Building Skills 4.0 through University and Enterprise Collaboration

SHYFTE 4.0

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This document presents a methodology for the technical and business evaluation of innovative technological solutions to be integrated in the developed Learning Centers of Excellence.

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Executive Summary

The objective of this deliverable is to report the methodology for the technical and business evaluation of innovative technological solutions that can be presented by the professors or students at the university. It will provide a knowledge-based framework for evaluating innovations to help them to proceed for training or business exploitation evaluations.

1. SHYFTE Learning Centers supporting Innovations

In recent years, Asian economies have experienced growing demand for highly skilled workers in order to achieve the increase productivity necessary to promote growth [1]. A predominant way to do this is by establish Learning Centres of Excellence (LCEs), which provide rapid and targeted improvements in the quality of training of the workforce, boosting labour productivity and diminishing the skill gap present between workers.

The imperative nature of LCEs is highlighted through the importance of learning, innovation and R&D to a country's economic success. In such economies, specialist skill shortages are a common occurrence that can be tackled through LCEs. This occurs in different ways. First, LCEs have the potential to increase training standards and boost productivity, tackling the emerging skills gap amongst the workforce in Asian economies. Second, it aligns training and research with current and future industry needs allowing the workforce to attain the most relevant skills. As a result, a better supply and demand interdependency arises as LCEs offer a higher degree of specialization and training catered specifically to niche markets within certain Asian economies [1].

An important aspect to consider is that the benefits of the implementation of LCEs in Asia have spill over effects, which impact the rest of the world. This is due to the fact that LCEs provide a degree of training that qualifies individuals to an international standard rather as opposed to a national standard. This ensures that individuals are equipped internationally recognized qualifications and therefore measuring up to global standards whilst meeting local needs [2].

In addition to raising training standards and increasing productivity, LCEs stimulate research and development by promoting learning and innovation. This is beneficial to both industries and to local governments since a higher level of productivity, learning and innovation contributes to economic success. Thus, LCEs can be used as a policy tool to supply highly trained individuals to key economic sectors that often suffer from worker shortages, hindering economic performance. As a result, LCEs can promote governmental organisations if training programmes delivered through the LCEs are aligned with government policies to foster economic development [1].

Furthermore, LCEs foster a higher degree of knowledge diffusion and exploitation, which maximise the accessibility of research to target groups such as firms in the industry and the government. The research produced as a by-product of this LCEs then provide reliable advice to the government and firms within the industry whilst also providing knowledge resources that can be utilized for policy recommendations and potential reforms to boost Asian economies [2]. The research attained from LCEs within Asia can then be utilized in the development of next generation products. This will provide firms within Asia with commercialisation benefits and competitive advantage in high-value sectors of the economy in comparison with their international counterparts.

The increase in academic mobility as a result of globalisation has served as a catalyst for Asian governments to enter the global competition for knowledge and talent. This is emphasized by the fact that the rapid economic growth experienced in several Asian economies is closely linked to the production of knowledge production through research and development and advanced skills, which has increased the demand for higher education. Such rapid development has also catered for specific skills in the service sector, which in recent years has been looked upon as an engine for growth in Asia.

The demand for higher education to fill the rising skill gap present within the workforce in Asia is conveyed through the estimates of the Asian Development Bank Institute, which suggests that by 2020 China will account for 30% of the world's university graduates between the ages of 25 and 34. India, who has the third largest economy in Asia (in terms of nominal GDP) is estimated three-hundred million individuals to its workforce in the next two decades [2]. This growth in the workforce will be derived by the youth that will need to be educated with the correct skills in order to address the emerging skill gap present in the country.

The ubiquitous link between technology and education has increased the demand for training opportunities for working professionals, students and providers in metropolitan, rural and remote locations throughout Asia. This has occurred through various channels, in particular through technology enhanced learning commonly referred to as e-learning, which refers to the use of technology in the learning process. The use of distance learning technologies serves as a mean through which the challenges of educational equity and social exclusion can be tackled [3].

Technology can enhance learning in through three different channels. Firstly, technology allows for the development of more efficient educational tools, which are more efficient in terms of cost, time and effectiveness allowing users to attain greater benefit from education. Secondly, technology can improve and enhance current teaching methods whilst allowing for greater development of skills by individuals thereby decreasing the global skill gap currently present globally [1]. Finally, technology has the ability to transform current teaching and learning tools thereby enhancing its effectiveness [4]. Thus, the implementation of LCEs - which contributes the transformation and development of existing educational tools and methods - comprises important benefits to society realized through the use of technology, leading to economic success.

The rapid growth experienced in the technological and educational sectors of various economies of the Asia-pacific region in last decade has stemmed occurred as a result of globalisation. Currently, there has been an emphasis placed upon the transfer of educational technologies from the western world to enhance teaching and learning tools in the Asia-pacific region [5].

As a result of globalisation, the economic environment amongst nations in the Asia-pacific region has become much more competitive. This has caused countries to lower their trade barriers and seek competitive alternatives for the development of their workforce in an attempt to lower the current technological and skill gap amongst individuals globally [5]. This has encouraged the use of technology enhanced learning environments such as LCEs, as awareness of the benefits of the link between technology and education through student-centred learning services increases.

Globalisation has also resulted in greater demand for professional and vocational courses amongst students. In the Asia-Pacific region - which has experienced exponential economic growth rates - graduates from these courses are looked upon as predominant drivers of the boom in economic growth predominantly due to the development and growth of the manufacturing and electronics industries, two of the largest exporting industries in the Asia-pacific region [5]. For example, Malaysia's manufacturing exports increased by approximately 19%, while Vietnam exports in the manufacturing sector grew by 14%. Japan's NLI Research institute estimates that the combined exports of Singapore, Malaysia, Thailand, Indonesia, Philippines and Vietnam, the six main members of the Association of Southeast Asian Nations, grew by double-digits in every month of 2017 apart from June [6].

However, policy makers within Asian economies must also consider how the effectiveness of technology in education and learning through LCEs depends upon the readiness of higher education institutions (HEIs) to implement alternative learning techniques with the help of sophisticated and high-fidelity device [4] The shift from an instruction paradigm towards an active learning paradigm, which involves teaching and learning strategies that ensure the involvement of students has been derived from globalization in education and must be supported by local governments [5]. This way of learning, which has gained momentum worldwide, is looked upon as an imperative tool to further improve the competencies of students both within their courses and later in the workforce.

Fourth Industrial Revolution, also known as Industry 4.0, might be seen as the new digital industry technology for transforming industries connecting machines to intelligent robots, transforming in order to achieve smart/intelligent industries [7], [8]. Industry is driven by competition needs to fast adapt to market request to produce better products or services with best possible price. To accomplish that are used technologies such as: Big Data Analytics, Autonomous Robots/ Robotics, Simulation, Horizontal & Vertical System Integration, Industrial Internet of Things (IIoT), Cybersecurity, Cloud Computing, Additive Manufacturing (such as 3-D printing), and Augmented Reality [9], [10].

Advances in Industry 4.0 encloses a variety of branches of technology, for instance: Information and Communication Technology (ICT), Machine-2-Machine (M2M) communication, wireless and Sensor Network (WSN) Cyber-Physical Systems (CPS) Internet of Things (IoT), Internet of Services (IoS). However, to accompany the progress of Industry and face the new challenges, a variety of emergent skills are needed. Those special skills will influence the job creations. Additionally, the workforce in Industry 4.0 will perform more complex tasks and in ever-changing work environments, and the workforce will need to be upskilled and be competent in new skills to adequately participate in Industry 4.0. The new required skill sets will not replace the existing skill sets. Rather, these new skills will be required in addition to the skills that are important in the current scenario.

Thus, it is important to analyse the gap between the skills acquired in trainings in HEIs and the skills required by Industry 4.0 i.e. HEI students and SMEs to be aligned with market trends and needs. Aiming to demonstrate how to solve the gap between HEI and Industry concerning Industry 4.0 domains through a skill-based perspective. In that context, developing a new model of Skills 4.0 aligned with the needs of the current market, that solves that issue will be valuable.

The hereby-presented research question is the following: in Industry 4.0, specifically in the “Industrial Engineering and Management”, “Software Engineering and Big Data Analysis”, “Wireless Network Analytics”, “Artificial Intelligence domains”, how is it possible, to define quantitatively and qualitatively the skills gap and fulfil such gap resorting to knowledge transference from HEI to SMEs?

Concerning what has been previously questioned, the authors argue by hypothesis that if it is possible to define quantitively and qualitatively the gap in Industry 4.0 concerning required skills for future jobs, than it is possible to define and propose knowledge transference from university to SMEs and vice versa through training.

2. A Methodology for Prototype Development

This section presents a methodology for supporting technological innovations in the context of SHYFTE trying to integrate technology innovation in training programmes to facilitate its further use by trainees namely in innovations creation. To define it the work started by analysing some pedagogical frameworks that integrates these specificities.

Although there is no formal definition of the methodological framework in the scientific community, there is a consensus around that concept [11] [12], converging to “a structured practical guidance or a tool, guidance guide user using stages or step-by-step approaches” [13]. Among the descriptions of the methodological framework is “body of methods, rules and postulates, employed by a particular procedure or set of procedures” [14] or "structuring how a given task is performed" [15].

To explore and conceptualize the conceptual methodological framework for SHYFTE Centres of Excellence labs, on one hand, the theoretical background is represented through structuring teaching-learning guidelines for the labs in the four SHYFTE domains. On the other hand, the framework, that might be seen as a real projection of the methodology into the SHYFTE multi-dimensional maturity model software, represents the knowledge and skills for teacher, student and the flux of knowledge transfer occurring through practice. Furthermore, it virtually represents the skills and knowledge that teacher needs to know to teach effectively and support students in the development of innovative prototypes in labs.

To structure the background for teacher-learner learning guidelines at SHYFTE labs, we selected the theory and practice of “design thinking”, which has been gaining recognition recently in university education [16] [17] and has the particularity of integrating new instructional technologies, i.e. [18] [19]. The concept of design thinking was introduced in 1987 by Rowe and might be seen as a paradigm for dealing with complex problems. Furthermore, it applies to a variety of professional fields, such as education, business, and Information Technology [20].

The framework methodology is developed in an interconnected theoretical-pragmatic way so it can be seen as a projection and an integral part of the SHYFTE Information System Maturity Model (SISMM). That framework-methodology background supports a creative and original computational component of the SISMM.

The proposed methodology as it is described in the following subsections, is based in HiSkill-TPACK framework (described in the next sub-section), which describes the kinds of knowledge required by teachers for the successful integration of technology in teaching trying to become a lever to catalyst innovations creation and subsequent prototype development.

Furthermore, this methodology defines a lab functioning for applications development and testing prototypes as those defined as remote labs, enclosing guidelines to support teachers and students in an innovative way of teaching. Technically, it is directly linked to the features (e.g. hard skills, soft skills, etc.) which feed the maturity model system that is the core of the e-learning framework.

2.1 Hi-Skill-TPACK Framework

The HiSkill-TPACK Framework is a conceptual framework that organizes elements, concepts and main ideas, perceived facts, beliefs, mental pictures, perceptions and theories that are the object of study of the proposed methodology. HiSkill-TPACK Framework is a particular projection of the recognised TPACK (Technological Pedagogical Content Knowledge) Framework (Figure 1).

The circled based areas of HiSkill-TPACK framework (Figure 1) might be seen as a representation of knowledge, in the mind of teachers, and that they need to know to be involved in the creation of prototypes/artefacts in the context of research projects in labs. Such areas in the framework represents also various types of skills which some of the very specific ones results from the intersections of the three main skills: TK (Technological Knowledge); PK (Pedagogical Knowledge) and CK (Content Knowledge).

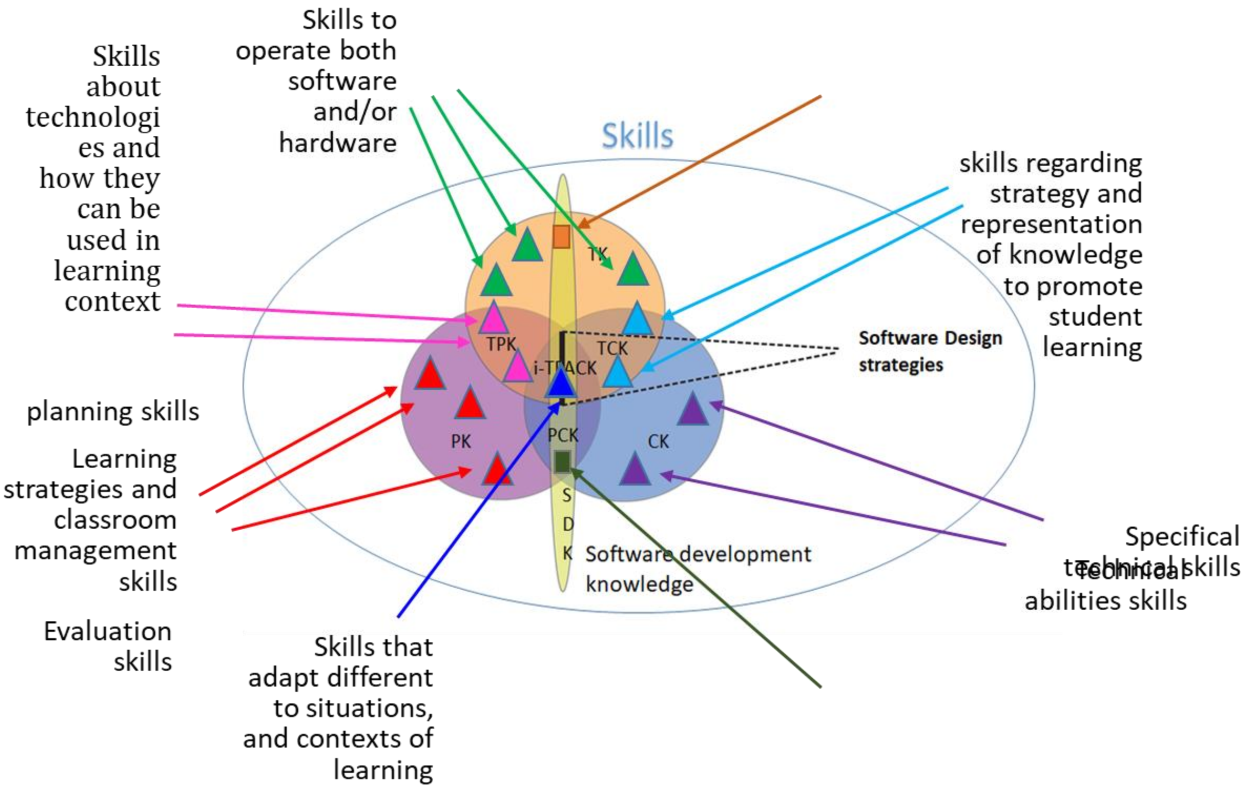

Figure 1. – HiSkill-TPACK Framework.

- **Pedagogical Knowledge (PK)** refers to the knowledge about practices, methods and processes of teaching and learning. A teacher with high pedagogical knowledge understands how students acquire skills and constructs knowledge. This type is linked to skills related to student learning, classroom management, lesson planning, development and implementation, and student evaluation. According to one study, [21] a pragmatic way to organize those skills is as follows: (i) planning skills include, educational needs of students, resource mobilization, designing a complete framework for implementation of educational; (ii) learning strategies and classroom management skills, including learning strategies used to meet students educational needs, students' involvement in learning skills (critical thinking, problem-solving, creativity); (iii) evaluation skills, including self-assessment, peer assessment, supervisor assessment and program assessment.
- **Content Knowledge (CK)** related Skills are in their essence, as described by Shuman, “the amount of knowledge per se in the mind of the teacher” [22]. They are also referred to as “knowledge about the actual subject matter that is to be learned or taught” [23]. In short, they represent the knowledge about a subject-matter knowledge that a teacher needs to teach.

Content Knowledge related skills refer mainly to the specific technical and technical abilities, which are “hard skills”.

For Pedagogical Content Knowledge, according to Mishra and Koehler [24], TPACK includes knowing what teaching approaches are appropriate to a specific context; and the organization of contents of teaching. It deals with the representation of content, pedagogical techniques, knowledge which application regulates the difficulty to learn; theories of epistemology. Additionally, it is related to the strategies to incorporate conceptual representations to improve understanding.

- **Technological Knowledge (TK)** refers to teacher knowledge about technologies, including skills to use certain technologies. Certain specific skills are related to this kind of knowledge, which allows selecting appropriated IT to promote learning. According to Mishra and Koehler [23], in the TPACK framework, skills associated with technological knowledge are those that allows the operation of certain technologies. They include knowledge of both software and hardware. Technological Content Knowledge (TCK) refers to Schulman’s aforementioned concept [25], [26]. It combines the knowledge of strategies and the knowledge of representation to promote student learning. Technological Pedagogical Knowledge is the knowledge of the technologies and how they are used in a learning context and understand the impact of using such technologies. Specifically, it refers to knowledge about how technology influences specific pedagogical practices.

Technological Pedagogical Content Knowledge (TPACK) represents the knowledge about the relationship between technology, pedagogy, and content, which allows teachers to define and apply appropriate context-specific teaching strategies. Skills-related TPACK skills are those that allow adaptation to different situations and different contexts of learning.

The proposed methodology is compatible with the learning framework of Center of Excellence since it enables the demonstration of skills transfers through the IS SHYFTE Maturity Model, but at the lab level. It is completely aligned with the e-learning maturity model-based for the education of the SHYFTE project, since skills in software training are part of the maturity model dataset.

2.2 HiSkill-TPACK Methodology

The proposed methodology (named as HiSkill-TPACK methodology) has the following main objectives in association to the SHYFTE LCEs Labs: a) technological innovation related to Industry 4.0 creation and testing; b) Promoting guidelines to help teachers and students use and create technological applications innovatively in teaching; c) Lab set-ups for use in application developments use and prototype testing.

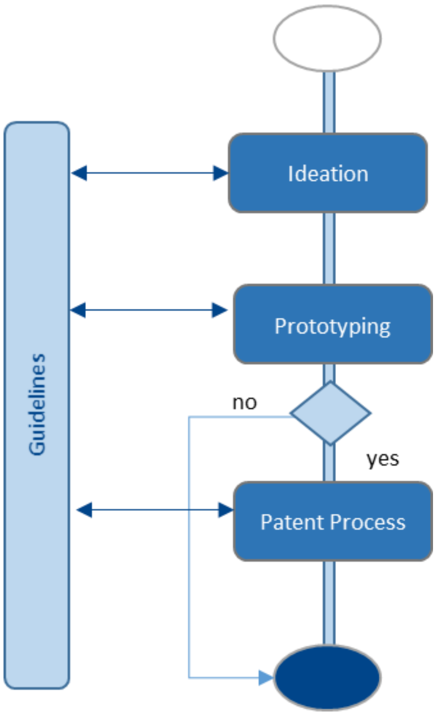

Figure 2 – HiSkill-TPACK Methodology – main phases.

The HiSkill-TPACK Methodology (Figure 2) aims to achieve [27] operationalization in the CoE labs, providing structured pedagogical teaching learning practical guidance aligned with Design Thinking theory. It guides stakeholders through the three phases of the main process via a step-by-step approach: I) Ideation, II) Prototyping, III) Patent Pro-cessing.

Furthermore, it supports teacher and students' interactions with the technology used for creating software applications/prototypes innovatively. The stakeholders are teachers, students, and SMEs. In LCEs, students, in groups or alone, are supposed to develop innovative prototypes to solve problems that might be proposed by the industry. LCEs teachers that support labs are experts in the specific field of SHYFTE trends in which students are being trained.

The methodological principle has its theoretical basis of knowledge transfer from teacher to students using technological teaching-learning approaches. For that reason, a variety of knowledge terms are explored: 1) knowledge that teachers need to know teachers to teach effectively using technology; 2) the students' knowledge; 3) knowledge of teaching-learning; 3) teacher-student knowledge transference; 4) academia-industry knowledge transfer.

Associated to each abstraction type of knowledge are associated skills, linked by the methodology to guidelines that express teacher knowledge and teacher "know-how", promoting the knowledge transfer. Those skills might be described based on the implicit taxonomy established defined in the SHYFTE skills framework: a) Hard Skills; b) Soft Skills; c) Meta Skills [28] [29].

In knowledge transfer, technology might be seen as a potential vehicle to ensure that proper learning takes place, i.e. that proper knowledge is transferred to students [30].

In this view, teacher knowledge is considered according to different principles based on the Shulman principle [22]. Pedagogical Knowledge represents teacher knowledge about technologies, including the skills to use certain technologies. Pedagogical Knowledge is framed as all issues concerning student learning, classroom management, lesson planning, development and implementation, and student evaluation. It may be seen as the knowledge about practices, methods and processes of teaching and learning.

Content Knowledge might be considered essential, and is described by Shuman as "the amount of knowledge per se in the mind of the teacher". It is also referred to as "knowledge about the actual subject matter that is to be learned or taught" [31]. In short, it represents the knowledge about a subject-matter knowledge that a teacher needs to teach. According to Schulman, it also refers to the teaching process, regarding the way students can learn the concepts and theories of a subject. Technological Knowledge rep-resents the knowledge acquired by teachers about both standard technologies (e.g. books, chalk and blackboard, internet and digital video). Technological Content Knowledge is a representation of the knowledge of how technology and content are interrelated.

Teachers need to know how the content can be transformed by the application of technology. Pedagogical Content Knowledge (PCK) refers to Schulman's aforementioned concept [26], [25].

PCK blends content knowledge, knowledge of learners and related context; and pedagogical knowledge. It combines the knowledge of strategies and the knowledge of representation to promote student learning. Lesson planning guidelines are an example of the development of PCK knowledge.

Technological Pedagogical Knowledge is the knowledge of the technologies and how they are used in a learning context and seeks to understand the impact of using such technologies. More specifically, it refers to knowledge of how technology influence specific pedagogical practices. Technological Pedagogical Content Knowledge (TPACK) represents the knowledge about the relationship between technology, pedagogy, and content, which allows teachers to define and apply appropriated context-specific teaching strategies. TPACK is graphically represented by the intersection of all areas of knowledge previously mentioned.

Technology plays an important role in education, both in terms of contents and methods and teaching materials. Furthermore, it might be applied to different domains in HEI and Industry, such as Industry Engineering and Management, Software Engineering and big data analytics, wireless and networks analytics, and artificial intelligence. In SHYFTE LCEs labs, these prototypes can be developed in the academic path, with the support of specialized teachers that use teaching-learning techniques with innovative approaches and corresponding guidelines.

Figure 2 represents the HiSkill methodology described next. On the top of the figure are the main areas supported in HEI Industry SHYFTE Lab. In the Lab, prototypes might be developed cleverly using teaching-learning methods that allow the creation of innovative solutions, such as design thinking, requirement elicitation and other techniques that might be used in prototype development. Through the application of those techniques, such as Brainstorming, specific guidelines can be given to students to support the creation of innovative technological artefacts. Those prototypes might then be evaluated to understand their innovative value.

The central part of the methodology, which is dedicated to the development of the innovative artefact, is organized into three parts: I) Ideation; II) Prototyping; III) and Patent; which will be described next. Part I of the methodology is represented on the central part of the figure and is dedicated to Ideation, the generation of ideas and the selection of those ideas. Part II is dedicated to Prototyping, which comprises the following stages: a) problem definition; b) requirements; c) lab set configuration; d) prototype development; and e) quality evaluation.

Part III of the methodology refers to the Patent Process and is preceded by a test stage hypothesizing if the prototype developed in stage II is eligible to ingress in a Patent Process. Part III is reached if, and only if, a prototype is eligible to be part of the patent process. Part III is composed of the following steps: a) Patent Preparation; b) Patent registration process; c) Patent Quality Evaluation.

On the right side of Figure 3 are teachers' needs to know to teach effectively, which might be expressed using guidelines.

Next, we will describe the skills directly related to teacher knowledge applied in teaching practice with the integration of technology. To promote such description knowledge as related to skills, we refer mainly to the three main categories: a) hard skills; b) soft skills and c) meta-skills.

Content Knowledge-related skills are those skills that are mainly related to the content itself. On one hand, those skills might be mainly technical. Content knowledge is linked to hard skills in the context of Industry 4.0, for instance: programming, design, Cyber-Physical Systems, CPS, Data management. On the other hand, in what concerns Schulman's vision, this topic covers the teaching-learning process, which is mainly soft skills. For instance, in programming language teaching, content knowledge skills are the most important.

Skills related to PCK might be seen as meta-skills related to strategies to promote student learning and representation. Representation meta-skills are those that allow the manipulation of different objects in the mind or the physical world, for instance, the logical-mathematical skills.

Adding these skills is required for teaching-learning strategies. According to one study [21], a pragmatic way to organize those skills is the following: (i) planning skills include educational needs of students, re-source mobilization, designing a complete framework for implementation of educational; (ii) learning strategies and classroom management skills include learning strategies used to meet students educational needs, students' involvement in learning skills (critical thinking, problem-solving, creativity); (iii) evaluation skills-include self-assessment, peer assessment, supervisor assessment and program assessment. In SHYFTE, trainee and student evaluations are acquired through questionnaires, and pedagogical evaluations aligned with a syllabus.

Technological Knowledge-related skills incudes those skills that are used to certain technology. Skills that are used to live in a world overwhelmed with information and communication technology, which are included in the soft skills concept. That group of skills might include, for instance, media literacy, information searching and processing.

Technological Pedagogical Knowledge-related skills refer to the skills employed in the knowledge of technologies and how they are used in a learning context, and in understanding the impact of using such technologies. Technological Pedagogical Content Knowledge related skills are skills in the intersection of technology, pedagogy, and content that allows teachers to define and apply appropriate context-specific teaching strategies. All this considered, meta-skills that might mainly be seen as reusable skills might be used in different contexts. For instance, the ability to create a mental model in a specific knowledge domain.

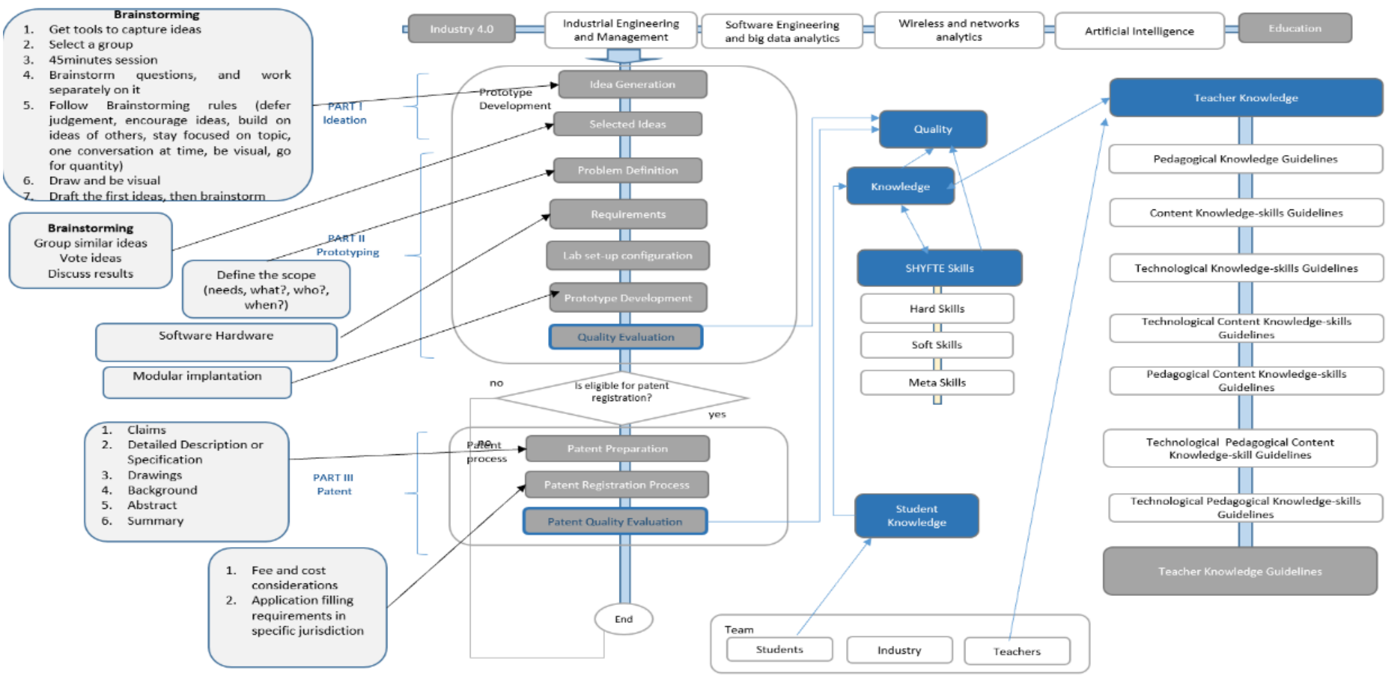

Figure 3 – HiSkill-TPACK Methodology.

The methodology implementation has three different phases and several stages, which provide guidelines to both teachers and students both. Those guidelines are aligned with the main stages: the first stage is dedicated to the research and idea generation and offers guidelines. The second stage focuses on prototype development, while the third stage guidelines are dedicated to the patent. A particularity of the recommended guidelines for teachers and students is that they are aligned with the relation skills-knowledge that is the theoretical background of the SHYFTE project. On the left side of the figure is an example of guidelines proposed in the previously mentioned methodology. Knowledge skills teacher guidelines aim to train specific skills in a knowledge domain.

3. In the support for the creation of Innovative technologies to support training or business exploitation

In SHYFTE was developed a case study to demonstrate the development of innovations able to be integrated in the training implementation, which is presented in the following sub-section. This worked as a test to the methodology and at the same time as a prototype able to further on be integrated in LCEs to actively support in the training programmes definition and training execution support. Additionally, was integrated in LCEs portal a solution able to act as an observatory of the innovations creation combining industry 4.0 related technologies. It also comprises a service to support such creations from the trainees. This is introduced in sub-section 3.2.

3.1 A Case Study: "Attention-Aware Embodied Pedagogical Agent for Skills and Technological Transference Improvement"

The main idea of this case study was to develop a prototype of an attention-aware Pedagogical Embodied Agent for knowledge transference and skill improvement able to be integrated in the SHYFTE LCEs. It intends to help directly in the training delivery moments by actively and dynamically ask for attention to trainees or it may be integrated to support the interactions of the SHYFTE LCEs. Anyway, this acts as a case study that was performed to test the methodology proposed and to have an additional innovative technological solution that can be developed by the professors or students of the university to support them in training.

This use case scenario is also supported by the SHYFTE teaching & Learning framework guidelines (Figure 4-A), allowing the Industry 4.0 skills and knowledge transfer. It is conceptualized to enable the minimization of the main skills gap, identifying the relationship between the skills and four SHYFTE domains. Trainees might belong to three levels of knowledge profile: beginner, intermediate, and expert. The SHYFTE Teaching & Learning Framework will be deployed in a Service-Oriented Architecture (SOA) aligned specifically to the centre of excellence objectives and processes. In terms of software, the components are the Information System Maturity, the ME Maturity and the Skills Maturity, dedicated to solving the skills gap.

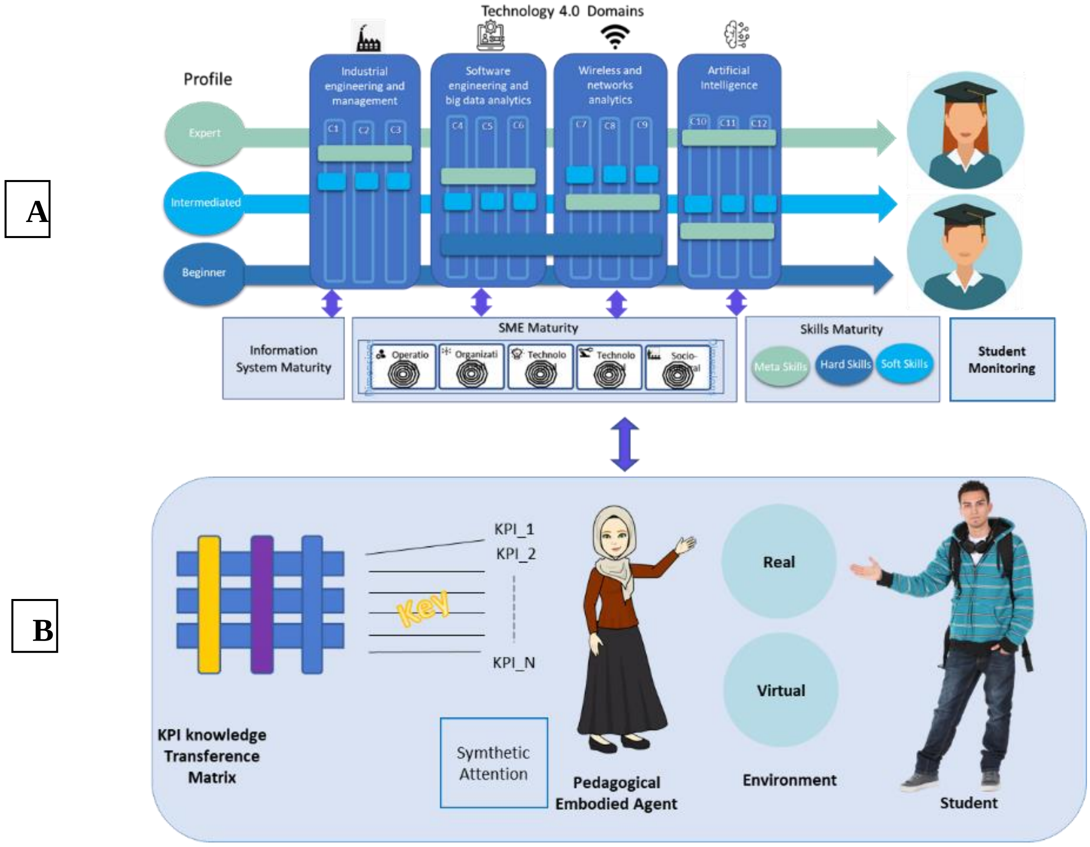

Figure 4 - Connection between A) SHYFTE teaching and learning framework, and B) Pedagogical Embodied Agent.

The Pedagogical Agent is necessary for information and features belonging to the SHYFTE maturity model. Important features of attention and cognitive load are included but are distributed in the SHYFTE maturity model. That information allows the Pedagogical Agent to have an appropriate manifestation with impact on student/trainee attention using machine learning algorithms and techniques.

The Attention-Aware Embodied Pedagogical Agent can be seen as integrable in a smart system connected to the SHYFTE platform. The latter refers to the implementation of a smart system that will be able to infer emotion and attention analysis based on bio signals using wearables, specifically ECG and EEG. That system will suggest recommendations such as study pauses, volume adjustments and presence/absence of music based on the attention levels of students.

3.1.1.1 Case Study Synthesis

This subsection aims to give an overview of the case study that is the object of this research, focusing on specific issues: problem, aim, scope, background, study design, results, discussion and conclusion, and further research (Figure 6). Following the step-by-step process makes it possible to determine the case study segmentally.

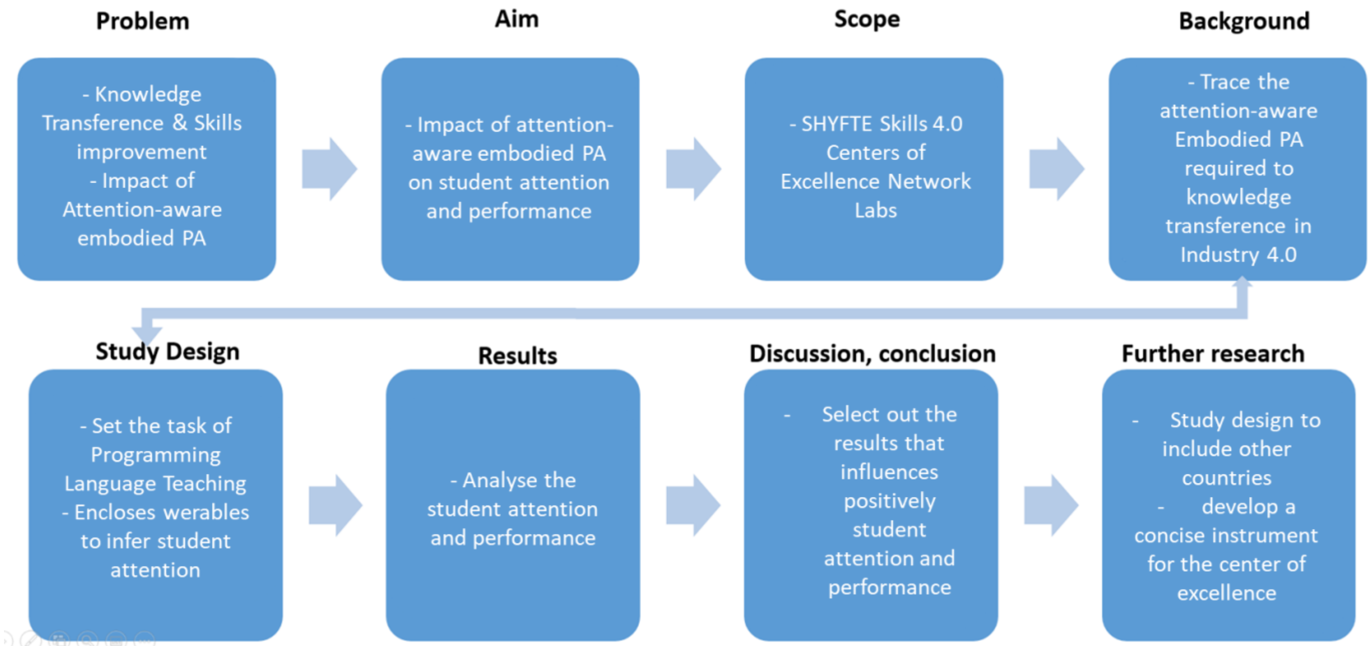

Figure 5 – Case study synthesis diagram.

The specification step of the Problem stage identifies the actual knowledge transference skills improvement opportunity in HEI. The research is dedicated to attention-aware embodied pedagogical agents. The case aims to study its impact on students' attention and performance. The scoping stage determines the scope of the study as the Centres of Excellence.

The background stage traces the attention-aware Embodied Pedagogical Agent required for knowledge transference in Industry 4.0. The study design stage allows determining attention-awareness to the task of Programming Language Teaching and then determines experimental online setting including wearables to infer student attention. The results stage is dedicated to the analysis of the student attention and performance.

Next, results that positively influence student attention and performance are selected, and results between evidence and the proposed framework are established. The further research stage proposes to enlarge the study to other regions and develop a concise instrument for SHYTE LCEs. These steps are described in more detail next.

- **Problem:** Currently, new challenges have appeared in the Higher Education ecosystem due to the Covid-19 pandemic situation. That raises an opportunity for online and virtual education to ameliorate skill sets with professional design in Industry 4.0 and new infrastructures. The "Building Skills 4.0 Through University and Enterprise Collaboration" project (SHYFTE) addresses knowledge transfer and student skills performance specifically, acting as a bridge between Industry 4.0 and HEI education, and creating the SHYFTE Centres of Excellence network, implemented with basis on a distributed architecture [32]. To date, there is little research in the context of HEI education for Industry 4.0 knowledge transfer and students' skills improvement that examines the impact of Attention-Aware Embodied Pedagogical Agents on student attention and performance.

- **Aim:** In the context of virtual environments, it is known that the incorporation of pedagogical embodied agents can influence student attention. Choices and modifications for the design and modulation of the pedagogical agents influence dependent variables often studied in the field, such as [33] academic success, motivation, and performance, appreciation, joy, interaction, and self-sufficiency. This research aims to study, knowledge transfer and skills, and the impact of attention-aware embodied pedagogical agents on student attention and performance, in the scope of Industry 4.0
- **Scope:** In Asia, the knowledge, and skills required for Industrial 4.0 empower workers for future challenges of new jobs that are appearing alongside technological advances. Nowadays it is important to create solutions, in operational, services, and technological levels simultaneously, at Higher Education Institutions (HEIs) capable of developing those competencies. In this context, the SHYFTE Skills 4.0 Centre of Excellence Network implements 4 pilot programmes in Asia: China, Thailand, and Malaysia. The study is limited to those SHYFTE Skills 4.0 Centre of Excellence Network Labs – four pilots programmes implemented in Asia: Thailand, China, Malaysia.
- **Background:** Tracing the attention-aware Embodied Pedagogical Agents required for knowledge transfer in Industry 4.0. Setting out known impacts of those agents on student attention and performance. Identifying the key points and areas of debate in the research community regarding the specificity of the study. Creating and justifying research questions through identifying parameters settings for the task and dependent vs. independent variables that make it possible to justify the research questions.
- **Study Design:** The case study applies an attention-awareness embodied pedagogical agent to the learning task, supporting students through appropriate recommendations. The experimental online setting includes wearable technology (e.g. electroencephalogram, electrocardiogram, eye-tracker) that allow to infer and study the student's attention. The case study approach has suitable characteristics suitable for this research, since it allows blending both numerical and quantitative data, and the prototypical data of mixed methods research, enabling the identification of correlations between those elements. Specifically, it allows acquiring and studying the correlation between data acquired from wearables, questionnaires, and usability tests. Variables to be gathered are recorded at the SHYFTE Centres of Excellence. Through the implementation of the case-study approach, it is possible to determine and demonstrate an understanding of data collection.
- **Results:** Analyse student attention and performance in the determined task of computer programming language, when support by attention-aware pedagogical embodied agents for knowledge transference and skills improvement.
- **Discussion, conclusion:** Select the results of the impact of attention-aware pedagogical embodied agents that positively influence student attention and performance, in the context of Industry 4.0 knowledge and skills transfer in Programming Language Teaching Tasks. Furthermore, clarify if it is possible to establish the connection between results provided from evidence and the theoretical proposed framework. Additionally, verify if it is possible to link the study to the expansion of the study to other countries LCEs.

3.1.1.2 Experimental Design

The methodology can be summarized as following:

- **Participants and Design**

Participants will be recruited from the Centre of Excellence Network (CoE), and might belong to two distinguished categories: students and trainees. The former category refers to CoE learners from university, while the latter are CoE learners belonging to SME organizations.

To keep the study from sample biases by participant competencies, the study carefully examines participants' knowledge in different countries, in four Industry fields: industrial engineering and management; software engineering and big data analytics; wireless and network analytics; and artificial intelligence, through the use of questionnaires (Annex A).

- **Variables**

This study follows a complex design that allows studying the effect of two or more independent variables in one experiment. This category of study is characterised by the fact that each independent variable can be studied with an independent group design or with a repeated measured design. Complex designs are also known as factorial designs since they involve a factorial combination of pairing interdependent variables:

- The independent variables, i.e. which controls or manipulate dependent variables to their behaviour [34] of the study are (1) gestures performed by Pedagogical Agents; (2) emotions performed by Pedagogical Agents; (3) speech performed by Pedagogical Agents.
- The dependent variables, i.e. those which allows measuring the behaviour to access the effect of the independent variables [34] of this study are attention, eye-gaze data, cognitive load, and performance.

- **Procedure and Data Collection**

Participants will be informed of the experimental procedures and participate after signing a consent form. Participants individually join the experiment and are introduced to the experiment. The procedure includes attention measuring biosignal devices: EEG, eye-tracker.

Data collection involves both questionnaires and biosignals acquired through electronic devices to measure attention. Questionnaires are applied to acquire information concerning learner background and knowledge. Cognitive loads will be measured using a Linkert-scale questionnaire and EEG devices.

The experiment applies PA cues that have been found to have an impact on student attendance. For the study, those cues might be grouped in different categories: emotional, gestures, and speech cues. The study encloses five experimental conditions: NC (no cues at all); GC (gesture cues); EC (emotional cues); SC (speech cues); and GEC (gestures, emotional, speech cues). The development of Pedagogical Agents and application cues follow the "priming effect", which uses perception to activate thoughts, emotions, and actions linked to concepts or situational contexts [35] [36].

Attention is analysed through attention measure devices and eye-gaze data, specifically: eye-fixation time, fixation counts, dwell time on design areas of interest. Eye-fixation represents the time duration of learners' attentive eye-movement behaviours compared to eye-dwell time. EEG electromagnetic waves. Additionally, the Heart Rate Variability parameters of ECG and Time Domain feature: the mean of interbeat intervals (Mean RR); the median of interbeat intervals (Median RR); the standard deviation of interbeat intervals (SDNN); the root mean square of successive interbeat intervals (RMSSD); the number of interbeat intervals that differ in more than 50 ms (NN50); NN50 expressed as a percentage (pNN50); and frequency domain features: very-low-frequency component (VLF), low-frequency component (LF[ms2]), high-frequency component (HF [ms2]), normalized units of LF (LF [n.u]), normalized units of HF ([n.u.]), and the ratio between low and high frequency (LF/HF).

- **Learning Environment**

Learning environments are video-based, with instruction led by a Pedagogical Agent presenting the lesson, focused on attention monitoring, precision sensing, 6Gand 7G networks, Learning Management Systems, Computer-Mediated-Communication in HEI, entitled “Improvement of Student attention monitoring supported by precision sensing in Learning Systems”.

3.2 Shyfte LCE Portal – Business Observatory

The Shyfte LCEs’ portals have integrated a mechanism to analyse the innovations created as result of the training executions. It is based in support requests made by users through the portal. The observatory process is associated to the fact that if the users have any problem with any project, either a prototype or just an idea, they can ask for extra help to LCE. To handle such approach the portal present in the main page a service to support or record such technologies creation (see red square feature in the following figure).

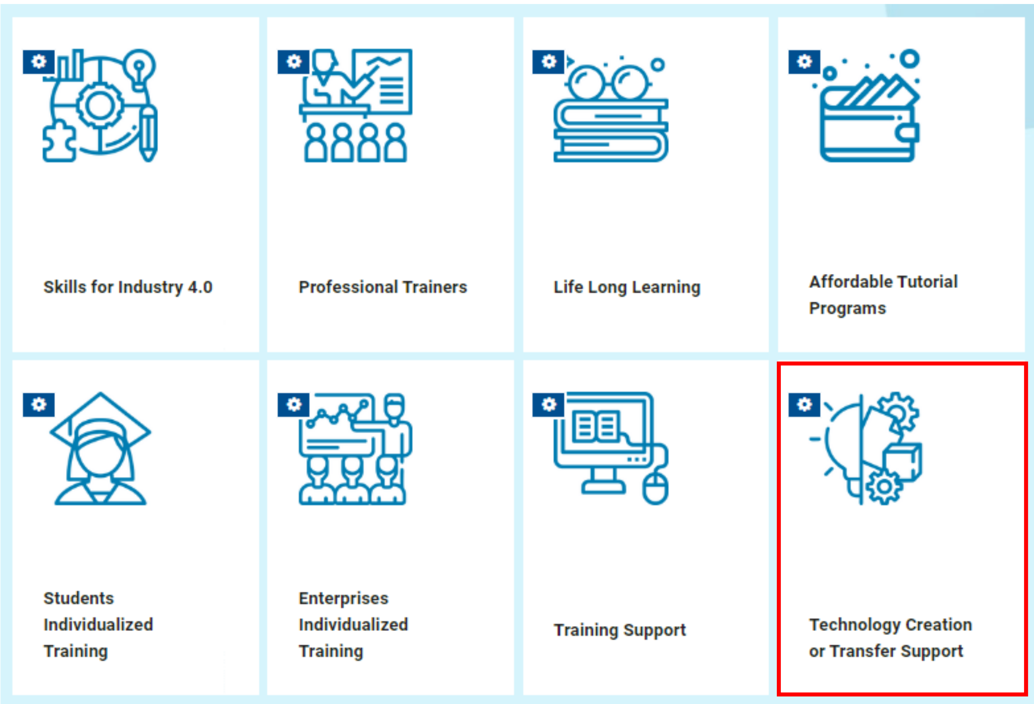

Figure 6 – Technology creation or transfer support.

If the user selects that area/service a specific form is provided to register any feedback or question that users may have related to technology creation (see figure 50). The subject that the user selects may help a further analysis. As an example, a subject topic may be about a specific technical support, or about a business exploitation planning or model, or even about any ethical issue, etc.

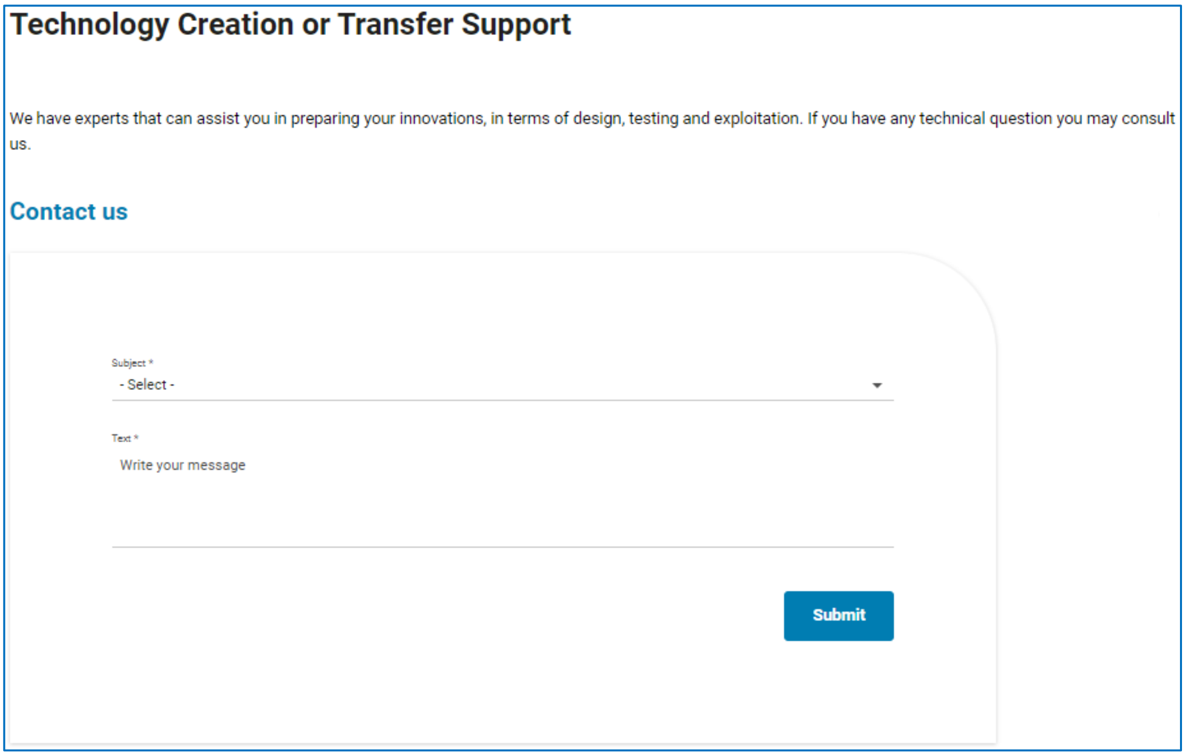

Figure 7 – Technology creation or transfer support.

Afterwards, the LCE administrator may see some graphs associated to such kind of feedback that could help analyze the penetration of the knowledge provided by the training in the LCE users. A dashboard example of what may be seen associated to such feedback feature is shown in the following figure.

There are other data that LCE saves that may be used for the LCE administrator as in relation to the type of enterprises that access to the LCE, or even the number of training programs generated to support SMEs and their correlation to the type of SMEs. These statistical data is also provided. As a conclusion all these data values accomplish the business observatory associated to the LCE.

Figure 8 – Sample of technology creation statistics.

4. Discussion and Conclusions

Considering various technological educational environments, ranging from presential learning to completely electronic learning, it seems crucial and valuable to consider frameworks or models for technological integration. In the literature, more emphasis is given to TPACK and its derivatives.

The literature review showed that there is still a lack of studies in the development of methodologies and frameworks that considers sensitive topics centered on the student, such as the sensing of student emotions and attention. Furthermore, the literature evidenced a tendency to combine theories in order to fill gaps and add new knowledge to the theoretical frameworks or models. For instance, Carrigton [37] combined Blooms' Taxonomy with SAMR, creating the Pedagogy Wheel, i.e. a com-bination of SAMR with learning models to support students' higher-level thinking.

This work presents a high level of complexity which is proportional to the level of detail. Since it combines the methodology and framework linking it to the maturity model software that belongs to the platform, whose validation is inferred by inner services of the software.

The hypothesis H2: if the process of creating an e-learning solution with dynamic reaction features to increase students attention can be supported by pedagogical experts (teachers) then it can effectively be improved, is also supported, considering the following rea-sons: a methodology/framework supported by pedagogical experts benefit the creation of technological artefacts through the definition of procedures and guidelines in educational settings.

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