 can reach it.

Process Description

Station 4: Packaging

To package one pair of roller skis it is needed:

- 1 Pair of Roller Skis from station 3
- 1 (Black) big piece of Cardboard. (Placed in front of the first bench)
- 2 (White) little pieces of Cardboard. (Placed in front of the first bench)

Step 1: Use the ready boxes on the station as a guide in the following process.

Step 2: Fold the little cardboard box (this is a piece that makes the skis stable in the box). First make sure that the brown part faces you. Then take the cutouts in the middle and push the parts that are bendable down towards the floor, now you have two 14 cm squares in the middle. Then take the bendable parts over the squares and fold them up towards you showing the white parts and fold it in towards the middle. Take the sides and insert it in the gap of the sides. Then take the two parts sticking out and fold them so that they hide the brown part of the cardboard. (Repeat steps to make the other little box.

Step 3: Fold the black and big cardboard. The white should be facing you. Fold the small sides of the cardboard towards the two slits. Fold the (24,5 cm) piece over the small pieces. Now you should have made the basis of the box. Then fold the lid. Make sure that the round pieces on the smaller sides go inside the gap that exists between the sides of the front.

Step 4: Insert the folded white cardboard into the black box (in the middle).

Step 5: Every time when you receive roller ski(s) from station 3 make sure that it/they is/are of good quality. (Meaning that the sticker is on straight, the wheels roll the way they should and the nuts and bolts are fastened properly) – If not stop the line and let the people know.

Step 6: When you are done go and help other students, or observe their work.

Step 7: When you have a pair of roller skis ready to be packaged, look at the pair and make sure that the nut on the wheel at the back of the ski is not assembled in such a way that when being used the nuts will scratch the side of the skis.

Step 8: Place the skis in the box.

Step 9: Put the packed skis into the storage space (right beside the station).

Process Description

You are a manager!

- Help those who need help.
- Observe the line.
- Make notes about visible problems and their improvements.

Appendix B

Interview Questions

Ask participants right after the activity:

1. What kind of changes did you do? Reflect on connection between the theory and improvements.
2. Give an example of improvement students mention and ask whether they used kaizen, waste types, efficiency or push/pull production system theory to come up with it.
3. Were improvements in different rounds built up on suggestions from the previous? Did you use experience from the previous round to improve during the next? How?
4. What kinds of waste did you eliminate during the activity?
5. Do you think such kind of activity is a valuable tool for the learning process?
6. What do you think is kaizen/continuous improvements?
7. Which production system is better to use in this case push or pull?
8. The improvements you applied have changed the system from pull to push or from push to pull?
9. What did you learn on your own?
10. What did you learn during the group discussions?
11. How did you make sense?
12. What if you didn't get the theory in the beginning of the activity?
13. What are advantages and disadvantages of participating in this activity?
14. What are your suggestions of improvement for the activity?

Ask participants in one week:

1. Which theoretical aspects you remember? List them (kaizen, push/pull, efficiency, waste types).
2. What kinds of wastes do you remember? How did you use this part of theory in the activity?
3. Was it a valuable learning experience?
4. After one week can you come up with any more advantages of participating in the activity? (Say what their answer was the first time – make them reflect on other sides that they might have thought about later).

5. After one week can you come up with any more disadvantages of participating in the activity? (Say what their answer was the first time – make them reflect on other sides that they might have thought about later).

6. What are your suggestions of improvement for the activity?