LEARNING FACTORIES OF INDUSTRY 4.0:
A REVIEW OF THE CHALLENGES IN ITS CREATION

ABSTRACT

Learning factory is an emerging ‘hands-on' approach in teaching advanced manufacturing technologies to establish a connection between industry, teaching faculty and students; it's created to understand their respective needs, while ensuring their engagement by focusing on real-time problems; however, the work done in learning factories till now, has mostly been conceptual.

The aim of this research, therefore, is to create a framework for implementing learning factories, culled from industry and academia, while highlighting some of the challenges faced during its implementation. This investigative work is inspired from the learning factory model of Pennsylvania University; it's based on a critical review of extant literature, along with a qualitative semi-structured survey of industry leaders, policymakers, trainers and academicians. Holistically, it provides a cause & effect framework for Industry 4.0 (I4.0) enabled learning factories, covering its enablers while depicting the barriers for its implementation, especially in the Indian context. Being a qualitative study, it would certainly have some limitations in terms of its universal application and acceptance.

Key Word: Learning factories, Digitization and Industry 4.0

1 INTRODUCTION

Giant strides made over the past decade in information and communication technology (ICT) have been radically reshaping the student-centered learning environment (Livingstone et al., 2012) as we see it today. Industrial revolution 4.0 is upon us, ushering along with disruptive technologies, which have been rapidly changing our personal and professional lives (Liao et al., 2017). During this transformative journey towards I4.0, intellectuals have often huddled up to discuss the pros and cons of learning and examination oriented teaching methods vis-à-vis student-centric learning experience; and how to manage smart technologies of I4.0 within the domain of learning and education (Durmus & Dağlı 2017; Martín et al., 2017).

Today, no country can claim to have adequate education methods to become I4.0 ready; successful transition towards I4.0 is only possible once we impart skills to manage these technologies. In this changing scenario, traditional engineering practices, for instance, are undergoing radical transformation, which in turn is changing the way we work vis a vis the skill sets required; giving rise thereby to new ways of learning, understanding and adopting new technologies (Abrahams, 2010; Reid, 2014) almost every other day. Competencies needed today may not be relevant in the future, and the I4.0 workforce would need new skills to manage and work with newer technologies (Muller, 2015). To cope with this, digitalization has been garnering high interest in all building blocks of learning innovation (Taylor et al., 2018); while technology adaptation is emerging as a priority reform in learning and development sectors (Persico et al., 2014).

However, despite all this high interest and the need, the level of implementation is low (Tondeur et al., 2017); traditional teaching pedagogies still continue to dominate learning systems (Wanner & Palmer, 2015).

It is time when the education sector (especially in India) needs to expeditiously adopt new technologies for creating student-centric learning systems, focused on restructuring the curriculum, processes, systems and facilities in order to bridge the gap between technology and academics by creating learning factories, and thereby bringing about a paradigm shift from traditional teaching to student-centric education (Abele et al., 2015; Müller et al., 2017; Kreimeier et al., 2014; Lamancusa et al., 2008).

Disruptive technologies in I4.0 reveal the stark reality of a gross mismatch in terms of the skillsets that are now required vis a visa those that are archaic, and unfortunately still being taught in educational institutes. I4.0 requires the successful adoption of learning systems to impart key skills in students as required in the changing work environment (Taylor et al., 2018).

The literature on implementing digital education system, for instance, is available, but very little work is actually being done to determine learning factory models for I4.0 scenarios and its associated challenges. The current system of education is unable to tackle the dynamics of I4.0 (Jones & Pimde, 2017), as it was shaped to satisfy the skill requirements of Industry 2.0, whereby the key focus for schools and colleges was to transmit contents to students for absorbing knowledge. Thus, faced with radical changes in the work environment, educators, policymakers, and researchers all over the world are struggling to come up with learning solutions that will serve future employability needs of students.

The pertinent questions today are writ large all over: what kind of professions is the current schooling structure preparing our youngsters for? Are we going to persist with our traditional education with its test scoring system, or do we want to shift to an education system that creates an environment in which students learn to solve real-life problems? Isn't it time that schools develop an environment wherein students are creative, and learn to solve practical problems working in small teams, and applying thereby relevant emerging technologies that are a part of I4.0! There is an urgent need to create learning factories wherein real-life job based and collaborative leanings takes place through different themes (Lamancusa et al, 2008; Matt et al., 2014; Hummel et al., 2015).

This research thereby aims to address these issues by answering the following:

- Why it is important to create & sustain leaning factories in India?
- Key technologies to be integrated into I4.0 enabled learning factories?
- What are the key enablers for establishing learning factories in India?
- Determine the challenges likely to be faced in managing learning factories.
- Propose an integration framework of government, universities, and industries to build learning factories.

2 LITERATURE REVIEW & DISCUSSION

2.1 What do we mean by learning factories?

"Learning factory is an extension of knowledge. It's earning while learning" (Vice-chancellor of a reputed university of India)

The term ‘learning factory' was first coined and patented in the year 1994 when the National science foundation (NSF) in the USA entrusted a conglomerate managed by Penn State University to cultivate a ‘learning factory' (Abele et al., 2015). The basic rationale of this ‘learning factory' was to focus on a hands-on/practical understanding of industrial learning, in order to explain to the students the actual problems faced in product R&D and manufacturing (Lamancusa et al., 2008; Abele et al., 2015; Leonard, 2000). A learning factory is supposed to deliver a tangible value chain for a physical process in which trainees may accomplish, appraise and replicate their personal activities in an on-site erudition methodology (Lanza et al., 2015; Abele et al., 2015; Prinz et al. 2016; Backer,2017). A learning factory is supposed to deliver a tangible value chain for a physical process in which trainees may accomplish, appraise and replicate their personal activities in an on-site erudition methodology (Lanza et al., 2015; Abele et al., 2015; Prinz et al. 2016).

Learning factory prepares students and makes them employable by the time they step out of the learning factory in figure 1 summarizes the learning factory concept.

Insert Figure 1 here

2.2 Why it is important to create and sustain learning factories in India?

> *"Learning factory surely is a helpful concept in providing a foundation to the students as they achieve real-time education. By the time students step into the end, of course, they should be able to understand the job profiles in detail like their challenges, process, profit loss, mechanism, control system, legalities and procedures" (Deputy director, Ministry of industrial promotion government of India)*

Student-centric experiential learning, which linked theory with practice in learning factories, will facilitate students' engagement, will help build life-long learning capability and provide inclusive learning, employability, and entrepreneurship (Barton & Delbridge, 2004; Abele et al., 2015).

All over the world a lot of attention is given to skill training; the percentage of skill training varies from country to country; 96% of the Korean workforce receives skill training, while in India only 5.4 % of the Indian workforce undergoes skill training (National skill development policy, 2015).

In order to harness the demographic benefit in India, there is a need to create the resources, systems and organization for up-skilling up /reskilling the new as well as the existing workforce by upgrading the Indian skill education system at par with international standards, and making on-the-job training a part of the Indian educational ecosystem along with the National skill development framework.

Development of skills is emerging as a significant approach for realizing the potential of demographic gain of the young labor force with a mean age of 29 years in contrast with the developed countries to produce human resources for enhancing competitiveness and growth. The mismatch among the skill requirements of manufacturing and the ambitions of the youth has amplified leading to an absurd state where the business is considering for skilled manpower and skilled people are seeing for employment and only 47 % of the people coming out from education institutes are employable (National skill development policy, 2015).

"Learning factories" could play a pivotal role, providing a university-industry partnership in order to create a world-class skilled workforce, thereby making a substantial transformation in student-centric education. (Reuter et al., 2017; Abele et al., 2015) and the same is reflected in the following quote of a policy maker.

> *"India hopes to provide skilled workforce worldwide and be known as the skill-capital of the world; however, this would only be feasible if the essential skill sets of the new and existing workforce meet the stated and implied industry requirements" (Dy. Director National productivity council, government of India*

2.3 Integration of Industry 4.0 technologies in learning

I4.0 transformation is characterized by real-time digitization based interacting technologies, including artificial intelligence based systems and processes, collaborative robots, 3D printing and other information and communication technology (ICT) systems and tools used on the industrial shop floor through adoption of smart engineering expertise (Wang et al., 2016; Sackey et al.,2017). The key technology drivers to be considered in I4.0 enabled learning factories are given in figure 2.

Insert figure 2 here

Organizations worldwide need to make sure that workforces remain the eventual benefactors of I4.0, rather than being left behind (Baena et al, 2017; Keménya et al., 2018). It is absolutely necessary to incorporate nine technology drivers (figure 2) in the learning environment as an integral part of the current education system (Faller & Feldmüller, 2015; Erol et al., 2016; Thiede et al., 2016) and same is validated in following statements.

> *"Modern classrooms must educate students to enable them to work with I4.0 technologies comprising of comprehensive automation, collaborative robots, real-time connectivity of suppliers and dealers through the Internet of things (IoT), artificial intelligence and mobile supercomputing using advanced technologies" (Vice president of an Indian manufacturing organization)*

> *"We need to build learner-focused curriculum and certification programs to practically connect theory to innovative applications in I4.0"*
> *(Dean of an Indian university)*

3 Methodology

The data collection and theory building have been based on four distinct phases on a steady theoretical exploration (Pentland 1999; Pettigrew, 1990). In the first phase, existing literature on learning factories, I4.0, its technologies and barriers for adoption of technology in education were reviewed critically, laying thereby a purpose, a foundation to build our basic thought process. This was followed by an expert survey of the work of Industry leaders, policy makers, academicians, consultants, and scholars, whereby we investigated the need to create learning factories, analyzed their benefits, looked into the perceived role of the government, universities and the industry, and identified the challenges associated.

The selected experts have mean experience of 21 years in the skill development in the respective organizations .The approval of Institutes and offices of the participants was obtained before starting interviews. Interviews of selected participants were done over a period of n=6 months in n=5 different locations. The interviews were either recorded or written, keeping in mind the comfort level of participants. Qualitative research questionnaire technique was followed (Patton's 2005).

This method allowed rephrasing and restating the key issues for evaluating the accuracy of the information which was again validated by its triangulation with other data sources. These one to one interviews were conducted at real working sites and lasted from n=30 minutes to an n=1 hour per expert, where experts were asked to think about the requirement of learning factories in the Indian scenario. Interviews were reflective in nature and provided genuine inputs.

Interviewers were asked to reflect on their perception of the current level of skills sets available in India as related to I4.0 scenario and the need to create a pool of young managers to run smart factories. Due to the fact that respondents in these expert interviews had good experience in learning and development, this carried away with the necessity for additional reconfirmation processes. First, we have sent e-mails to the nominated experts to explain them the objective of the study, requested them to contribute and to provide a time for the investigator to call them.

In the next phase, our research analysis moved to further theoretical level for inductively abstract theoretical descriptions (Pentland 1999; Pettigrew, 1990) where we outlined our conceptual framework addressing the learning factories model in the Indian context. The flow chart of the research methodology used is given in figure 3.

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4 DATA ANALYSIS

A total of thirty interviews were conducted. Recorded data was compiled and stored in a database. Collected information was analyzed using the NVivo qualitative research software. This helped the researcher with better access, control and ready repossession of precise information. Experts provided inputs about their understanding of what are learning factories, their perceived benefit, challenges and role of all stakeholders. They also came out with their suggestions covering requirements to build the framework for learning factories. We audited our research process through an independent peer to check for conformity and dependability of the issues (Golafshani, 2003). The audit process consisted of the evaluation of original transcripts, analysis of documents, and voice recordings of interviews and analysis of the findings; with the objective of checking the accuracy of findings, interpretations, and conclusions. Purposive sample consisted of n=30 interviewees, who are industry leaders, policy makers, trainers, consultants and academicians who have worked in skill development. The synthesis of all statements of participating interviewees was done, followed up with clustering of formulated statements, especially common phrases in the themes. After obtaining all the themes, the researchers approached a few participants for validation of the findings as per the validity approach (Meadows & Morse, 2001). The validation of the work was ensured by confirmation of a few participants, coding by highly experienced researchers, checking by participants to ensure the meaningful and trustworthiness of findings.

.5 Results

Thematic analysis facilitated in endorsing the constructs recognized and new theme of Hub and Spoke model for learning factories, enablers and challenges to creating sustainable learning factories. These themes have not been covered in Pennsylvania University's learning factories.

5.1 Hub and Spoke model for learning factories

The proposed Hub and Spoke model complements the previous work done by Pennsylvanian university by formalizing collaboration between universities, government, and industries to leverage the industrial advancements, making high quality learning cost-effective, and reachable for the massive mainstream population.

The learning factories works like a hub. Its three main spokes are universities, government and industries. If any of the spokes do not join in the hub or breaks off the hub will not be a success so in order to let the hub function smoothly amalgamation of all the three spokes is very important.

The experts suggested that "all three agencies (government, industry, and academics) need to combine and join together. Everyone should participate, understand and facilitate each other for creating and sustaining learning factories. The proposed hub and scope model based on a summary of expert's feedback is given in figure 4.

Insert Figure 4 here

Universities set up the replica of the factory in the university itself or vice versa. They train students to build an industry-ready workforce and connect the industries with students. They will research for the future and provide training to the faculty as well.

> *"Universities must align themselves to industry need and it is must for them to tie up with good companies for industrial experience"*
> *(Professor of the practice of Indian University).*

Industries will allocate infrastructure. They will provide real-life problems to academia. They will also provide experts in specific fields to academia.

Administrative support and funding will also be provided by the industries. Joint certification programs to be carried on with academia.

> “*Universities need the support of technology from Industries "to bridge the gap between academics and universities. Industries will have to tell universities their expectations, what gaps they feel one person joins (Academic Dean of an Indonesian University)*

5.2 Key Enablers for learning factory

“The students coming out from learning universities will be gold mine”
(General Manager of India-Japan collaboration MNC)

The key enablers of the learning factories depicted in relation diagram in figure 5 are built on the basis of the learning factory model of University of Pennsylvania, University of Puerto Rico-Mayaguez (Lamancusa et al., 2008) and synthesis of the experts' feedback.

Insert figure 5 here

Most Industrial experts emphasized that learning factories are the need of the hour and will help students to learn both hard and soft skills by working on real problems; creating an ‘industry fit' skilled workforce.

> *“A skilled, nimble and prepared workforce provided by learning factory has the potential to become the heart of skill India strategy”*
> *(Ex. additional Director General, Ministry of heavy industries and public enterprises, government of India)*

The experts saw a win-win-win situation where learning factories enabled the society, trainee and an organization by and large. ‘Society' becomes a winner when it engages itself in developing the youth for constructive skilling; trainees win by grabbing employment opportunities with valid certifications. Eventually, the organization wins when it acquires effectively trained human resources. This responses of experts are given in figure 6.

Insert Figure 6 here

5.3 Challenges to create & sustain technology-enabled learning factories

> "*The first and the foremost challenge faced by these learning factories is high expenditure and the second challenge lies with the faculty who is slow to assimilate this technology into the learning process" (Professor of an Indian skill university)*

The issues related to creating and sustaining learning factories were discussed with experts by getting answers to the following two questions:

1. Why some institutes embrace technology-enabled real time projects to create a learning factory while others don't?
2. What influences faculty in adopting technology?

Causes underlying above two questions if understood can play a vital role in using technology in learning factories in educational institutions. The summary of key responses of policymakers, industry experts and academicians on challenges to build and sustain technology-enabled learning factories is given in cause & effect diagram shown in figure 7.

Insert Figure 7 here

Although institutions and the Government are committed to implementing ICT in the education sector, yet this adoption is facing roadblocks (Keengwe, et al. 2008), including those related to infrastructural issues, undependable equipment, inaccessibility of technical maintenance, lack of resources, policy concerns, etc.; most importantly, the mindset and resistance to change (Afshari, et al. 2009; Mumtaz, 2000; Keengwe, et al. 2008).

> "*Innovativeness is the need of the hour but educators are technophobic and due to their past experience there is fear and anxiety of accepting technology. "The faculty is contented in imparting the monotonous and traditional type of knowledge they are least interested in adapting themselves with the technology as they feel that such knowledge can be attained with the job (Academic Dean of an Indian University)*

Barriers specifically at the institutional level include hardware and software constraints, non-availability of digital set-up, dearth of technical support, unavailability of digital resources, lack of vision of leadership , high workload on educators , lack of motivation of faculty to adopt emerging technologies among others (Pajo & Wallace,2007; Sahin,2006).

> *"The cost of acquisition and maintenance of technology in learning factory is too high". Universities lack a clear strategy, have unclear goals, skimpy deployment plans, low investment and no reward system for building learning factories (Associate Professor of an Indian University)*

> *"There is a lot of workload on faculty in private institutions and the new technology requires teachers to spend hours in the understanding of the technology/software's and time for implementation of the new concepts which result in burnout" (Dean of an Indian University)*

Most top management executives of universities interviewed, point out that although educators have years of experience, they exhibit conflict in priorities and lack control on the pace of the class while executing real-time projects in collaboration with industries.

6 CONCLUSION

This research carried out a comprehensive literature review, followed by a qualitative survey of industry leaders, policy makers, trainers, consultants, and academicians.

The objective was to create a framework for the establishment and sustenance of learning factories; keeping in view its enablers and associated challenges.

We synthesized the feedback of industry leaders, policymakers, trainers and academicians by connecting the dots to propose a hub and spoke model to create I4.0 enabled learning factories, relation diagram of its enablers, and cause and effect diagram to determine the associated challenges for its implementation.

The hub and spoke model for I 4.0 enabled learning factories is built over the previous work done by learning factories in University of Pennsylvanian and University of Puerto Rico-Mayaguez (Lamancusa et al., 2008) to serve a majority of learners (students and working professionals). These I4.0 enabled learning factories will be set by University-Industry Collaboration for I 4.0 and will include I4.0 lab and demonstration center through collaboration of Industry, technology providers and Universities to connect theoretical content with innovative applications using projected work on real-world problems of I 4.0 enabling learner focused curriculums which improve learning experience through enhanced student engagement.

Research in I4.0 technologies as done in institutions and Learning Factories need to then be transferred to industry; this will bridge the gap between academia and industry, thus promoting open innovation. Theory linked to its practical applications helps in building the capability of new technologies at low training and development cost and effectively prepares the industry-ready workforce. This, in turn, may lead to earning while you learn programs, thereby enhancing employability in India. The cause and effect diagram shows the challenges faced when creating sustainable learning factories.

6.1 Research limitations/implications

This research is qualitative in nature and has limitations related to the quantification of causes that hinder the creation of sustainable learning factories. The causes identified as challenges to implementation of sustainable learning factories will support policymakers, researchers, academicians, and practitioners are given the task of establishing sustainable learning factories. Going forward, quantification of the proposed model can be done through quantitative research; a potential area of future research.

6.2 Practical Implications

The proposed model of I4.0 specific learning factories will create a holistic system for preparing young engineers to achieve employability in smart factories. This is an essential need in India and other developing countries that want to compete at home and abroad by building I4.0 digitized factories and businesses. Traditionally, academia and learning in most universities lag developments and practices prevalent in the real world. Our model of learning factories, when implemented, will catalyze academia-industry collaboration, open innovation, and creation of real-world related curricula. All this will result in a quantum leap in the education system and its connection to the current industrial and business environment.

6.3 Relation to other Concepts and Future Conceptual Work

In the future discussion, the concept of Learning Factories should be put in context with two other approaches to innovation in education and learning settings.

The first is known as problem based learning (Kolmos, et al., 2014). The core idea is to use real-world problems as a basis for learning projects for students. This approach can be applied to a variety of academic disciplines, with especially broad application in medicine and engineering. Aalborg University in Denmark has an outstanding experience with this approach since 1974 all academic programs at Aalborg University are problem-based. Other advanced centers of application are Maastricht University in the Netherlands, McMaster University in Canada, Tun Hussein Onn University of Malaysia and Republic Polytechnic in Singapore. When applied in continuing education, the corresponding concept is work-Based Learning (Light & Hartmann, 2011). Here, projects from the working environment of the students are transformed into learning projects and used as the basis for academic learning.

A complementary concept to learning factories as specific learning environments is the learning-intensive design of real-world, industrial work systems. Thus, working environments are designed to operate as learning environments at the same time (Hartmann & Garibaldo, 2011). In the context of I4.0, digital assistance systems – in some cases explicitly designed as tutorial assistance systems – are introduced as key elements of learning intensive work systems. The full potential of work based, project-based, or action based learning will unfold if such concepts – like learning factories – will be introduced in educational institutions, and at the same time, real-world workplaces will be designed to be learning places as well.

6.4 Future Research

Going forward, validation of the proposed model, its enablers and associated challenges by quantitative research can be a potential area of future research along with benchmarking best practices of learning factories and development of a comprehensive maturity model for assessment of readiness and implementation of technology in education enterprise The latter is expected to be our next step in this research area, so as to lead us closer to developing a globally accepted maturity model for the implementation of the learning factory.

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Appendix

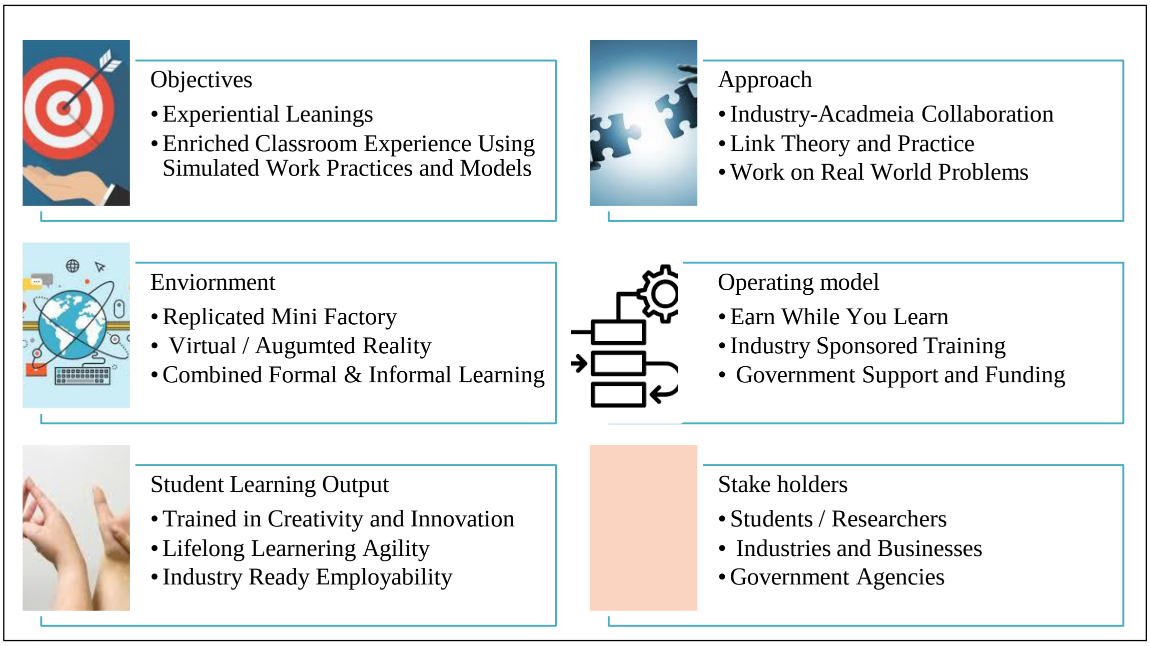

Figure 1: Key aspects of a learning factory

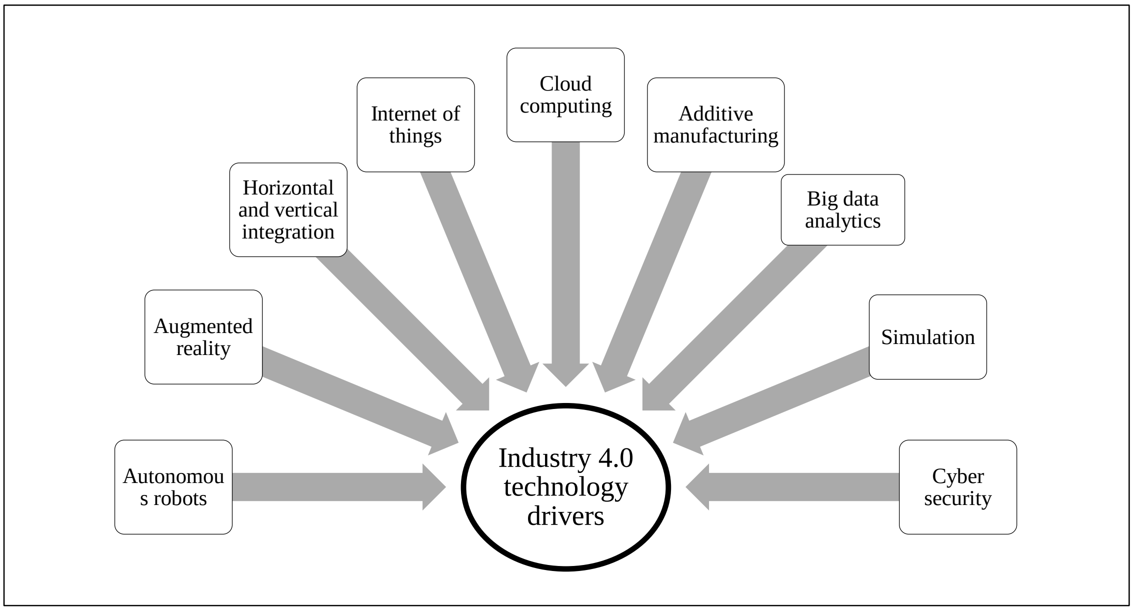

Figure 2: Technology drivers of Industry 4.0

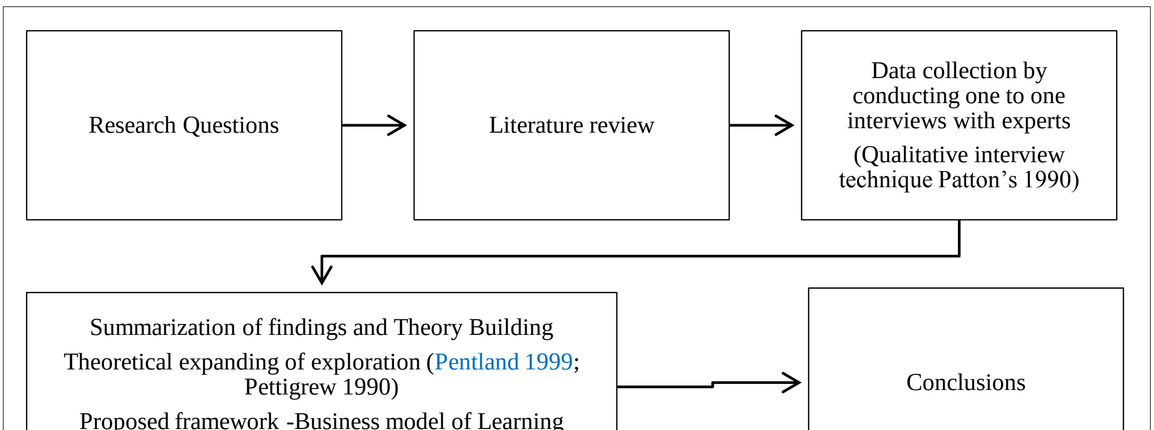

Figure 3: Research methodology

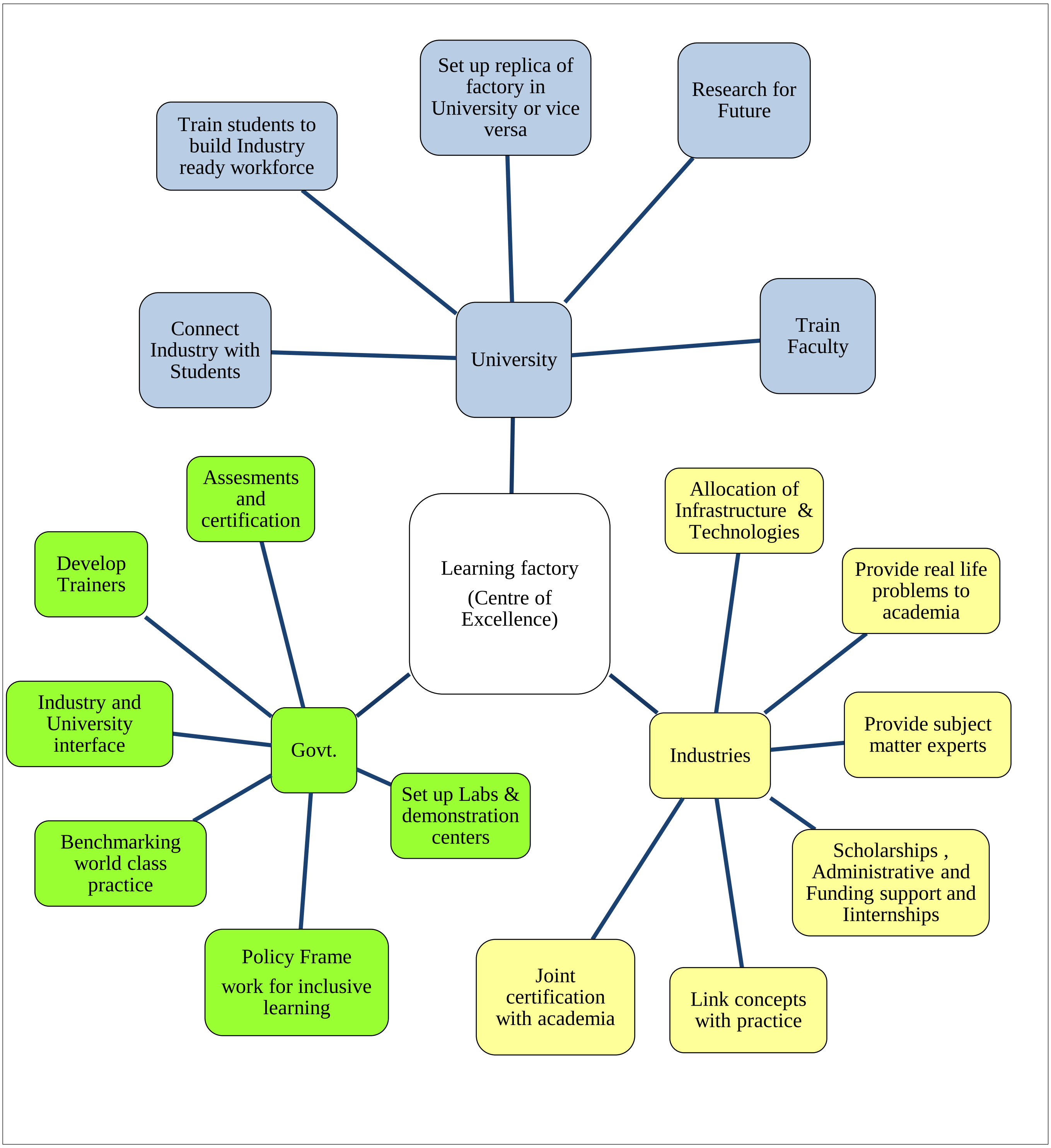

Figure 4: Hub & scope model of learning factories

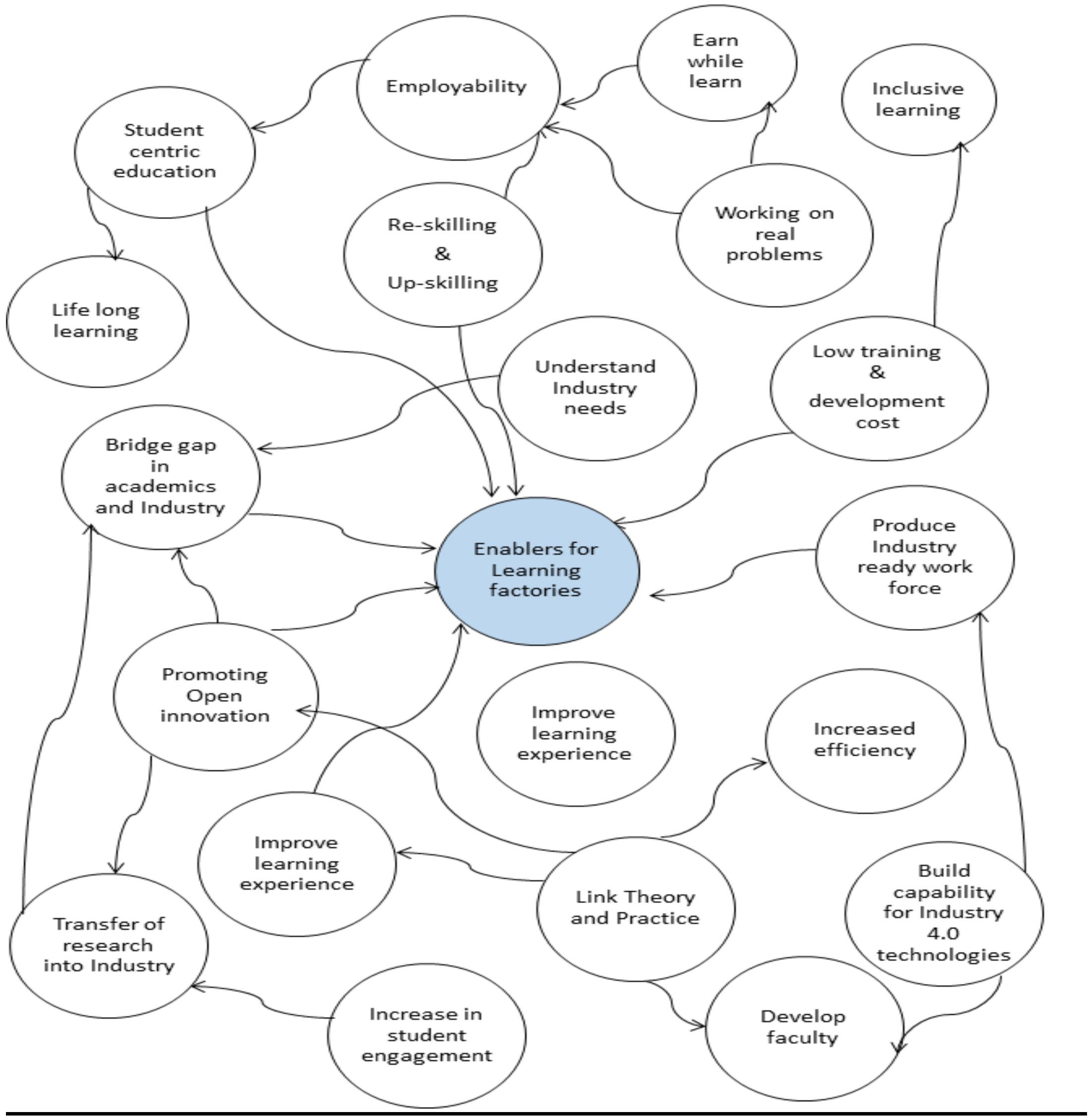

Figure 5: Key enablers of learning factories

- “The skill need of industry is somehow different from what has been taught in University”
- “Our degree level course content is decades old “
- “Students joining factories are highly ambitious, have good IQ but practical approach is missing”
- "There is an enormous gap between that which industry needs and that which is produced by most of our institutes"
- “Learning Factory is an extension of knowledge. It’s earning while learning”
- "Industry machines and workshops became labs for learning , application and open innovations"

Figure 6: Key responses of policymakers, industry experts and academicians on enablers for learning factories

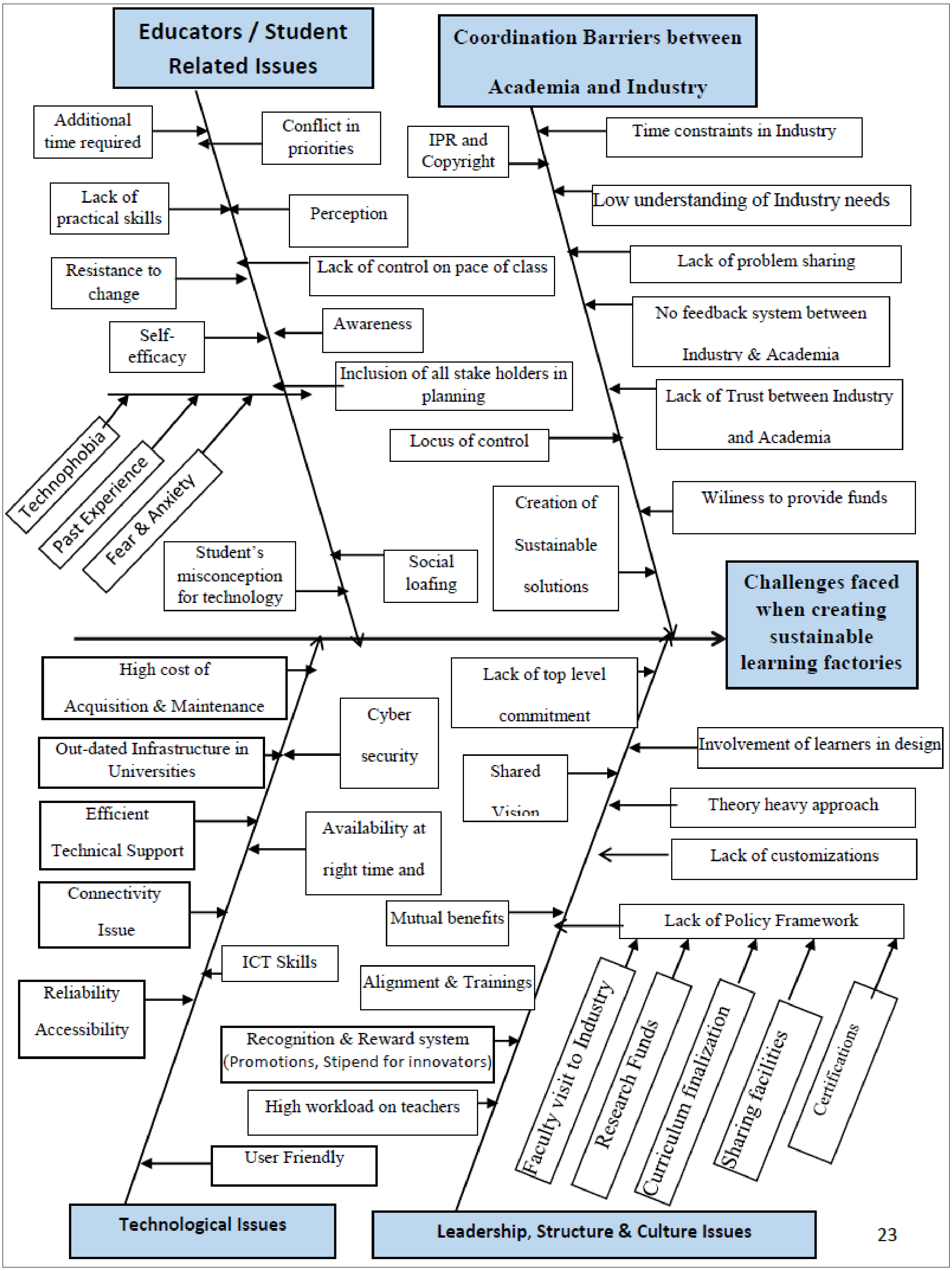

Figure 6: Cause and effect diagram of challenges faced in creating sustainable learning factories