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Roller skis assembly line learning factory – development and learning outcomes

Olga Ogorodnyk[a]*, Malin Granheim[a], Halvor Holtskog[a], Ievgen Ogorodnyk[b]

[a]*NTNU in Gjøvik, Teknologivegen 22, Gjøvik, 2815, Norway*
[b]*National Technical University of Ukraine "KPI", Prospect Peremohy, Kiyv, 03056, Ukraine*

Abstract

This paper describes the process of creating a learning factory based on an assembly line of roller skis used 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. It also includes description of learning outcomes received as a result of taking part in the activity. Literature review and group interviews were used to conduct the study and evaluate developed educational activity. Practical case study approach was also applied. The study has shown that application of learning factories, experience based learning, game based learning and serious games leads to enhancement of learning experience gained during educational activities.

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Keywords: Learning Factory; Manual Assembly Line; Experiential learning; Game based learning; Learning outcomes.

1. Introduction

The concept of learning factories is becoming more and more popular nowadays. The term was first used in 1994 when Penn State University developed a learning factory, under the grant of the National Science Foundation. Since then, the use of learning factories has increased, and the design has taken diverse variety of forms aiming to intensify the learning experience of participants [1]. This paper offers to take a closer look at development of a learning factory based on serious games, game and experience based learning as a source of knowledge and sense creation.

The learning factory is a copy of a real assembly line of roller skis used at ABC company, thus the educational activity makes it possible to combine 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

* Corresponding author. Tel.: +47-486-305-83.
E-mail address: olga.ogorodnyk@ntnu.no.

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being held in the real world brought into the classroom [1]. *"Learning Factories pursue an action-oriented approach with participants acquiring competencies through structured self-learning processes in a production-technological learning environment"* [2]. Studying within such environment gives students opportunity to look at the possible challenges and problems that might appear on the assembly line implemented in the real company.

The following sections of the paper are dedicated to description of creation process of the learning factory and showing which learning outcomes where gained by students from it. Also, suggestions on how to design an educational activity in order to enhance the learning outcomes in the field of engineering and manufacturing education will be provided. The following section gives an insight of theoretical concepts used during creation of the factory.

2. Theory overview

In order to proceed to the description of learning factory it is necessary to look at some of important terms used to create it and explain why they were chosen. As mentioned before, the activity includes elements of experience based learning, game based learning and serious games. These terms are important since they form a basis of the educational activity.

According to Nöhring, Rieger [3] *"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"*. Experiential learning is an active learning method, which is one of the most beneficial for manufacturing and engineering students, as here they get to work in the real situations. This type of learning process is stated to be a key factor that allows students to gain knowledge through experiencing things [4]. As a result, after graduation they have knowledge that can be easily applied. *"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"* [5]. Experiential learning cycle shown in Fig. 1 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 [6].

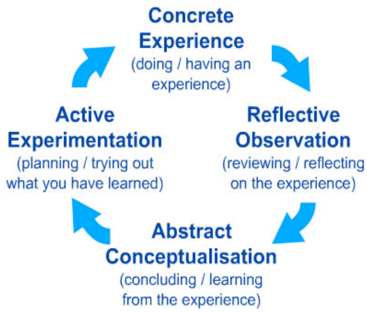

Fig. 1. Experiential learning cycle [6, 7].

Game based learning can be defined as set of *"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"* [8]. Serious games, in their turn, are games that have a purpose to provide learners with *"authentic learning experience where the entertainment and learning are seamlessly integrated"* [9]. 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. Serious games are often used for medical and military training, as well as at schools to increase pupils' interest in certain disciplines, some examples of serious games can be: VHealthCare™ [10], America's Army [11], Quest Atlantis [12], etc. Use of passive learning methods leads to decrease of interest and amount of people willing to receive higher education, especially in the field of engineering and manufacturing [13]. Klopfer, Osterweil [14] state that games frequently give player freedom along five different axes, that can be rarely found within educational activities: freedom to fail, freedom to experiment, freedom to fashion identities (experience things from perspective of different characters), freedom to effort, freedom to interpret. Each of the "freedoms" if implemented within educational activity will give a student possibility to be engaged and interested, instead of being stressed about a grade, thus allowing to have a will to learn rather than to be forced to learn. After giving an insight of the most important theoretical concepts used during creation of the factory, its development process and description will be provided.

3. Description of developed factory and its creation process

3.1. Description of the learning factory

The learning factory was planned as a copy of an assembly line for roller skis used for skis production at ABC company with minor changes necessary for enhancement of the learning process. The line at the factory contains of four stations corresponding to four processes as parts of the overall process of the roller skis assembly. 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 factory. Students' main aim is to decrease the assembly time of the roller skis. Fig. 1 shows a roller ski and its components without stickers.

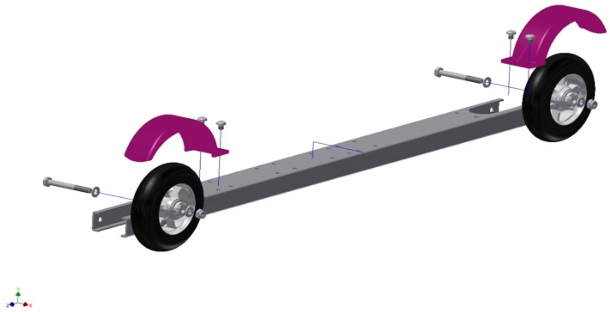

Fig. 2. A roller ski and its components.

It is possible to produce two main models of roller skis on the factory – *classical* and *skate*, which have differences in the assembly process, since there is different amount of parts needed to assemble the models. The main difference is hidden in the assembly of wheels, thus making it impossible to use delayed differentiation, as adding the wheels on the ski frame is required to proceed with the process. On the other hand, the assembly line doesn't need any reconfiguration to switch from production of one model to another, as all the necessary tools are the same.

The factory consists of 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. Fig. 3 shows the stations of the factory.

Fig. 3. The roller skis learning factory.

The stations include only those tools that are necessary for the assembly process as well as related instructions/drawings, while all the parts are situated on two separate tables. The first station has bearing press and a drawing of a wheel assembly; the second one ski frame holder and two drawings illustrating the process of adding wheels and stickers to the frame; the third station contains ski frame holder, compressor, bolt-riveter, illustration of putting on mudguards and the binding plates and example of a half-assembled roller ski shared with the second station; the last station includes examples of packaging units.

Such setting of the stations is done 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 the very beginning of the activity the stations have the setting as described previously. 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 blank pages for notes. Next, the theory in the pamphlets is presented by the guiding teacher or trainer, participants also are given 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.

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. 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.

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. During the following two runs, there were six students taking part in the first and five in the second run. The interviews were held only with participants of the usual runs and not of the test run.

3.2. Creation of the learning factory

Before the start of the activity's development a broad literature review was carried out. This was done in order to get familiar with necessary theoretical topics and understand which of them can be used. As a result, tools and concepts mentioned in the previous section were decided to be applied to create the learning factory. *"In terms of enhancing employees' improvement abilities with the use of learning factories, existing education and training programs are remodelled by the means of competency-oriented, scientific-founded didactic concept"* [2].

As students were going to work on the copy of the real assembly line, experiential learning was applied to 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 [4, 5]. According to Kolb and Kolb [6] experiential learning follows six important propositions, one of the principles states that learning is always better if it is 're-learning', that is why developed educational activity contains several practical and theoretical rounds. 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 mentioned previously. 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 [2] and was chosen to be used as students might not be familiar with theoretical topics that they need to use.

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 [14] were attempted to be embedded into the activity. Freedoms to fail (students have possibilities to make mistakes), to experiment (participants can use everything they have access to), to fashion identities (students can try different roles) and to interpret (every participant perceives the activity differently) are fully present within the activity.

Serious games are games at their core, but their preliminary goal is education, rather than entertainment [15], this makes them to be an attractive tool within educational activities development. Serious games are stated to have the following performance indicators: rule and goal, sensory stimuli, control, challenge and interactivity [16]. The indicators were used to improve the activity, however, rules are not present as such. 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 developed as the one making it interesting and joyful to learn, instead of having the boring and unengaging process.

3.3. Learning outcomes

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 have learnt something was possible only through running the activity and holding interviews with participants afterwards.

According to answers on the interview sessions students have gained learning outcomes in form of both theoretical and practical knowledge on the aimed topics. They could define the major concepts 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 in practice. In their opinion, the activity is valuable for the learning process, as it gave them possibility to gain practical knowledge of application of the 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.

3.4. Boundaries of the study and future work

It is also necessary to describe boundaries of the study to give the readers a clear picture and to make it easier to understand what 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. The second limitation is connected to number of people that can take part in the activity simultaneously. Currently the facility can host from five to six participants at a time (four students busy at work stations and one or two acting as managers). Among others, the limitation of technology is present in the study. Since the assembly line used during the activity is manual, it does not include technological appliances such as screens showing time used for a certain stage of the activity or operation within it, sensors, etc. However, this can be added in future during expansion of the learning factory and activity based on it. This can be done through application of Industry 4.0 concept. It is also important to know that the focus of the study was on interaction with students from Technology, Economy and Management faculty at NTNU Gjøvik. In future, it is necessary to conduct a study with bigger number of participants from different departments. This would give possibility to receive more solid results and increase both reliability and validity of the study. The next section will give suggestions for creation of similar activities.

4. Suggestions for creation of similar activities

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. Holistic picture of application of learning factory, experience based learning and game based learning concepts can be a recipe for building a good learning activity.

To have an educational activity, that is interesting and capable of brining practical knowledge to engineering and manufacturing students, experience based learning and game based learning need to be included, as one brings the component of actually gaining experience and practice, while another makes it engaging, challenging and playful. 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"* [17].

Learning factory is a good tool to be used during the learning process, however, it needs experience based learning and game based learning to be applied together with it in order to enhance the learning outcomes. Lack of these concepts leads to inefficient learning process that doesn't bring students as much benefits as combination of the listed techniques.

5. Conclusions

The paper was aiming to provide description of the roller skis learning activity development and application, as well as give suggestions to facilitate creation of similar activities. Learning factory might be a good educational tool, but application of it together with experiential and game based learning will increase value of the activity significantly. Such educational activities are important for the learning process, as use of conventional learning techniques leads to a problem of students not reflecting on the presented material and often just passively writing it down [18]. 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"* [19].

Proposed approach is beneficial since it enhances learning outcomes received after taking part in the activity. It gives students possibility to gain not only theoretical knowledge, but also experience of working on a real assembly line. In addition, learning by doing allows to remember perceived information and skills for a longer time, this was tested through holding the interview with students in a week after completing the activity. However, to reach described results it is important to use the proposed approach with all the mentioned components and concepts, as taking away one part does not guarantee achieving the same level of learning outcomes.

The article 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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