Student's role in the Implementation of a Lean Teaching and Learning Model

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Abstract:

This paper presents a pilot study based on the application of lean concepts to teaching and learning in higher education. It is based on findings carried out within an optional course called "Lean Enterprise", which is part of the 5th year of the Integrated Masters degree program of Industrial Engineering and Management (IME), at the University of Minho, Portugal. The study aims to discuss students' active role in the improvement of teaching and learning. The main structure of the methodology used is based on the implementation of PDCA cycles of continuous improvement in each class. A set of standards were created at the start to make the continuous improvement effective. One of the standards created was the standard structure for the class. The classes followed a pattern established of 100 minutes per class, with a defined instant to start and a defined instant to finish. At the end of every class (total of 12 sessions), the students were asked to give feedback about the class performance. Data collection was based on online questionnaires to students, applied at the end of each class (for process evaluation) and also at the end of the conclusion of the course (overall evaluation). Findings based on students' perceptions suggest that the model applied was useful and contributed to improve teaching and learning, showing that students´ play a very important role in supporting teachers with feedback about course planning, delivery and assessment. Implications of the application of this model based on lean concepts to educational settings will be discussed in the paper.

Keywords: Active Learning; Engineering Education; Lean in Teaching.

1 Introduction

Lean philosophy named by Womack, Jones, and Roos (1990) to address the principles and concepts behind the Toyota Production System (Onho, 1988) is bringing higher productivity and competitively in organizations. Lean means doing more with less, respect for people, team work and continuous improvement. Starting to be applied in industry it is now applied in every type of organizations, from healthcare to construction, office work and education.

Lean principles and concepts can be applied in theory in any activity sector although its traditional tools may not. Applying lean in education organizations is more or less the same of applying it in offices and public services but applying lean philosophy in teaching and learning processes is a bit more difficult. Some work has already been done by Emiliani (2015) but a log way is still to be travelled in order to determine the more effective tools and techniques in order to materialize lean in this type of environments.

The objective of this article is to make a contribution to the knowledge on applying lean principles, concepts and tools in order to bring more effectiveness and efficiency to the teaching and learning process. This article describes a pilot study in the University of Minho in the Integrated Master Course Degree in Industrial Engineering and Management.

2 Literature Review

What is now known as lean philosophy started in industry in the decade of 1950 under the name Toyota Production System (TPS) (Ohno, 1988). According to the first published article written in English about Toyota (Sugimori, Kusunoki, Cho, and Uchikawa, 1977) the TPS was based on two basic concepts: the first concept is

the cost savings achieved by reducing production waste (activities with no value adding) and the second concept is treating workers as human beings and with consideration. In the context of TPS waste is any activity that does not add value to products or services. There are 7 types of classic waste very well described by Coimbra (2009): Overproduction; Materials waiting (inventories); People waiting; Defects; Excessive or inappropriate processing; Transport; and Motion. Although the second concept (treating workers as human beings and with consideration) is central in any lean implementation and success it can be used here as "respect for people" in general.

This production approach became known worldwide in the decade of 1990 through a famous book written by Womack, Jones and Ross (1990) although the lean principles were only expressed later by Womack and Jones (1996), being:

- Value - the value must be defined by the customer since the customer is the one that will pay for the product.
- Value Stream – Identification of all the steps needed to build a product from raw material to the customer.
- Flow - the products should flow through the various process steps without interruptions or delays at the rate that the customers need.
- Pull Flow – nothing is performed without being required by the next process or by the customer.
- Pursuing Perfection – the organization need to always find ways to improve, to do better and better all the time.

These principles are largely applied not only in industry but also in other organizations such as hospitals (Graban, 2011), offices (Keyte, 2004), construction (Alarcón, 1997) as well as in other sectors of activity. Education is also an activity where at least some lean principles and concepts may be applied.

A key lean concept applied in the experience documented here, is the continuous improvement. The continuous improvement model, often used in Lean environment to materialize the 5th principle of Lean (Pursue Perfection), is frequently based on PDCA cycles and the concept of Standard Work. The concept of standard procedures or Standard Work (TPPDT, 2002) is based on the assumption that if an operation or set of operations are carried out always in the same way then the result is always the same both in terms of quality and in terms of time spent (important for planning).

Taking as its starting point an opportunity for improvement or a problem to solve a particular case, the PDCA cycles can be summarized as follows: (Plan) the current situation is clearly defined and a plan is developed in order to make the desired change; (Do) the plan is executed to reach the desired state; (Check) verifying if the results is what was expected or not; and (Act) a decision taken about what to do in the next PDCA cycle. A new cycle will then be initiated. The PDCA methodology only work effectively if there is a default rule or procedure (Standard Work) assumed for the case in which the PDCA cycles are applied. Whenever the PDCA cycles result in an improvement then the standard procedure should be updated to ensure that the gains are maintained. Another relevant concept is the creating of flow (third lean principle). Flow is based on a likely unintuitive aspect of Lean thinking. The act of processing products in batches is naturally seen as a way of reaching high performance but that is not exactly true. Batch processing is the opposite of flow and in lean approaches flow is required as much as possible. Flow is achieved when products flow continuously along the system processes. Flow principle can be represented by water stream where the water flows continuously along the river bed (Cousineau, 2012) in opposition where there is water stagnation at some points along the process. The desirable limit of flow is called "One Piece Flow" which in fact reflects perfect flow since the items (products, parts or components) never wait to be processed, advancing from process to process in a perfect rhythm.

2.1 Lean in Teaching

Lean associated to education is commonly referred in the literature as the application of lean concepts, principles and tools in the university as an organization in the public sector (Ziskovsky and Ziskovsky, 2007) (Thirkell and Ashman, 2014). Another dimension of lean in education is the focus on how lean is or should be taught in universities (Fliedner and Mathiesona, 2009) (Alves, Kahlen, Flumerfelt, and Siriban-Manalang, 2014). The application of lean concepts and principles in the teaching and learning process which is the focus of this

article is not very popular in the literature and no much work is known in this subject. The intangibility and complexity of the learning process makes the application of lean philosophy a quite big challenge. The learning processes are difficult to be defined precisely and also very difficult to be evaluated. For these reasons the application of lean thinking in these processes becomes a very difficult task. Nevertheless, since lean thinking has being applied in more and more non-industrial environments, it also may bring improvements in teaching/learning environments. Emiliani (2015) has already proposed a model for lean teaching where some lean principles are applied with success.

The Lean Teaching model applied in this experiment was mainly based on: (1) A standard structure to be followed in every class, (2) PDCA cycles, and (3) Punctuality grading. The standard structure for a 100 minutes class is as follows:

- Discuss the evaluation results collected from students in the previous class
- Remember key points from the previous class (using visual information)
- Present the class plan to the students
- Identify the student learning outcomes for the current class
- Activity 1 (~30 min) Presentation of material or group work (active learning). Note that even presentation of material also must incorporate active participation of students.
- Activity 2 (~30 min) Group work if activity 1 was presentation or the other way around.
- Product evaluation – Groups of 3 students perform a test to verify the learning outcomes achieved. During the test, the students in each group will discuss and learn with each other.
- Process evaluation – Students will respond to a questionnaire.
- Each team presents the work performed since last project presentation. Feedback is provided by the teacher and by other students. This project work is assessed.
- Open discussion on lessons learned, improving opportunities and next steps.

The PDCA cycles are naturally implicit in the standard structure as long as the planning adjusted according to the Checking phase (product and process evaluation presented in the standard structure).

The punctuality grading is important to motivate the students to be present on time in order to make the standard structure feasible. It is also important to clarify the respect for people concept of lean and to eliminate the waiting waste (lean concept).

2.2 Student's role to improve teaching

In student-centred learning environments, such as project approaches and other cooperative learning environments (Fernandes, Mesquita, Flores & Lima, 2014; Johnson, Johnson, & Smith, 1998) students play an important role in the construction of their own knowledge, by being actively engaged in the learning process. Unlike traditional teaching methods, where the responsibility for learning rested with the teacher and where the learner played a passive role, active learning emphasizes the importance of the relationship between the student and the teacher in the learning process. Therefore, students also participate in the assessment process in a very dynamic way, as their feedback and continuous assessment will provide teachers with inputs to improve teaching and learning. The evidence collected from students will support decisions that allow changes and/or improvements in teacher performance and in the organization of the learning activities. Designing assessment methods that promote student learning include the use of several frequent tasks rather than one end of course assessment (or build in steps) and also providing timely and detailed feedback to students (Gibbs & Simpson, 2004). Feedback and formative assessment is crucial for effective learning (Yorke, 2003). Teachers must use feedback to evaluate how well the classes went and how they can be improved. Several sources of information may be useful here, such as student evaluations, open discussions with students, the teachers' own experience with the course, etc. All evidence collected from these sources can provide important inputs for improving the teaching and learning process. In summary, student's role to improve teaching is determinant for successful learning also.

3 Methodology

The objective of this study is to analyse student's role in the evaluation of a Lean Teaching and Learning (LTL) model implemented in a Lean Enterprise course at the University of Minho. It is based on a qualitative research approach aimed at analysing student's views and feedback in regard to the teaching and learning process based on the lean principles applied in the classroom context.

3.1 Context of the study

The study was carried out in the context of a course named "Lean Enterprise", which is part of the 5th year of the Integrated Master degree program of Industrial Engineering and Management (IME), at the University of Minho, Portugal. This is an optional course that involved 31 students. The students were male and female regular students aged in general from 22 to 24 years old. Only 2 of them were a bit older and having part-time jobs. Classes took place during September and October 2015. During the 6 weeks of the course duration, there was room for a total of 12 sessions of 100 minutes each. The aim of this course is to help students develop skills in the context of creating continuous improvement systems in companies and the application of concepts and Lean thinking in non-industrial processes such as lean office, lean accounting and in Lean leadership aspects. Applying concepts of lean thinking in the course makes a lot of sense since the course itself is about that. The methodology applied in the case presented here - Lean Teaching and Learning (LTL) - is inspired in concepts and principles of lean thinking as well as in some tools that have been developed to help the materialization of lean concepts and principles. This paper will give special attention to short term PDCA cycles in each class and long term PDCA cycles in each semester. This article is mainly focused on the long term PDCA cycle.

3.2 Data Collection and Analysis

Data collection was based on an online questionnaire applied to students at the end of the 12 sessions. This questionnaires aimed to collect student's feedback in regard to the course and the new model based on the lean concepts applied to the teaching and learning process. The questionnaire included 9 questions based on a Likert scale. Six out of these 9 questions asked students to justify their answers with an open field that allowed students to provide qualitative feedback. This mixed approach, considering quantitative and qualitative data, intended to provide the teacher responsible for the course and the researchers involved in the project with as much detail as possible in order to provide room for improvements. These improvements should support the PDCA cycles.

The online questionnaire included the following questions:

- Q1. Applying the same standard in every class was positive. Why?
- Q2. The applied standard work was the most adequate. Why?
- Q3. PDCA and Standard Work applied in the classes helped clarifying the concepts.
- Q4. Product evaluation (with online group tests) and process evaluation (with online surveys) was useful. Why?
- Q5. Being assessed every class (through tests and group work) was positive. Why?
- Q6. The contents lectured in classes were relevant for the industrial management and engineering profession. Why?
- Q7. The teacher played a key role in the course success. Why?
- Q8. The punctuality grading system promoted class quality.
- Q9. The project was relevant for learning effectiveness.

These questions were followed by 2 open-ended questions:

- Q10. Identify the most positive and less positive aspects of the course
- Q11. Other comments or suggestions

For data analysis, descriptive statistics (average results) was used to describe and discuss the quantitative data achieved in the questionnaires collected from students. This analysis was complemented with simple graphics that allowed a better understanding and comparison of results from different items included in the questionnaire. For the qualitative data analysis, these questions were analysed based on two main categories:

one related to lean concepts and practices; another, related to educational issues (see table 1). The analysis of results will be presented in the next section, flowing this categorisation.

Table 1. Questions categorised by lean and educational issues

Lean concepts and practices	Educational Issues
Q1. Applying the same standard in every class was positive. Q2. The applied standard work was adequate. Q3. PDCA and standard work applied in the classes helped clarifying the.. Q6. The course contents were adequate. Q8. The punctuality grading system promoted class quality.	Q4. Product and process evaluation was useful. Q5. Student assessment in every class was positive. Q7. The teacher played a key role in the course success. Q9. The project was relevant for learning effectiveness.

4 Results

The results obtained from the questionnaires are of both quantitative and qualitative. The quantities results are presented in Figure 1 in terms of average values. One of the questions with the highest scores (4.52 out of 5) was "The punctuality grading promoted classes quality". The students appreciated the fact that all students were at the classroom before the starting time and therefore the class time was effectively used. The reason was that 15% of the final grading system was based on punctuality. Interestingly, the students appreciated it. The other question with the same high score was "PDCA and Standard Work applied in the classes helped clarifying the concepts". In fact, the main structure applied in the classes is based on PDCA cycles and Standard Work concept and students recognized its application and usefulness.

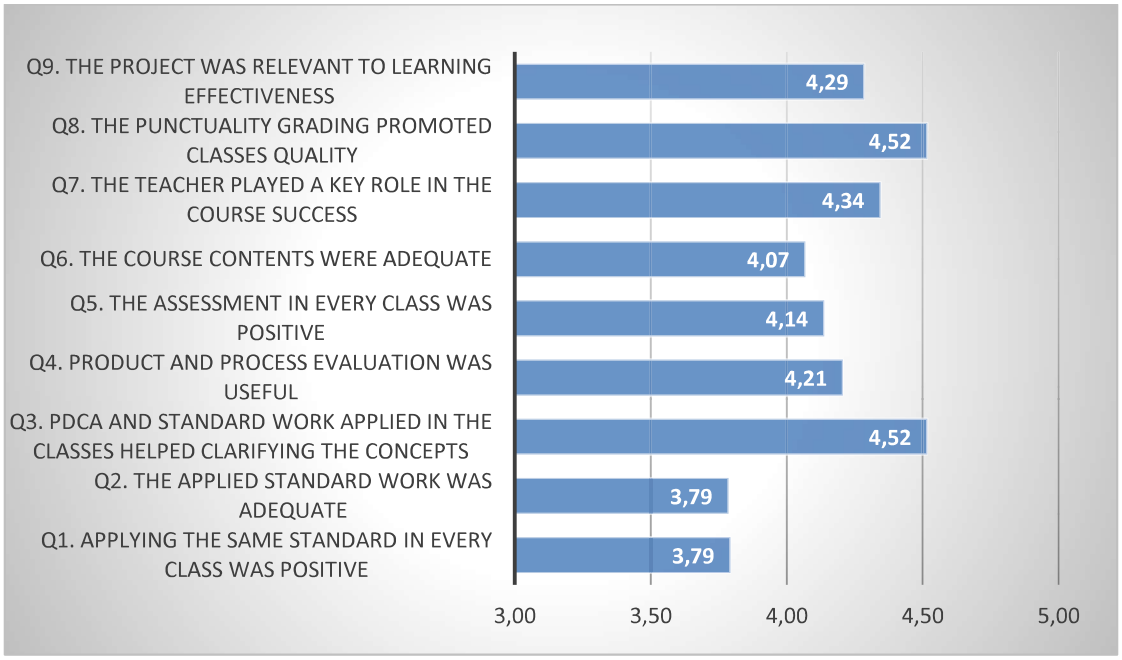

Figure 1. Average results obtained from the final Questionnaire

On the other hand, the answers with poorest score were "Applying the same standard in every class was positive" and "The applied standard work was adequate", both with 3.79 out to 5. This finding requires greater reflection and deeper understanding on how to improve and redesign the class structure standard in order to be more effective and satisfy students' needs.

4.1 Lean Issues/perspective

The lean issues/perspective is analyzed here based also on the quantitative results but with more focus on the comments from students in the open-end question.

4.1.1 Standard Work

A very popular practice in lean environment is the implementation of "standard work" concept as mentioned earlier in the article. The existence of a standard structure in every class was implemented expecting similar advantages as the ones known in other areas of activity. Two questions were put to the students in the following way: "Q1 – Applying the same standard structure in every class was positive" and "Q2 – The applied standard work was adequate". The average student evaluation on these question was 3.79 out of 5 (see Figure 1) being interestingly the same for both question and being the lowest feedback of all questions. Arguments in favor and against the use of standards exist in industrial or office environments and they were also found here. Although the majority of the answers from students were in favor of the use of standard, some students also express some disagreement. Examples of student comments (quotes) in favor of standards:

> "Creating routines is positive for good class organization"
>
> "Allow the knowledge on how the class was going to run"
>
> "Allow the development of habits that lead to more effective learning"

Examples of student comments (quotes) expressing some disagreement on the use of standards in class:

> "Important changing standards to create motivation"
>
> "Following a standard in a class is 'excessive strictness'"

Regarding the applied standard students mentioned the difficulty in meeting the time in many activities or the limited time assigned to some tasks that needed more time to be effective. Examples of comments were:

> "I think that it was adequate but there is always space for improvements"
>
> "The standard was not followed many times leaving some learning activities unfinished"
>
> "We should alternate with other standards"

From the feedback obtained from students and also from our own experience, the use of a standard structure in every class needs some improvements in order to be completely effective in the eyes of students (clients).

4.1.2 Team work and empowerment

Team work is very important in lean environments because it creates the necessary culture for problem solving and continuous improvement. Teams are critical in lean environments since without them lean is impossible to sustain. Teams are responsible to identify improvements opportunities and work together to find the appropriate solutions. Team work, promoted in every class, was recognized by students in comments such as:

> "It is important to develop interaction capacity in groups and having the perception that success is easier achieved with team worker…"
>
> "Team work it is an excellent way to work because it force us to interact, discuss ideas and reach to conclusions"
>
> "Team discussions promoted the exchange of ideas and helped clarify doubts than alone would be impossible to clarify"

Apparently students recognize that team work is an effective way of finding solutions for problems. This recognition is not only related to student life but also in real professional work in organizations.

4.1.3 PDCA cycles

PDCA cycles are essential to continuous improvement and they were used in the class room. The question Q3 ("PDCA and Standard Work applied in the classes helped clarifying the concepts") with 4.52 out of 5 had together with question Q8 the highest score. Students strongly recognized that the practical application of the

PDCA cycles in the class room helped in clarifying the concept. Examples of student comments regarding the PDCA cycles and its effectiveness in continuous improvement are:

> "The students were interested in learning because of the ´checking´ at the end of every class and that worked very well. The ´checking´ helped the teacher to understand what could be improved"
>
> "The teacher was concerned with the improvement of every class"
>
> "The check phase at the end of every class was important to confirm immediately if the concepts were actually learned"

4.1.4 Respect for people and Waiting Waste

Respect for people is a key issue in lean environments and the waiting waste is one of the 7 types of wastes found in production. In the questionnaire these issues were covered partially in que question Q8 ("The punctuality grading promoted class quality"). This issue was recognized with the highest score (4.52 out of 5) with comments such as:

> "… the punctuality grading was a positive factor since it allowed that all students were in class in time …"
>
> "one of the most positive factors in this course was the punctuality of the students"
>
> "the most positive aspect was the punctuality grading since resulted that all students were present on time and the class time was totally availed"

Regarding the respect for people some students added comments in the existing open-ended questions with comments such as:

> "The teacher was always kind and understanding"
>
> "One of the most positive achievements in this course was the exemplary conduct of students"

4.1.5 Creating Flow and Inventory Waste

Creating flow in production is a lot easy to understand than creating flow in teaching and learning. Some comments from students show the recognition of the advantages of flow in learning.

> "…testing and project presentations every week avoided the work being accumulated and continuous improvement"
>
> "…allowed us to assess our knowledge in the same day, helping to reinforce our knowledge. Having tests in every class requires us to be alert in every class, as opposed to other courses where we could study only before the final test"

4.2 Educational Issues

4.2.1 Product and Process Evaluation

In students' opinion, product evaluation and process evaluation were considered useful for learning. The main reasons mentioned by students are related to the importance of feedback provided by the mechanisms implemented. The online group test, used for product evaluation, at the end of each class, allowed students to reflect upon the contents and knowledge achieved during the class. Also, through the discussion of ideas with other students, students were able to clarify and understand concepts in a better and deeper way. This kind of learning leads us to conclude that cooperative learning and assessment strategies are very powerful tools that contribute to effective learning. Process evaluation, through the collection of data with an online survey at the end of each class, was rated very positively by students. Some of the issues explored in the online survey applied to students at the end of each session included dimensions such as: clarity of learning objectives, duration of class activities, teaching strategy used, assessment methods, group work, student involvement, teacher's role.

From an educational perspective, the concepts of continuous assessment and formative feedback (Black and William, 1998) are very evident in students' answers:

Students were interested in learning in all the classes due to the evaluation method and this became a great way to consolidate knowledge. The surveys helped the teacher to see if there was anything to improve and what it was!

With the surveys, we were helping the teacher to improve his lesson plan and improve things that did not go so well.

It was positive because we were able to give feedback to the teacher about what went right and wrong in class. It also allowed us to evaluate our knowledge of the class on the same day, consolidating knowledge, moreover, the fact we had tests every class required us to pay more attention in class unlike other courses that we only study just before the final test. The evaluation process also served as a tool for the teacher to improve the way he gives lessons, based on student's feedback.

Yes, with the tests we can see immediately if the concepts learned in class were effectively understood.

4.2.2 Continuous Student Assessment

Students were satisfied about being assessed at each class. Some of the reasons pointed out by students highlight the importance of discussing and sharing ideas with other students as a successful learning process that helps to clarify the understanding of concepts and also consolidate knowledge. At the same time, students state the advantages of continuous assessment which does not concentrate learning at a specific time at the end of the course. Besides these positive arguments related to the continuous assessment, other issues related to the cooperative assessment strategy used were also referred by students. The group assessments promoted the development of teamwork skills, student engagement and active participation in the learning process. These competences are aligned with the Bologna Process and student centred learning.

Student assessment at the end of each class allowed to consolidate and test knowledge from class to class. This discussion and exchange of ideas at the end of each class led to a better understanding. And the tests allowed us to summarize the general ideas about class contents from class to class.

I enjoyed the idea of having rotating groups, which allowed us to work with different team members.

The assessment strategies promoted teamwork and they were also a way to strengthen something that will be crucial for our future.

The assessment was a way to consolidate the class lessons. Having group presentations in all classes allowed us not to delay our work and improve continuously.

It makes students reflect upon their work in an immediate way and not delaying that reflection to a later phase.

The fact that students are assessed in every class gives me more motivation to study.

4.2.3 Teacher's role in the Learning Process

Student´s opinion in regard to teacher's performance is very positive. The teacher was kind and comprehensive with students. The teacher tried to improve performance at each class, based on student's feedback. Also the teacher's wide experience in Lean, due to contact with enterprises, allows the teacher to provide examples and link theory to practice. The idea of "practice as you preach" is very present in the classes.

He was kind and understanding, and was concerned with the improvement of every class.

Due to the teachers experience in the implementation and coordination of lean projects, this resulted in better teaching and learning.

Because of the fact that the teacher lives according to this philosophy, he deals with the activities from a Lean perspective, sets an example and shows improvements with this behaviour.

The teacher was important since we already have some experience in this area and sometimes que would add to our knowledge with his own experiences lived. This allowed a greater

> understanding of knowledge and concepts. (And also for being kind and understanding with everyone)

The quotes reveal a good learning environment. The teacher motivated students and provided engagement in each class. The teacher showed enthusiasm and excitement for the contents being taught. The following quotes from students' answers confirm the important role played by the teacher in the teaching and learning process.

> The way he kept students motivated through different activities. Moreover, keeping the punctuality as an evaluation criteria was a very positive issue in this course as it made all students be in class in time to start. The teacher's support in the projects also contributed to the success of course.
>
> Tried to motivate students to be more proactive by creating a learning situations that promoted this involvement.
>
> The teacher knew, in a way, how to use the appropriate methods for teaching the course and knew how to motivate the audience.
>
> I agree, the teacher assumed a very important and motivating role for the next phase of our lives (world of work). In addition, he demonstrated commitment to the course and was willing to try new alternatives proposed by the students.
>
> For helping us to think "outside the box" and the teaching methods used.

5 Conclusions

From this empirical study one of the conclusions that is possible to draw is that some lean concepts and principles can be used in teaching and learning contexts to improve its effectiveness. In reality some of those concepts are already aligned with educational theories that focus on student centred learning, but some others are new in educational contexts. There is still a lot of improvements needing to be done but from this pilot study results show that concepts such as standard work, PDCA cycles, continuous improvement, elimination of waiting waste, reduction of inventory waste and creating flow, are bringing improvements in teaching and learning processes. The study also draws attention to the importance of student's role in providing feedback in regard to the learning process, understanding of course concepts and also teacher performance. By developing an on-going system that allows to collect data from students in a systematic way, teaching can be improved and learning can be made more effective.

Future work will focus on applying other concepts and tools, especially ways to improve students' empowerment and ways to introduce visual management, value identification and the identification of more non-value adding activities.

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