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PAPER

A Fabricator Competency for Engineering Students in Tertiary Education

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ABSTRACT

This article presents the development of fabricator competency for engineering students in tertiary education during the seamless era. This study explored the approach to synthesizing, designing, and developing fabricator competency. The study identified six key components of fabricator competency: 1) Knowledge of materials, 2) Problem-solving and design, 3) Using design software, 4) Using hardware and machines, 5) Safety knowledge and awareness, and 6) Communication and publication. This study emphasizes the importance of human potential development, specifically in the case of engineering students in tertiary education. A competency framework for a fabricator in the seamless era has been developed by synthesizing, designing, and developing fabricator competencies based on published research on fabricator competency.

KEYWORDS

fabricators, competence, fabricators competence

1 INTRODUCTION

Currently, competency development is an essential factor behind productivity development. Competency development accelerates the development of new technology, innovative capability, and personnel competitiveness [1]. In the last four decades, psychologists and human resource professionals in industrialized countries have developed a behavioral competency framework for human resource development. The behavioral competency framework that employers and employees prefer is the usage of competency frameworks in various human resource jobs. There is a great deal of research into human performance development that focuses on formal studies to accomplish societal and other objectives. Developing a technical competency framework that showcases every detail of work-related tasks can be applied universally across different businesses and industries. Such a competency framework can be utilized in hiring and performance appraisal systems, in order to select behavioral competencies relevant to specific technical tasks [2]. Additionally, digital

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technology has revolutionized how people work and access learning resources with technological advances. Humans can develop their inventions more efficiently at a reduced cost. However, one of the significant challenges in the digital world is leveraging information and communication technologies to produce innovations that meet the needs of a dynamic society [3]. At the present time, an increasing number of companies are utilizing modern technology to enhance their services by combining suitable personal techniques with the necessary social skills to achieve digital success [4]. In addition, unemployment is also a global problem resulting in poverty and other problems. Efficient problem-solving in such a context requires the development of human potential before entering the world of work, involving developing the necessary skills and encouraging a systematic and creative thinking process [5]. The world of employment is being affected by continuous advancements in various industries and technology. As a result, the skills required for jobs are constantly changing. Industry experts, especially in engineering and technology fields, are calling on educational institutions to update their teaching methods and equip graduates with the specific skills needed for current and future job opportunities [6], [7]. Therefore, human resource development is essential in the modern work landscape with various challenges. A person's competency indicates their knowledge, skills, and abilities surpassing standard qualifications. It represents an advanced proficiency level demonstrated through creative actions, problem-solving aptitude, and adaptability in unexpected circumstances [8]. It also involves the ability to acquire engineering knowledge, along with fostering responsibility, flexibility, communication, collaboration skills, self-motivation, problem-solving, and innovation development [9].

Whether in the realm of technology or innovation, the act of inventing involves a systematic application of various creative skills. It is used in educational institutions as a foundation for learning through building and enabling non-technical people to develop prototypes with technologies and materials [10]. Manufacturing is partly based on the revival of the DIY culture and a return to 'invention' [11]. Thus, over the past decade, there has been an increase in the field of invention resulting from the advancement of technology. Moreover, by adding a workspace with devices, more readily-available tools, ease of access, and creating opportunities for the possibility of invention such as the establishment of more Fab labs around the world [10], it can be seen that fabrication is the foundation for the development of new things. It encourages the development of various innovations to meet the changing needs of human life, increase convenience, increase productivity, increase product value, and ensure an efficient operation process. It also empowers humans to cope with the impacts of globalization and technological advancement. For this it is necessary to develop human-based competencies [12]. Specifically, how should the competencies of fabricators in the tertiary sector for fabrication in the seamless era be appropriately defined in order to guide the development or measurement of basic competencies that enhance human abilities and stimulate the drive to create fabrications, technological innovations, or new products?

Therefore, this paper presents the tertiary fabricators' competencies for engineering students in tertiary education. This study aimed to identify the approaches needed for fabricator competency development. This will involve synthesizing fabricator competencies and designing and developing these by focusing on the needs of university engineering students. These can then be used to develop human potential, and to provide a necessary basis for innovation, development, or fabrication that can be used in this digital age as a force for future country development.

2 LITERATURE REVIEW

2.1 Competency

The terms 'knowledge' and 'competency' often need clarification. 'Competency' can be thought of as 'applied knowledge,' that is, the ability to use knowledge effectively in practice. Furthermore, 'meta-competence' refers to the specific competencies required to transfer or apply acquired knowledge in practice. In other words, 'competence' links principles, theory, knowledge, and practice. It is the application of principles, knowledge, and theories [13]. The term 'competence' was first mentioned in a 1959 document by R.W. White as a performance motivational concept. According to Parts et al. [14], competency is primarily defined as a set of characteristics that contribute to superior performance. Salmans et al. [15] cite White [16] as referring to 'competence' as an identifiable personality trait that leads to superior performance. In the 1970s, Craig C. Lundberg formulated the concept of 'Planning the Executive Development Program', which was featured in Boyatzis's 1982 book 'The Competent Manager' and adopted more widely in the late 1980s [17]. McClelland, a professor of psychology at Harvard University and founder of McBear and Company (later called the 'Hay Group'), published a study in the 1980s titled 'Testing for Competence Rather Than for Intelligence,' which led to increased use and examination of the term in a variety of human resource management practices and studies [18]. The contemporary consumer goods industry is marked by intense competition. In response, organizations must strive to establish a competitive advantage. Despite resource parity across the board, human resources remain a pivotal factor in gaining and sustaining this advantage. Implementing competency modeling significantly aids in recruiting highly qualified personnel to bolster the organization's capabilities [19]. It increases the ability to develop one's potential to create new works—producing innovative, functional, and practical inventions. Add product value or work to the original that already exists to be higher. Moreover, it is an opportunity to generate income or develop further in business. Competence frameworks are prevalent among practitioners [20]. McClelland [21] defines competence as a psychological or behavioral aspect associated with an individual's success in life or as personality traits hidden within an individual that can drive them to produce good performance or meet specific criteria in their job responsibilities. Some of these competencies, such as reading, writing, and numeracy, are basic. Soderquist et al. [22] defined competency as the knowledge, skills, and abilities that support effective or successful performance and that can be observed and measured. Murphy & Strategists [23] define competency as the essential ability of a person to deliver superior performance on the job in roles or situations determined by their competencies, including skills, attitudes, knowledge, and other characteristics such as values, motivations, and self-concepts. In addition, Salman et al. [15] discussed the holistic competencies of individuals, which can divide into two aspects: 1) competencies, such as knowledge, skills, and behaviors, that tend to be characteristics evident in the individual, and 2) soft competencies, which are the essential traits of the individual, such as character, motivation, attitude, values, and self-image. Visible results are measurable regarding standard/operational success, whereas invisible results are challenging to measure but can be observed in performance and skill demonstrations.

Therefore, competency refers to knowledge, skills, attitudes, or observable behaviors, including individual characteristics such as motivation and character traits, that support or contribute to the practical or successful performance of tasks in that context.

2.2 Types of competencies

According to research studies on competencies, the classification of competencies has been discussed. Based on the different types of competencies used in various fields and contexts, defining a competency framework in any organization provides employees with a clear understanding of performance and expected outcomes. Competencies in any job position determine which skills or behaviors will be accepted by the organization. Scholars have tried to clearly and comprehensively describe the competencies and their corresponding levels required for different job positions. According to Mansfield [24], each specified competency should be assigned a corresponding set of competency levels. The details of these competencies are described as follows: The IEEE RCD standard (IEEE Reusable Competency Definitions) [25] presents competency dimensions, including Knowledge, Skills, and Attitude (KSA), and it also includes learning goals. Performance and ability are considered synonymous, but the definition of competence is not limited to work activities. Murphy & Strategists [23] explained competency components, including skills, attitudes, knowledge, and other personal characteristics such as values, motivation, and self-image. They applied the Competency Iceberg Model, which consists of skills, knowledge, self-image, characteristics, and motivation. Khimmataliev, Olmov, Abdullaeva, Ergashev & Chulponova [26] summarized the characteristics of qualifications reflected in professional competence, including 1) Social Competence, 2) Special Competence, 3) Personal Competence, 4) Technological Competence, and 5) Extreme Competencies.

Therefore, competencies can be divided into three main categories: Knowledge, Skills, and Attitudes. These competencies have specific details that vary according to different contexts, such as work, organization, or social needs, and they contribute to the development of high-quality human resources.

2.3 Fabrication

The fabrication capacity involves applying human creativity to producing or developing objects for specific purposes, such as inventions for practical use. Fabrication has improved human life by providing comfort, aesthetics, and decoration. Creating new items is linked to people's everyday lives and is associated with their practices, customs, and even religion. The maker culture phenomenon, built on a long-standing DIY culture, is explained by Katterfeldt [27], where people express themselves by designing and creating things themselves. The creator's mind includes playful, thoughtful, and organized values shared within the community. While digital technology has a huge influence on today's creator culture, educational institutions are also using this technology to facilitate learning and foster creativity [27], [28]. Padfield et al. [10] explain that fabrication provides a foundation for learning and enabling prototyping with technologies and materials. Classroom crafting, described as an activity that focuses on designing, building, modifying, or reusing material objects for play or utilization, with a focus on the creation of products that can be interacted with or demonstrated, involves both traditional craftsmanship and digital technology in production and design [28].

2.4 Fabrication competency

According to the Merriam-Webster Dictionary, the term 'fabricator' is defined as a person, or something involved in fabricating or creating by assembling parts or materials. In the context of a fabrication lab, often referred to as a 'Fab Lab,' fabricators can be individuals or participants who utilize the tools, equipment, and resources available in the lab to build or fabricate objects, prototypes, or projects. Fabricators generally have access to the Fab Lab, which incorporates technology and digital manufacturing skills such as 3D printers, laser cutters, CNC machines, and traditional handicraft tools. These resources enable lab users to transform their inventions into product prototypes. Santos, Murmura, and Bravi [29] conducted a study on the skills and abilities of Fab Labs, which encourages users to develop creative skills by categorizing the primary skills into three areas: 1) Component Business and Design Skills, 2) Software and Hardware Skills, and 3) Material Skills. According to STEM [30], 'Fabrication Skills' are a vital section of a modular course that aims to develop essential practical abilities. These skills are essential for teachers and technicians to conduct metalworking activities successfully. The Practical Metalworking curriculum by SQA (Scottish Qualifications Authority) assists technicians and teachers in gaining confidence and skills in using equipment such as folding machines, cutting machines, and spot welders. Therefore, the study of fabrication competencies covers three aspects: knowledge, skills, and abilities. It focuses on individuals' behavior and technical abilities [31]. The study of inventor competency at the tertiary level serves as a standard to certify learners' abilities and prepare them for entering the industry. Additionally, Saorín et al. [32] state that engineers should be able to address challenges using innovative and imaginative approaches, which necessitate both individual and collaborative decision-making. They must have creative skills in designing new products or enhancing existing ones and the ability to engage in the creative process to formulate solutions or design products. This aspect is crucial to the field of engineering.

2.5 Seamless era

According to the Cambridge Dictionary, 'seamless' means without seams or obstructions and happening without sudden changes, interruptions, or difficulties. According to Uosaki et al. [33], seamless learning is characterized by smooth transitions between in-class and out-class learning, as well as between handheld and desktop use. This definition aligns perfectly with the concept of the 'seamless learning ecosystem', which encourages learning without restrictions on location or learning processes. Seamless learning adapts to the needs and availability of the learners, bridging the gap in accessing content and making learning easy across various mobile devices. The system aims to integrate seamlessly into learners' daily lives, maximizing its utility. The primary focus lies on developing the system to cater to learners' needs while also increasing motivation and introducing challenges in the learning process [34]. This seamless learning approach combines formal and informal learning and integrates various teaching methods and activities [35]. In addition, B. Flanagan and H. Ogata [36] define seamless learning as learning in different environments regardless of place or time. Students can benefit from learning in different contexts and provide teachers with insights into learning progress. This learning type can occur in informal situations outside the classroom. The concept of seamless learning highlights several key features, with a strong emphasis on learner-centeredness, empowering students to take initiative, follow up on their progress, and solve problems. It also fosters continuous stimulation of self-generation and collective knowledge acquisition, facilitated by access to various learning resources and domains [37]. Furthermore, L. Mei, L. Zhou, and F. Fan [38] introduced an innovative learning methodology called Seamless Flipped Learning, which integrates information technology with the principles of seamless learning theory and the flipped learning model. This approach utilizes social media-based learning platforms like cloud classrooms to create a continuous inverted learning pattern. It facilitates the seamless connection of individuals, groups, and social learning spaces in formal and informal educational environments, enabling independent learning and personalized one-on-one instruction.

Therefore, fabrication refers to using human creativity to create or invent objects for practical purposes. The fabrication of useful things contributes to people's daily lives in a seamless era where digital technology greatly influences invention [27], [28]. Such fabrications have the potential to transcend different environments and overcome the limitations of materials, tools, equipment, place, and time, ultimately enhancing human comfort and well-being.

3 RESEARCH METHOD

This study is descriptive research that reviews relevant literature and analyzes and synthesizes repeated processes, focusing on developing fabricator competencies in tertiary education during the seamless era. The study includes the following steps:

1. Reviewing trends, research, and documents related to the development of fabricator competencies for engineering students, and
2. Analyzing and synthesizing the relevant research.
3. Synthesize details of fabricator competencies for each aspect.
4. Design and development of the fabricator competency for fabrication in the seamless era.

4 RESULT

The study's results, available in reputable research articles and reliable sources, comprise; 1) A table of synthesis of fabricator competency, providing an overview of key components; 2) A table of synthesis of fabricator competency details, offering in-depth analysis; and 3) A figure of a fabricator competency for engineering students in tertiary education, visually illustrating essential aspects relevant to engineering students.

1. The table of synthesis of fabricator competency (Table 1) provides valuable insights on fabricator competency from reputable research sources.

Table 1. Synthesis of fabricator competency

Competency	[2]	[29]	[39]	[30]	[40]	[41]	[42]	[11]	[43]	Summarize
1. Knowledge of materials		/	/	/	/	/		/	/	/
2. Problem – solving and design	/	/	/	/	/	/	/	/	/	/
3. Using design software	/	/	/	/	/	/	/	/	/	/
4. Using hardware and machines	/	/	/	/	/		/	/	/	/
5. Safety knowledge and safety awareness	/	/	/	/	/	/	/	/	/	/
6. Communication and publication	/	/	/		/	/	/	/		/

Based on the synthesis table of fabricator competencies, six aspects can be summarized: 1) Knowledge of materials, 2) Problem-solving and design, 3) Use of design software, 4) Use of hardware and machines, 5) Safety knowledge and awareness, and 6) Communication and publication.

2. A table of synthesis of fabricator competency details, providing in-depth analysis, presents the specifics extracted from another research. It categorizes the findings into subsections for each competency and is labeled as Table 2.

Table 2. Synthesis of fabricator competency details

Competency	Core Competency			Details
	(K)	(S)	(A)	
1. Knowledge of materials	/ 1.1	/ 1.2 1.3		**1.1** This pertains to knowledge of materials, including metals, ceramics, polymers, and composites [44], [45]. **1.2** Choosing the suitable material for the workpiece [44]. **1.3** Assessment of availability of materials [40].
2. Problem – solving and design		/ 2.1 2.2		**2.1** The ability to solve problems through a problem-based learning experience [46]. **2.2** Design involves discovering new and diverse ideas, options, projects, products, or processes [47].
3. Using design software	/ 3.1	/ 3.2		**3.1** Basic knowledge of creating 3D models and familiarity with the basic tools in design software. **3.2** The use of software for design work, including Solidworks [39], [48], [49].
4. Using hardware and machines	/ 4.1	/ 4.2 4.3		**4.1** Basic knowledge of tools and equipment. **4.2** Use of tools, including 3D printers [49]. **4.3** Assessment of availability of tools and equipment [40].
5. Safety knowledge and safety awareness	/ 5.1 5.3	/ 5.2	/ 5.2	**5.1** Knowledge of safety practices, including the proper use of safety equipment, is necessary for working with chemicals or other hazardous materials. **5.2** Safety awareness by taking safety precautions when using equipment and materials, including wearing personal protective equipment [31], [40], [41], [50].
6. Communication and publication	/ 6.1 6.2	/ 6.1 6.2	/ 6.1 6.2	**6.1** Communication is the ability to transmit knowledge, understanding, and thoughts to the intended recipient in a way that enables them to accurately comprehend the desired message. **6.2** Publication involves sharing knowledge, understanding, and ideas with the public [40], [31], [15].

Abbreviations: K, Knowledge; S, Skills; A, Attitudes.

The synthesized table that outlines each fabricator's competency reveals that the core competency model follows the KSA's framework, which consists of Knowledge (K), Skills (S), and Attitudes (A). The first sub-competency relates to knowledge (K) and skills (S) related to materials. This sub-competency has three detailed aspects: (1) knowledge of materials such as metals, ceramics, polymers, and composites, (2) the ability to select the appropriate material for a specific workpiece, and (3) the capacity to assess the availability of materials. The second sub-competency pertains to Problem-Solving and Design, which also requires knowledge (K) and skills (S). It includes the ability to solve problems based on problem-based learning experience and Design, which is the creation of new ideas, options, projects, products, or processes. The third sub-competency, Using Design Software, is another competency that requires knowledge (K) and skills (S). It involves having basic knowledge of creating 3D images, using basic tools in design software, and utilizing software such as Solidworks. The fourth sub-competency is Using Hardware and Machines, which requires knowledge (K) and skills (S). It encompasses basic knowledge of tools and equipment, the ability to use tools such as 3D printers, and the capacity to assess the availability and suitability of tools and equipment for work. The fifth sub-competency involves Safety Knowledge and Safety Awareness, which requires knowledge (K), skills (S), and attitude (A). It includes having a comprehensive understanding of how to use safety equipment at work involving chemicals or other hazards and being aware of safety precautions when using equipment and materials, including wearing personal protective equipment. Lastly, the sixth sub-competency pertains to Communication and Publication, which requires knowledge (K), skills (S), and attitude (A). It involves effectively conveying knowledge, understanding, and ideas to others through communication and sharing them with various public channels.

3. A figure of fabricator competency for engineering students in tertiary education visually summarizes the details from Table 2 as Figure 1.

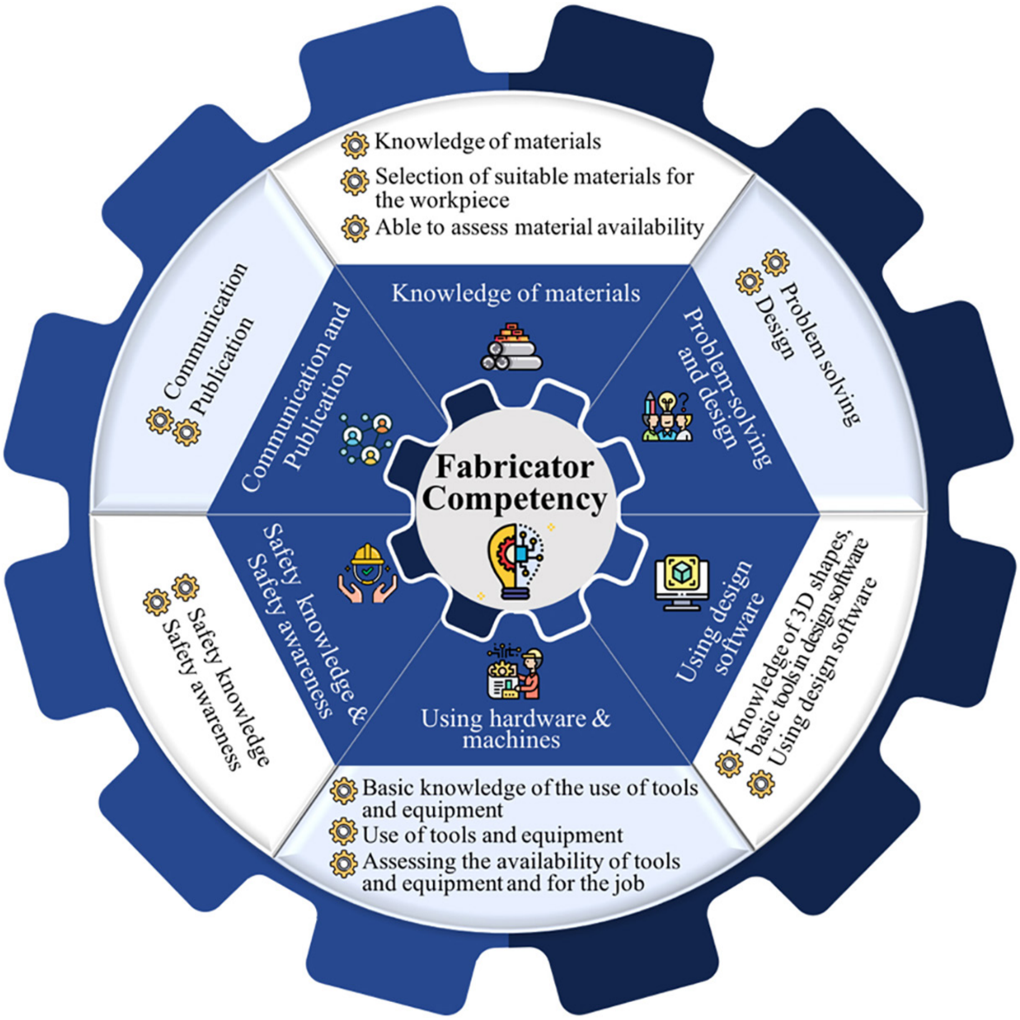

Fig. 1. A fabricator competency for engineering students in tertiary education

5 DISCUSSION

This paper discusses the competency of tertiary education fabricators and presents the key components of fabricator competency in six areas: 1) Knowledge of materials, 2) Problem-solving and design, 3) Using design software, 4) Using hardware and machines, 5) Safety knowledge and awareness, and 6) Communication and publication. These core competencies, which are based on knowledge, skills, and attitudes, can be used to guide learning through fabrication and to enable prototyping involving technology and materials in educational institutions [10].

The modernization of the education system and vocational training is crucial for the development of professional competencies [26]. This will prepare students to meet the needs of the labor market [51] and organizations' transformation in pursuit of the requirements of Industry 4.0 (I4.0). This will result in changes in job descriptions and competencies required of personnel. Therefore, developing the right workforce competency framework to meet the needs of Industry 4.0 is essential [4]. Consistent with Tzanova [51], the publication 'Work in Progress: Competence Building in Engineering Education in Mongolia' is an account of competence building in the tertiary sector to develop and implement innovative electrical engineering curricula during a period of industrial expansion. Intending to transfer knowledge between the European Academy of Advanced Engineering and the tertiary institute in Mongolia, it has led to the modernization of that university's curriculum in electrical engineering in such a way as to develop student competencies in electrical engineering, in order to meet expanding industrial needs.

Moreover, engineering students should cultivate ethical decision-making abilities with a focus on social and environmental obligations, while embracing lifelong learning to keep up with emerging technologies, challenges, and demands. In the 21st century, a constantly-evolving society necessitates changes in learning, communication, and working methods, driven by the advent of modern concepts such as Industry 4.0 [52] and Society 5.0 [53]. The new industries associated with these concepts require new competencies for engineers [54] that emphasize the importance of creativity and imagination in engineering design, stimulating learners to create new ideas and approaches to solving complex problems. Moreover, it will be essential to develop the innovative, creative thinking skills necessary to become an engineer [55]. The skills mentioned above are consistently integrated into the subheadings of all six competencies examined in this paper.

Furthermore, Srisawat et al. [56] introduce a comprehensive scientific learning model that identifies four critical components for effective learning: 1) Components of a Seamless Learning Environment, 2) the Educational Learning Process in Science, 3) Components of a Fabrication Lab, and 4) Fabricator Competency. This article examines fabricator competency as a guiding framework and assessment tool, encompassing the essential knowledge and skills that engineering students require to excel in their professional work.

Therefore, to enhance the learners' potential to meet the needs of industrialization, focusing on fabricator competencies in tertiary is vital, especially in the seamless era. These competencies should encompass individuals' knowledge, behavior, attitude, and technical abilities or skills, as highlighted by Fahad & Qureshi [31]. The competencies developed in this way can guide cultivating high-quality human resources capable of driving essential changes in society and promoting sustainability in the new industrial age.

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