Knowledge Creation in Engineering Education (University-Industry Collaboration)

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1. Abstract

This paper is an effort to develop an effective engineering education model in the university for a continuous Knowledge Creation (KC) and utilization. Universities are facing new issues due to the increase in distance & online education. Therefore, they are trying to attract and retain students by providing facilities like learning factory (LF). Learning factory being a platform for knowledge creation & learning, it also creates an environment for interaction between students, academics, and industrial participants. It is essential to understand how knowledge creation takes place within learning factory settings. Knowledge creation is a process of generation of new ideas, and studies are broadly within industrial organization thus ignoring educational context such as within university. Therefore, it is crucial for the university to take this challenge and address these gaps, which is above mentioned, i.e., identifying a model and its applicability. We have conducted qualitative research, which includes a detailed literature review, workshop, informal interview and focus group with participants. A literature review has shed lights on the advanced model of knowledge creation, and this model is based on a framework of the unified theory of dynamic knowledge creation through SECI mode, 'Ba,' knowledge assets, and Leadership or simply known as Nonaka's model. The workshop reports on knowledge creation and applicability of this model in learning factory setting. The finding shows that a unified theory of dynamic knowledge creation model fits our existing learning factory setting with minor adjustments to serve our local industries. In summary, this paper applies the unified theory of dynamic knowledge creation model for the learning factory settings and from findings; it highlights the importance of the application of the knowledge creation to develop the education system and the role of management in learning factory settings. The results of this research should interest both management of university and industry for shaping their learning process and continuous knowledge creation.

Keywords: Knowledge creation, University-Industry, Learning Factory, SECI mode, Ba, Knowledge Assets

2. Introduction

Knowledge is an essential organizational asset and considered as a crucial source for sustainable competitive advantage (Ragab & Arisha, 2013). The growth of present economy and society is based on knowledge (Toffler, 1990) (OECD, 2014), as knowledge is an enabler of continuous innovation and it is the driving force for development in this ever-changing world. Hence, creating, utilizing, and managing knowledge is a key for any organizations competitive advantage (Cyert, et al., 1993). There is widespread recognition of commercial organization becomes successful as they convert to knowledge-based. It is also dependent on the knowledge workers contribution to decision-making and creating innovation (Oliver, et al., 2003). To be competitive, industries are seeking creative and new ideas outside their organization, work in partnership with universities provide them with new knowledge for their improvement (Chesbrough, 2003).

Similarly, the university a continuous knowledge-creating organization recognize the importance and acknowledges it. Universities are stirring from traditional education model (Lectures, assignments & exams) to more towards dynamic education model (learning by doing, games, knowledge-based, etc.) especially in engineering education (Cachay, et al., 2012). Moreover, the researchers (Leung, et al., 2012) claims that the demand for quality in the education system is increasing and with the introduction of distance and online education, universities are required to attract and retain students.

Therefore, universities are looking for new alternatives focused on quality teaching method and something that distance and online education cannot provide. To face these challenges universities have adopted a new model for engineering education, the concept of LF. Learning Factories (LF) is useful for developing theoretical and practical knowledge in a real world-manufacturing environment. It is a common platform for knowledge creation & learning process between industries and universities; it creates an environment for interaction between students, academics and industrial participants, which is a success model (Kreimeier, et al., 2014). Despite all these facts and importance of LF, there is little understanding of knowledge process in LF settings.

The remainder of this paper is organized as follows: section 3 reviews the relevant theoretical background related to knowledge and learning factory. Section 4 highlights the research objective and methodology of implementing. Section 5, provides detail about the workshop. Section 6 highlights the results and discussion, and finally, Section 7 summarizes the entire paper and provides the direction for future research.

3. Theoretical background

3.1 Learning factory

The university is a renowned institution for teaching and research work; it provides the undergraduate and postgraduate study. The university vision is to transform classroom activities from the traditional model to a more interactive model with technology (smart class environment, simulation, etc.) for theoretical learning and LF for practical knowledge.

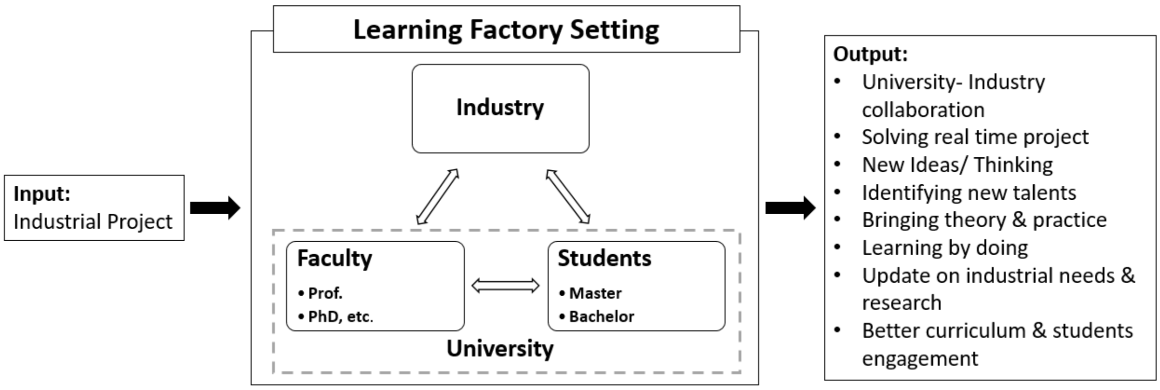
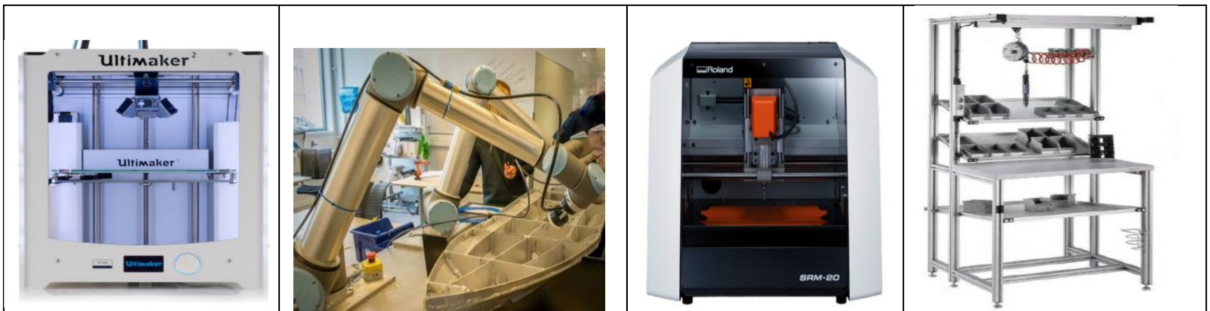


Figure 1: Learning factory setting

Learning factory is a room with required resources such as digital (software), virtual (Virtual reality), and physical (robot, 3-D printing, etc.) resources (Abele, et al., 2017). Figure 2, shows the physical capability of the lab this includes Ultimaker 3D printer FDM, UR 10 Robotic Arm, Roland SRM 20 Mill, Bosch Rexroth Modular workstation, Vinyl Cutter, Laser Cutter, Arduino Compatible kits, Plotter, Manual machines for cutting, drilling, welding, etc. Software includes 3D modeling CAD software (NX, AutoCAD), Cura, Simulation (20 sim, Technomatic), etc.



Ultimaker 3D printer	*UR -10 Robotic arms*	*Roland SRM 20 Mill*	*Bosch Rexroth workstation*

Figure 2: Learning factory Physical capabilities

The learning environment of this course is unique as LF involves theoretical lectures from faculty and industrial participant with practical examples for students understanding. The lecture covers the basics of Lean philosophy and principles related to manufacturing, held at smart classroom for theory and learning factory lab for practical work for students of various competence (Automation, Product & Ship design) and the sum of 30 students have participated in this workshop program. The duration of the course increases the complexity, as it is only a week there is a more challenging factor to consider.

The industrial partner is a local furniture manufacturer, and the industrial participants are a production manager and an engineer. Academic and Industrial participants are experienced lean practitioner. The industrial project (i.e., real-time problems) are delivered to the students during the workshop to brings together theory with practice and solve the problem with new ideas. LF has potentials and limitations in education, and training but researcher (Kreimeier, et al., 2014) states that both university and industry recognizes LF as a success. Also, this gained knowledge is used for the education of students and the training of industrial participants (Kreimeier, et al., 2014). This type of educational model has more benefits, as shown in figure 1. However, there are several shortcomings such as the role of management is not clear in this particular case. Since, the most of the collaboration is project based the knowledge is discontinuous, and diminishable.

3.2 Knowledge

According to (Hayek, 1945) knowledge is context-specific, as it involves time and space. There are two types of knowledge namely tacit and explicit. Tacit knowledge tends to reside within the individuals so hard to articulate, whereas explicit knowledge lies within the formalized setting in some tangible form such as words, audio recordings, or images (Dalhir, 2011). Researchers (Tyagia, et al., 2015) have stated that knowledge creation is a continuous process of updating and increasing the knowledge base or assets of what one knows now. Interactions among internal (Industry) and external resources (university) can exploit to create knowledge from existing knowledge unlike other passive resources (Leonard & Sensiper, 1998).

At initial screening, there are few criteria stressed to identify the right model for our case, i.e., knowledge creation and conversion (tacit to explicit & vice versa) and a framework to adopt. (Dalhir, 2011), have analyzed some KM model with a holistic approach (such as people, process, organization, and technology); these models are most reviewed, critiqued, discussed in the literature and tested in the field. Choo sense-making model (Choo, 1998) and the Inukshuk KM model (Girard, 2005) both use the SECI model for knowledge creation process. Similarly, researcher (Gregorio, et al., 2008) proposed an Epistemological–Ontological (EO)-SECI knowledge creation model this is a version of the SECI model. The researcher (Virkus, 2014) have analyzed these well-known models and concluded that the SECI model is widely adopted the model. The researchers (Leung, et al., 2015) from Vietnam have suggested that students need to go through the process of SECI to transform learning into a new set of tacit and explicit knowledge.

The SECI model proposed by (Nonaka, 1995) is noticeably the influential with few enabling conditions for knowledge creation (autonomy, creative chaos, redundancy and requisite variety). Autonomy promotes commitment and source of unexpected knowledge. The interaction between the organization and its external environment is endorsed by creative chaos. Redundancy denotes information overlapping supports tacit knowledge creation. Requisite variety mentions availability and accessibility of information throughout the organization. In time this model is further advanced as a unified model of dynamic knowledge creation using the theory of SECI modes, 'Ba' (Physical, virtual & mental space) and knowledge assets in the article (Nonaka, et al., 2000). Considering their positive outcomes and ease of implementation makes it favorable choice to select this model and implement.

3.3 Knowledge creation model

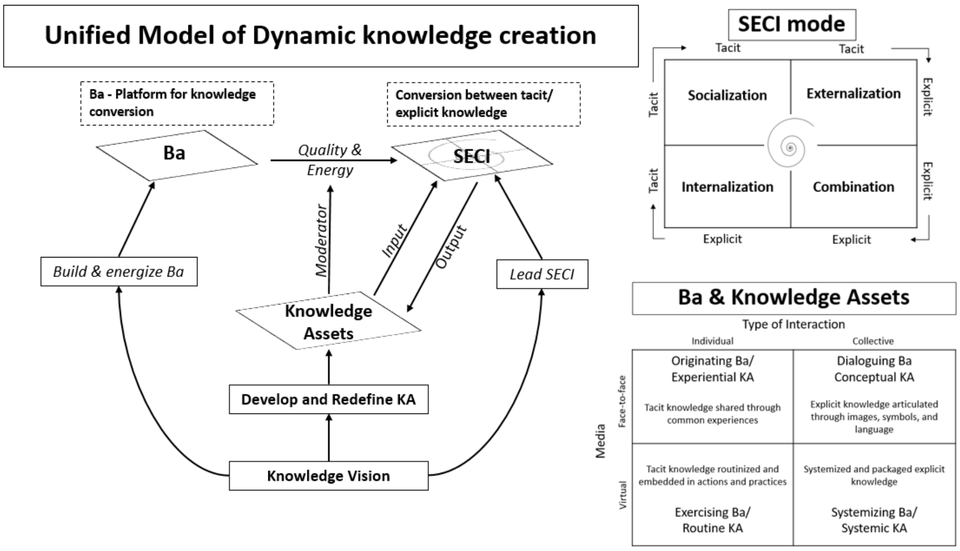


Figure 3: a Unified model of dynamic knowledge creation, & three elements of knowledge creation SECI mode, Ba & knowledge assets

3.3.1 SECI Mode

Figure 3, shows four modes for knowledge creation in the organization through the interactions amongst individuals and their environment (Nonaka, et al., 2000). Socialization mode offers sharing of experience to create tacit knowledge and improve collaboration (Oshria, et al., 2007). It supports face-to-face interaction and allows individuals to spend time together in the same environment to exchange personal or specialized knowledge (Li, et al., 2009). Externalization mode reduces the difficulties faced in the previous mode, and the new knowledge is formed while articulating tacit to explicit form (Choi & Lee, 2002). In this mode, the know-how and skills of individuals are articulated from abstract ideas, concepts, hypotheses, metaphors, analogies, and models for clarifying in generic form through demonstration, comparison, and experimentation for concrete information (Salmador & Bueno, 2007). Combination mode is essential to maintain expertise for a longer period, all the reports, thesis, and dissertation are integrated, classified, reclassified and synthesized with a view, to form a cluster of organized knowledge resulting from simple knowledge from the previous mode into 'systemic explicit knowledge' (Tyagia, et al., 2015). Internalization mode represents the completion of single iteration in the knowledge spiral, where collective explicit knowledge is converted into tacit knowledge, updating the mental representations of individual organization members (Vaccaro, et al., 2009).

3.3.2 Knowledge Asset

Knowledge creating process heavily depends on knowledge asset (KA) this means it is the resources that create value for an organization. Know-how, skills, thesis, Ph.D. dissertation, project are the created KA while journal articles, conference paper, professional association & technical reports are acquired knowledge asset. Knowledge creating process requires KA, as it is input, output and moderating factor (Nonaka, et al., 2000) and this moderation determines characteristic of 'Ba' (Tyagia, et al., 2015). Figure 2 shows, four types of KA such as experiential, conceptual, systematic and routine.

3.3.3 Ba (Shared context)

'Ba' is a concept proposed by Kitaro Nishida (Japanese Philosopher), and Shimizu has redefined (Nonaka, et al., 2000). 'Ba' roughly means 'place' (abstractly unites physical, virtual & mental place), where information is interpreted to become knowledge. According to (Tyagia, et al., 2015), knowledge creation can only occur in a place and time; it depends on the method of participation and the individuals who participate.

(Nonaka, et al., 2000) State that KC process is context-specific and it is important for KC that participant involves in the process of 'Ba' by interacting with each other in time and space for understanding the shared context and forming a common language. 'Ba' provides a base for SECI modes for sharing among individuals and a group in physical and virtual space.

The author is motivated predominately because of lack of research performed in this context. To the best of our knowledge, none of the researchers targeted the application of the unified model of dynamic knowledge creation in learning factory setting. The past literature focuses on knowledge management within Industry, and few have advanced in higher education, but these literature did not put learning factory in the context of knowledge creation. The underlying proposition is that dynamic knowledge creation in the educational organization within learning factory setting improves & upgrade engineering educational curriculum continuously.

4. Research objective & methodology

This study aims to understand the knowledge creation in the learning factory setting and then the applicability of the chosen model (Nonaka, et al., 2000). To answer the research question, initially, a literature review is performed among the existing model, which fits our need. It is evident from the literature review that integrated dynamic knowledge model (Nonaka, et al., 2000) is advanced, clearly shows the knowledge creation in a practical setting and it is well known amongst researcher and industrial practitioner.

This paper further discusses the implementation of the model in the learning factory setting to improve the learning outcomes. Students learning outcomes are evaluated with the help of their group activity, and presentation and an informal interview are conducted for feedback purpose. Knowledge creation in university is an extensive topic to discuss thus restricting research within learning factory setting in engineering education.

5. Workshop by a furniture maker for formulating assembly procedure.

As part of the curriculum, lectures are given to students about lean tools and principles for developing a basic understanding of core concept. The 30 students are divided into groups for the workshop, and the industrial participant describes the assembly of furniture product (Chair) & process involved. Also, the background of the factory was also presented this includes production, quality control, factory layout, supply chain, policy, inventories, assembly process, number of operators, problem statement, etc. For supervision, a professor, doctorate candidate, and research assistant were involved from the university while a production manager and lean practitioner participated from industry. The workshop takes place in the lab, which acts as the 'Ba' (physical place). Students were to perform the assembly process with consideration of lean principle one by one, as each iteration passes by the complexity of assembly have also grown. After each iteration, students have to discuss with rest of the group and supervisor to share their understanding.

From a university perspective, this brings theory and practice together, educating students by learning by doing, building teamwork, solving a real-world problem and future industrial project for university. From an industrial perspective, it aims at understanding the difficulties in the assembly line of the new product, time measurement, and develop a standard operating procedure. This innovative assembly process may bring changes such as faster and quicker assembly rate with the help of process simulation, without troubling the actual assembly line. The author participated in all the activities during observation and conducted an informal interview with all participant to receive their feedback. The final step of the workshop is to determine the progress of the student learning. It is essential to make sure that learning has taken place and students have understood the basic principles. To do this evaluation is required and the best way to do this is to allow the students to show their learning, understanding through presentation and group work. The faculties and industrial participant analyze the students understanding of the concepts, and their ability to connect the theory with practice.

6. Findings & Discussion

6.1 The SECI mode in learning factory for knowledge creation

During socialization, students spent time with the industrial participant (production managers and Lean practitioner) to observe, imitate, get hands-on training on activities and to practice. Also, sharing experience, mental model, and technical skills with students create and develop individual tacit knowledge. At this phase, students understood the product, process and its problems involved in assembling the chair manually in the current scenario as in a factory. This mode helped the students to understand the problems during training. This provided a shared mental model and common experience.

Students practicing manual assembly

Discussion of Focus group after iteration

Figure 4: SECI Mode in learning factory

At externalization mode, students collect data, report idea, view, understanding, and suggestion. During the discussion, groups are appreciated to create hypotheses and concept to solve the problems. It is notable that students identify the problem and solution that is associated with their competency and education. This show the students with a mixed group of competence have the potential to recognize more problem and bringing up solution. At this mode, tacit knowledge of students is converted into explicit knowledge by articulating through documentation and allowing it to be shared. Sharing with another group after each iteration is essential so that these groups can learn from each other & improve their methods. After a few iterations of the assembly process, each group developed their unique methods and reduced the wasteful activities. Externalization mode requires high involvement and participation from qualified professional, academician and students for successful completion.

In the combination, mode enables to collect the explicit knowledge of individuals to combine them through various media for systemizing. Each group explores the internet to collect the details (this includes published literature, project report, thesis, and dissertation) for similar problems from other industries and then prepares a final presentation of linking those theories with practice with valid evidence, proof for their views and suggestions. After the study, the students suggested innovative ideas. With lean principle as the core, they proposed few ideas such as a change in factory layout for continuous flow, digitalization for visualizing the movement of goods, process simulation for engineers to plan, ergonomic workstation & tools for operators, rapid prototyping of work tools, automation, and design for assembly to reduce time in operation and quality inspection.

Supervisors use the collected data for further processing and analyzing in the future. These solutions are documented in the structured report, and they are stored into organized explicit knowledge in both industry and university. The knowledge assets are systemized documentation, manuals, specifications, database, patents, and licenses. This act as the knowledge repository for both the organization, which forms the knowledge platform for the spiral of SECI mode. The 'Ba' in this mode would be virtual tools for organizing knowledge, blackboard, internet library and the intranet. Blackboard, a well-integrated information management system, is accessible to students to deliver reports, have a discussion, etc., while for faculty to post assignment, information, course material, etc.

During Internalization, individual students and academics embody the created explicit knowledge, further will socialize during other courses, project, thesis, and in coming years, thus starting a new spiral of knowledge creation. On the other hand, industrial participant shares result with the development team, across the department, and create a routine within the organization for improvements. The 'Ba' is the virtual tools, which includes collaborative knowledge networks, and databases. The knowledge assets are the organizational culture, routines, and the expertise.

Industry being satisfied with the results of this workshop interested in initiating these projects through master and bachelor thesis. The next step is that academics investigate the financial feasibility of these concepts and ideas followed by setting the right complexity for the thesis work. In addition, implementing this routine improves the university curriculum. Therefore, knowledge creation is continuous in LF setting; the internalized tacit knowledge will form the base of the spiral for new knowledge and will repeat the SECI process.

Table 1: Knowledge creation in SECI mode and relation with other elements

Mode	LF	Ba	Knowledge Assets
Socialization	Physical	Individual, Face-to-face interaction	Lectures, Learning by doing, know-how and skills of individuals
Externalization	Physical	Collective, Face-to-face interaction	CAD Model, Sketches, languages, and symbols
Combination	Virtual	Collective, Virtual interaction	Report, thesis, article, conference paper, dissertation documentation, manuals, specifications, database, patents and licenses
Internalization	Virtual	Individual, Virtual interaction	organizational culture, routines, and the expertise

6.2 Learning factory as Ba

The LF acts as 'Ba' (physical place), where the actual work such as socialization & externalization takes place, while library system, information management system (Blackboard), e-mail and other technology serve as a virtual place for storing and sharing information. The mental place being the shared ideals of that particular group. LF where individuals or a group can come, create, share the knowledge and move on based on their project but the shared context can evolve through time and utilized by the individual/ by the faculty in the future. The new knowledge is made explicit by articulating it as thesis, research project report, and dissertation, which is stored in the knowledge repository as knowledge assets. These new knowledge assets form a new base for a spiral of knowledge creation, thus adding to the new platform.

6.3 Role of management & leadership

In comparison with Nonaka model, the role of management and leadership in LF setting is slightly modified from the traditional model, which is represented in figure 3. The leadership team is comprised of a middle manager for the LF. In contrast, students are the primary knowledge producer here rather than the middle manager. The role of management and leadership team is vital as it sets the knowledge vision that gives a direction for further research, transcends existing boundaries and take a leading role in facilitating all the three elements of the knowledge-creating process. Therefore, they should read the situation and foresee the future; develop the knowledge vision that synchronizes with industry, and finally articulate and communicate the vision throughout the organization.

They should provide virtual space for more effective communication amongst all, which is also an enabling condition for KC (Requisite variety). Some of the enabling conditions for knowledge creation in student groups such as autonomy, creative chaos, redundancy and requisite variety were scrutinized. Autonomy increases the chances of innovation, finding new knowledge and enabled them to be creative. However, feedbacks from the informal interview state autonomy is not entirely successful among students as there was a lack of understanding and misinterpretation at the initial stage. Redundancy, as it refers to the overlapping of information, is not advisable if the course duration is short.

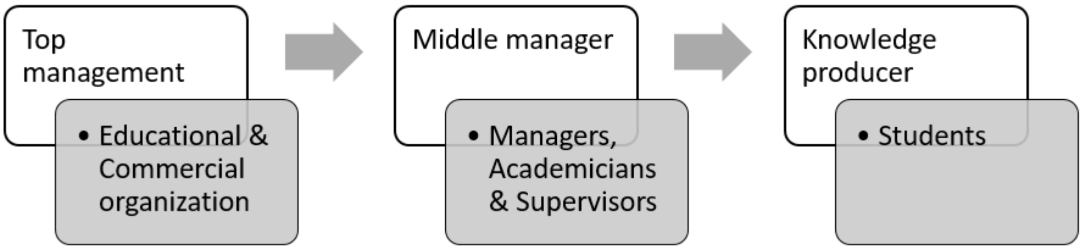


Figure 5: Role of management

The leadership team introduces creative chaos by increasing challenging task after each iteration such as reducing waste, time and improve efficiency. The feedback from students states that this challenging task helps in reconsidering and developing new methods. Middle managers should build, connect and energize 'Ba,' i.e., LF. They should keep track of KA; when required they should help the students in creating new or for exploitation of knowledge from KA. To manage knowledge creation efficiently, universities have to categorize the existing knowledge assets and map them often regularly. It is essential for the university to updated knowledge vision on a regular interval.

It is important to note that identifying the industrial partner, related problems and solving it is a complicated and time-consuming activity. This should be taken care without compromising the number and duration of each session of theory classes. Faculty should form a mixed group of students and support weak teams in complex scenarios, to boost the overall competitiveness. For a successful deployment, it is crucial to align the industrial objective with university objective and a deeper understanding of course content, curriculum, available knowledge assets, training of skills and competencies. In LF setting, as individuals, and as group students played essential roles such as performing activities, documentation, and presentation, etc. in the knowledge creation process. From observation and feedback from students' shows, they use both tacit and explicit knowledge to accomplish the task; forming student group have positive effects, a reflection of understanding is higher as the iteration goes up and utilizing methods of other group becomes more common. To reflect on the experience after each iteration briefing and debriefing sessions were done, where tacit knowledge was converted into explicit. This is required because students learn from their own mistakes and by learning from others. Quantifying learning outcomes from LF is not achievable for now. However, this experience and positive feedback give us an impression that it is favorable.

7. Conclusion

The paper used an integrated dynamic knowledge creation the model (consisting of SECI modes, 'Ba,' and knowledge assets) to highlight the importance of the application of the knowledge creation model to develop the education system in learning factory settings. The findings of this study show that this model could support continuous knowledge creation in learning factory setting and discussed the importance of the role of management. Socialization and externalization mode are the key knowledge creation process, while combination and internalization are key for knowledge sharing. Also, argued efficient management of knowledge assets would reduce the level of knowledge gaps and contributes to students learning, projects, educational quality and a higher degree of knowledge within the organization. In essence, this article investigated how unified model of dynamic knowledge creation help in learning factory setting for the effective engineering education model. It is important to note that sustainability of this model is essential for its effective utilization and a solid knowledge management mindset in the work culture throughout the organization is vital for its success. The next step is to consolidate the approach with more students for generalization and empirical evaluation to estimate the improvements in the academic curriculum.

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