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Mirinig's Inductive Content Analysis for Providing Technological Literacy Standards for University

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Abstract

Engineering graduates are one of the elements of intangible value creation; hence, technological innovations are the heart of knowledge-based economy. Today technology is used to efficiently solve economic, defense and social needs, and to resolve unemployment.Thus, providing technological literacy standards for the integration of engineering education curriculum which leads to job placement, employment and entrepreneurship can be a suitable solution to the unemployment problem. At the very beginning, Mirinig's inductive content analysis was used in this research to develop standards. In the next step, 20 experts in engineering education were asked to write important factors in training a creative engineer. Then their concepts and writings were coded based on five technological literacy standards of engineering education curriculum in this study and the frequency of these five standards was extracted according to these concepts and the coefficients of these indicators according to experts' views were determined based on Shannon entropy. According to Shannon entropy analysis the importance coefficient of technological standards in engineering education are as follows: (1) human management, (2) knowledge management, (3) the integration of science, technology, arts, mathematics and economics, (4) meaningful teaching, and (5) early education.

Keywords: Engineering education, Technological literacy, Curriculum, High school

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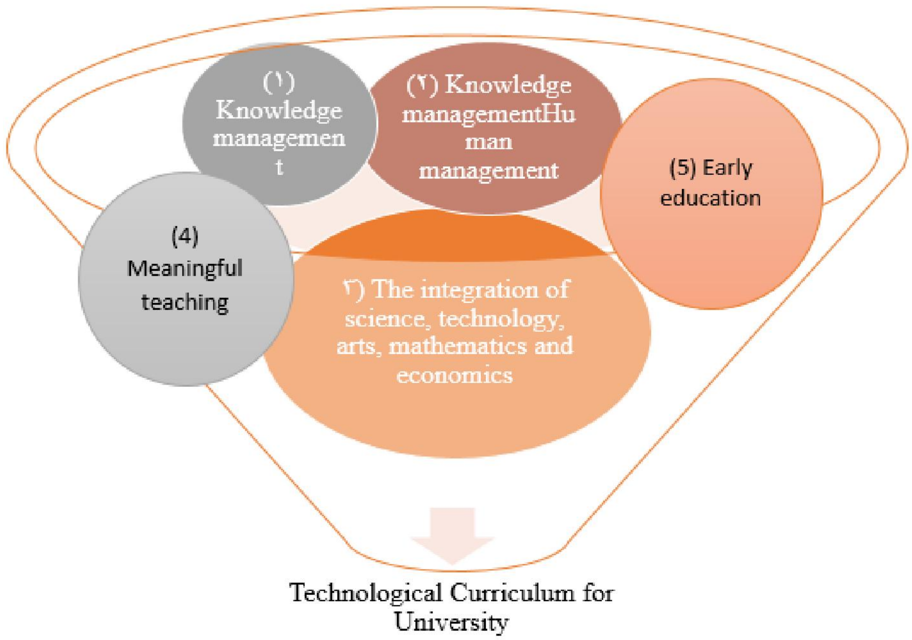
Graphical abstract



Highlights

- A series of technological literacy standards in engineering education has been proposed
- Technological literacy standards improve and will strengthen higher education for resurgence in global markets
- Content analysis of experiences MIT University, University of Utah, NJIT University

Abbreviations

Massachusetts Institute of Technology(MIT), New Jersey Institute of Technology(NJIT),Japan Science and Technology Agency (JST), the Ministry of Education, Culture, Sports, Science and Technology (MECSST), Council of Science and Technology (CST), the Science and Technology Foresight Center (STFC) and the National Institute of Science and Technology Policy (NISTEP)

Introduction

A technology-driven economy, its prospective growth in the future and the key role of entrepreneurship demand engineers technically sophisticated, socially cognizant and entrepreneurship savvy. On the other hand, it is critical to recognize the importance of engineering or the vital role of engineers when encountering the big world challenges ahead. In this regard, the fourteen challenges set forth by the American Academy of Engineering provides a list of important issues faced by the world in the 21st century, where engineers play an important role in resolving the issues (Davami & Khodabakhsh Pirkalani, 2010). Hence, engineering graduates are one of the unseen elements of value creation constituting a portion of economic growth. According to statistics provided by the US Department of Labor, it was demonstrated that between 1950 and 1985, there was a close correlation between average annual increase of engineering graduates and productivity growth in Japan and USA (Ghaffari & Pakpour, 2007). Many institutions and organizations have been expanding the abilities and skills of engineering graduates. A few instances are the Accreditation Board of Engineering and Technology (ABET), International Technology Education Association (ITEA), National Center for Engineering and Technology Education (NCETE), CDIO Standards and National Academy of Engineering (NAE). The engineering fields are extremely sensitive since the engineering labor market is constantly changing and neglect will reduce employment opportunities, competitiveness, productivity and socio-economic prosperity (Azizi, Hosseini, Hosseini, & Mirdamadi, 2010). In this regard, the findings by (Oosterbroek, van, & Auke, 2010) suggested there is a positive correlation between technological and entrepreneurial activities, economic growth and innovation. Only a century ago, it was expected that learners would adapt to the campus settings. From the 1970s onwards, however, the sciences emerged with in another context known of technology, which later became a fundamental guideline for many nations. Universities cannot keep themselves in isolation and away from developments, since they rather host the heart of developments (Tayefi-Nasrabadi, 2011). In his interview with Forbes magazine in 1997, Drucker (cited in Abdus Salam, 1993) argued that universities will only act as monuments thirty years from now and higher education will be in a profound crisis. Three major factors propelling universities toward such crisis were identified; including failure in adoption of technology, mismanagement and poor technological self-sufficiency. Universities today have two choices ahead: 1) resorting to darkness and despair, 2) determination to deal with the future, fundamental changes and technology generation and creating a link between science and economy (Abdus Salam, 1993). Any discussion of the relationship between science and economy was once insignificant, but it now makes no sense when that significant relationship is denied. In fact, science and economy are bridged through technology. When it develops into technology and generates wealth, knowledge gains economic value. Therefore, higher education will be merely a monument so long as engineers fail to become entrepreneurs (Ahmadi, 2013). In that light, any reform and improvement in the engineering fields requires a new understanding of the role of science in innovation and the application of technology. It seems crucial to reform engineering education particularly given the high unemployment rate among Iranian engineers (18.6%), low rank of Iran (130) among 140 countries in terms of labor productivity, poor economic workforce in innovation with a rating of 113, weak employment in the engineering curriculum and predominance of theoretical and general courses over practical ones, excessive output of universities compared to the available capacity of the industries and non-entrepreneurial nature of universities (Tofighi & Entezari, 2014). Achievement of a desirable technological edge in universities requires fundamental measures taken through curriculum. Hence, this paper intended to explore and inquire the relevant documents to improve the engineering curriculum, thereby to propose several components of technological literacy.

Research objectives

- Analysis and exploration of concept relevant literature in order to provide the components of technological literacy in engineering education.
- Analysis and exploration of expert opinions in order to determine the weights of components extracted

Definitions of Terms

Technological literacy: It refers to the individual ability to utilize knowledge and processes to solve problems and expand human capabilities(ITEA/ITEEA, 2007)
Technology: According to the United Nations, technology refers to the essential knowledge and skills to produce goods and services as an outcome of human thinking and understanding of rules found in nature. Broadly speaking, it covers the application of science in industries through adoption of systematic procedures and studies (KazemnejadVaghefi & Moosakhani, 2010).
Curriculum: Curriculum involves a formal or informal process through which the learners gain some knowledge under the supervision of schools. The learners understand how to acquire knowledge and skills, while changing their attitudes and values (Yarmohammadian, 2012). Curriculum implies recognition and representation of individual past experiences for future practice. It is a social process in which the individual gains a greater understanding of self, others and the world through interactive re-conceptualization (Schubert & Schubert, 1986)

Literature review

The documents reviewed in this section concern the curriculum in technology and engineering education, completed by Keirl (2015), Reed (2010), Apelian, D. (2013), Adams, Turns, & Atman (2003), Cheek (1997), Denson, Kelley, Wicklein (2005), Ambrose (2013), Householder and Hailey (2012), all of which directly mentioned the term *curriculum*.

1- The impact of the American Project of "Technology for All" on the process-oriented curriculum for development of technological systems in the curriculum:

One of the effective guides for the development of process-oriented curriculum is the American project of "Technology for All". With the release of this project, a new structure was proposed for technology studies that raised well-known generalities in the field of technology including processes, knowledge, and technological fields related to the development of technological systems. This process includes activities such as invention, design, transport, engineering method, control, maintenance, and the use of results or systems involving human activities from design to the development of technological systems, control of systemic behaviors, and assessment of the consequences of technological systems (T. R. Kelley, 2008).

2- Correlated and interdisciplinary curriculum for professional education:

In a curriculum project developed by Venville, Rennie, & Wallace, (2004) et al., consultation with other knowledge sources such as parents and other teachers has been mentioned to be necessary. This finding obviously corroborates the notion of going beyond the subject-based standards in order to evaluate the extent and depth of learning that occurs in integrated learning environments (Venville, Rennie, & Wallace, 2004). Technology education has the potential to be organizing for comprehensive curricula. Technology is so varied in nature that can be addressed with different areas of content. Also, technology has brought the tools needed to integrate science and mathematics (Reed, 2010). Cochran (1970) has listed the project of "Correlated curriculum and interdisciplinary nature of professional education" as one of the top five innovative programs in the chapter "Integrated Program". Many of the current leaders in technology education support the advantages and benefits of integration of technology curriculum with other areas. The majority of recent research in education technology curriculum includes some aspects of curriculum integration, integration of science, technology, engineering, and mathematics (STEM) content that has turned into a central theme in the educational system (Cochran, 1970; Reed, 2010). Byers, Seelig, Sheppard, and Weilerstein (2011) studied the growing interest in entrepreneurship education to prepare students for an innovative economy. In 2011, the National Science Foundation (NSF) awarded a $10 million grant in five years to establish a center for the STEM talent expansion program of (STEP) at Stanford University for teaching innovation and entrepreneurship in engineering. The authors studied the initiatives for entrepreneurship education in the curriculum and shared some successful stories and cases. In addition to engineering education content, presentation methods with the development of new technical capabilities are being evolved (Apelian, 2013; Byers, Seelig, Sheppard, & Weilerstein, 2013).

Through a series of studies in the US, computation science the Competitiveness Report of America has revealed that computational science fields have a critical approach to scientific leadership and economic competitiveness. Looking at the skills required in the twenty first century, if countries would like to remain in the global arena of competition, they must include two new skills in all levels of curricular planning; specialized thinking and complicated relationship. Specialized thinking considers the abilities that students require and through which they can solve the problems that are non-addressable with other terms and criteria, but require critical thinking skills and creativity. There are limited pieces of evidence and documents indicating that the technology education curriculum in the past 30 years has been based on specialized thinking. The second skill, complicated relationship, is a requirement that helps students to separate information and communicate with a wide range of audience in different forms and ways. Critical constructivism is the foundation of complicated relationship computation science (Householder & Hailey, 2012).

3- Practice-based curriculum in the development of technological systems:

In the study conducted by Wanasupa (as cited in Ambrose, 2013) applicability of the technology education curriculum and the ability to use knowledge and skills in new situations have been emphasized. Since transfer itself is an active process and does not happen easily and automatically, an important issue is transferring technology education to the planned curriculum, as it has been done in some places such as California Polytechnic State University. Reed (2010) stated that an interesting approach for many in the process of technology education is a three-dimensional development of student activities. There are many examples for this approach such as design-construction-assessment (according to Australian Education Committee, 1994) and determination-design-construction-assessment and stating the problem-hypothesis-model-test (in the US, according to the International Technology Education Association, 1998). Problems of unlimited design have been improved through repeated challenges in the technology curriculum. In this method, students use the divergent thinking practices to identify the classification of potential results and then choose one of them for investigation and subsequent developments. However, challenges of unlimited design do not thoroughly reflect the expected nature of design (Lewis, 2006).

4- A Binaural approach to the design of technology education curriculum:

Keirl (2015) proposed a binaural approach to the design of technology education curriculum. In his opinion, the binary hermeneutic method is very suitable for interpretation of the human technology complexities and a search in technology education curriculum. A Binaural approach raises the arbitrary nature of technology and the concept of reliable and powerful technology. Binary means both at once and dependency between two things. However, binary is different from dualism, because it does not talk about distinction but it is about uncertainty. Keirl (2015) emphasizes combining different cases in technology education, such as human and technology, natural and artificial concepts, and visible and invisible technology, in order to extract basic concepts in technology education curriculum. One of the binaries in the studies of Keirl (2015) is whether the universities and technology education seek to make changes or maintain the status quo and whether technology education is just about using tools and technical skills or technological behaviors (Keirl, 2015).

5- Apelian and Tryggvason Model in the curriculum of engineering schools :

The curriculum of engineering schools also underwent changes to emphasize the creative nature of engineering. This model shows the dimensions of the four broad areas including humanities, arts, science, and engineering. Humanities is described through culture (such as literature, art, and history), art activists deal with culture-building, science involves the study of the physical world, and engineering is to make thing in this physical world. This curriculum has been developed to promote technology and information literacy and also critical thinking, problem solving, and decision-making skills required for economic competition in this ever-changing world. This curriculum, which requires strengthening the multidisciplinary understanding of scientific and practical knowledge and skills, increases the conceptual understanding of students and procedural knowledge skills and helps to solve social problems using technology. In this approach, students actively participate in the learning process and learn how to efficiently take part in getting access to discoveries and combining information in the future (Sharkawy, Barlex, Welch, McDuff, & Craig, 2009).

6- Smith College curriculum in engineering education:

In Smith College, engineering has been defined as a liberal and professional art at the service of humankind. According to this definition the engineering education curriculum focuses on three aspects of knowledge unity, technological literacy, and fostering entrepreneurship. This college supports research and activities that develop an exciting and learner-centered curriculum and challenge the students, develop a combinative curriculum that encourages mastering over engineering foundations in a social and human context, encourage social responsibility and sustainability-based thinking, and support and develop the language of technology (Motahari Nezhad, 2015)

7- The curriculum proposed by the US National Academy of Engineering:

However, the leading researchers in the field of engineering education have expressed their concern that the current educational model is not efficient enough to prepare engineering students as future experts of this area (Dall'Alba, 2009).

The research findings of Ambrose (2013), the Vice President of Teaching Department and Learning and Professor of Education at Northeastern University, supports the curricula that meet the following standards: environment and continuous integration over time and lessons that promote the transfer of existing knowledge and skills to another environment, early exposure to engineering and engineers to build the foundations of future learning, significant contribution of the best possible time to the promotion of in-depth learning, creating opportunities for reflection on the relationship between thought and action, development of metacognitive abilities of students in order to foster lifelong learning skills, self-centeredness, and trial and authentic learning opportunities for the implementation of the theory in the real world .

According to Spencer and Mehler (2013), components which can make the engineering education curriculum more creative include practical training, generalizability, entertaining, encouraging the sixth sense, opportunities to display good character, and freedom of action for experiencing failure and defeat. Teamwork is very important in the career of an engineer. It is a long time that engineers have been working through what is called abnormal or individual genius. Such engineers may sometimes come up with better ideas than groups and follow non-conventional and advanced approaches. In addition, students look for a career path that both is challenging and provides social interactions. Engineers are humans in the first place and then an engineer or they should be such. They not only deal with facts and laws of science and engineering but also communicate with people, so they should possess arts, character, positive feelings, and honesty. They need sensitivity and empathy; they should be able to put incomplete and scattered information together and achieve a fact from observations. Considering the facial expressions and tone of voice of people, competent engineers can use their sixth sense to identify the facts, opinions, and motivations in order to reach the right decision. They must also be aware that although engineering examinations often require a correct answer, many real situations are ambiguous and may have more than one correct answer. For these reasons, engineering education must be expanded to involve both the humanities and the arts and value the instinctive skills. Emphasizing the human commitment, philosophers have ignored the sixth sense and instinct over the ages, so that their decisions and actions have been based on excessive justification and excuses, even with the knowledge that those decisions and actions are wrong. As engineers' work directly affects the lives of millions of people, it is important that they refer to their sixth sense at any stage. Institutionalization of writing in the curriculum can help to increase deeper processing and improve and students' ability to retrieve and use knowledge through stimulating the students to reflect on what they have learned, the way they can relate it to what they know, and how this knowledge would be possibly used in the future (Spencer & Mehler, 2013).

8- PBL-based curriculum in engineering education:

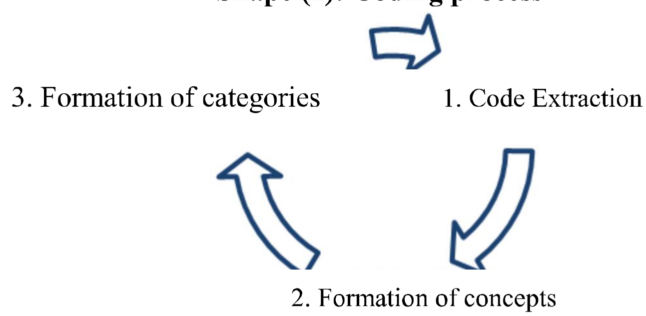
Students should be continuously involved in intellectual processes at a high and complicated level through the curriculum, and not only in the last year of study. Accordingly, they will find improved abilities to solve the structural problems with the approach of problem-based learning (PBL). Researchers have found that PBL increases the motivation of students, improves performance in transfer of functions, and creates a deeper understanding of content, especially in the form of long-term memory. Additionally, experiences of PBL can be helpful in the development of mental models in hard sciences and mathematics concepts. Bass (2010) also states that the optimal method of learning is "continuous and mutual interaction between practice and content". This method of learning is opposite to the common curricula that are based on content and engage students in practical activities only in the last stages. The best possible situation is an educational space that comprehensively provides relations between the pilot and the official curriculum. Teachers of engineering disciplines well know that lessons of initial design should focus more on conceptual design methods and pay less attention to the specific structure of an area, because the first-year students do not have the technical background to carry out these tasks (Bass, 2012).

One of the cognitive objectives of the engineering education curriculum is development of systemic thinking abilities. "Systemic thinking" means to understand how the overall parts interact and relate to each other. When students are engaged in an engineering design challenge, they should bear in mind a wide range of relevant variables as developed solutions. While analytical thinking penetrates into the engineering design activities, integration of components and subsystems is vital for successful resolving of all design problems, except for the simplest ones. As a result, thinking system plays an essential role in solving the complex challenges of engineering design, while they simultaneously address environmental issues, safety, ethical implications, and economic factors. Thinking systems allow students to flee from narrow definitions of a problem, reflection on related systems, the way they can affect or be affected by them, and advanced technologies (Householder & Hailey, 2012).

Methodology

This research was an inductive content analysis from the methodological perspective. It involved a review of literature relevant to technology education curriculum, training and technological literacy. The sampling was theoretical, purposive, where the sample size depended on theoretical saturation until no new data could be obtained. Hence, a total of 14 documents and 4 international organizations (ITEA, NCETE, CDIO and NAE) were analyzed in the field of engineering and technology education. The data were collected through desk review and field study, where the notes were taken from relevant documents while employing an open questionnaire. The data were analyzed through theoretical and analytical coding based on Shannon's entropy. The data were interpreted and coded through line-by-line examination. Data analysis involved cumulative categorization. In this procedure, there is no place for pre-existing theories while avoiding any preconceived categories. In fact, relevant literature is reviewed to gain a thorough understanding of the concept. Cumulative categorization is adopted when the existing theories in this regard are limited. Given the components of technological literacy mostly concern high-school courses, three sections were studied: engineering education curriculum, technology education curriculum and technological literacy components. The categories were extracted through coding the semantic units in the literature according to the research objective, i.e. extraction of technological components in engineering education. The codes were then classified according to similarities and differences, by comparison of which the main categories were obtained. Figure (1) illustrates the conversion codes into main categories. The reliability of review was maintained in two stages including the completion of categories by 50% and the other after the project finalization. At the end, 20 experts in engineering education (engineers running knowledge-driven companies) were asked to enumerate the most important factors in fostering a creative engineer. Then the concepts and corresponding sources were coded based on five abstracted components from the relevant literature. Then, the weight of each factor was obtained through expert opinion based on Shannon's entropy.

Shape (1): Coding process



Findings

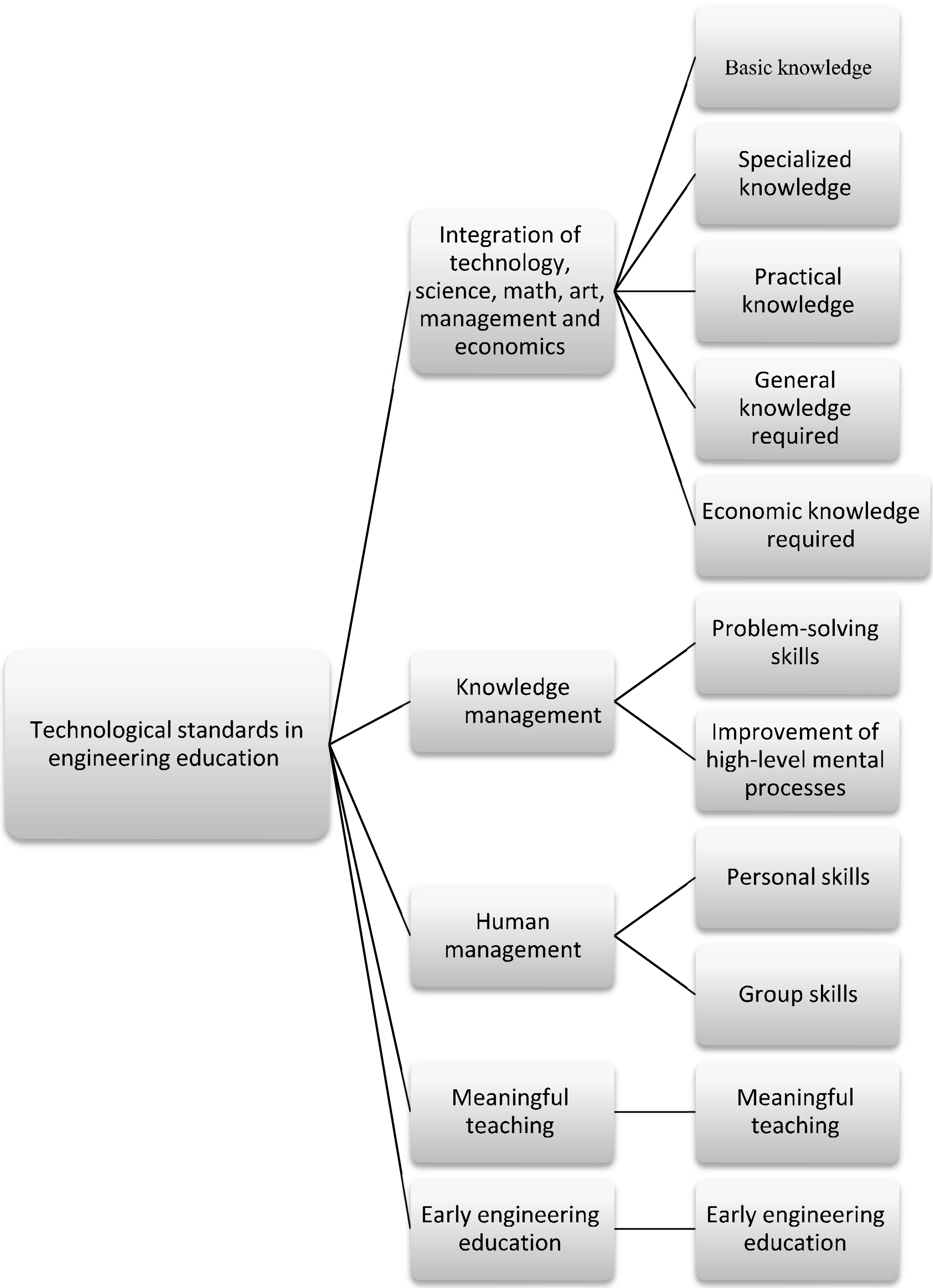
Analysis and exploration of concepts from relevant literature in order to provide the components of technological literacy in engineering education.
For this purpose, the research findings of Sanders (2009), Ambrose (2013), Ritz (2009), Rose (2004), Motaharinejad (2015), Mehler and Spencer (2013), Kelley et al (2009), Apelian (2013) , Daugherty (2005), Ernst & Haynie (2010), Householder & Hailey (2012) and components of 4 international organizations involved in engineering education (ITEA, NCETE, CDIO and NAE) were analyzed (using inductive content

analysis. The following tables display the codes, concepts and categories after open and selective coding.(Adams, Turns, & Atman, 2003; Ambrose, 2013; Apelian, 2013; Baskette & Fantz, 2013; Cheek, 1997; Daugherty, 2005; Denson, Kelley, & Wicklein, 2009; Ernst & Haynie, 2010; Householder & Hailey, 2012; T. Kelley & Kellam, 2009; T. R. Kelley, 2008; Motahari Nezhad, 2015; Ritz, 2009; Rose, 2004; Sanders, 2009; Shackelford, 2007; Spencer & Mehler, 2013)

Table 1: Semantic clusters development

Main categories	Sub-categories	Code
Integrating technology, science, math, art, Management and Economics	Basic knowledge required	Introduction to Math, Differential and Integral Calculus, Prerequisite Algebra, Academic Algebra, Statistics, Mathematics, Physics, Physics 2, Chemistry, Earth Science, Chemistry, Biology, Basic and Advanced Engineering Knowledge, Algebra, Geometry, Newton's First Laws, Energy Issues, Spreadsheet, Trigonometry
	Specialized knowledge required	Description of energy development, materials, energy principles and their complete application, energy and power, power and power systems, power and transformer, electronic (analog and digital), robotics, systems control, automation, fluid power, manufacturing, industrial organizations, information technology, wood products manufacturing, metal products manufacturing, multimedia systems, graphics, printing, understanding agricultural technology, production, food, chemical fertilizer, herbicides, additives, basic principles of botany, anatomy, biotechnology, medical technology, dynamics, design of machinery, civil engineering, materials processing engineering, computer networks, dynamics, design of machinery
	General knowledge required	Familiarity with the nature of technology / familiarity with IT job category / boundaries of technology / familiarity with the differences between science and engineering and computer / familiarity with technology threats and opportunities, improving the lives of people with technology / social sciences / language arts / mastering foreign language / inclusion of various arts / familiarity with technologies needed in transport and energy and bio / understanding the interrelationship between technology, society and the environment / description of energy development, materials, information and resources and its importance in human development / the development of understanding the advancement of technology and its effect on society and individuals' careers/ description of using technology and physical effects, such as producing, manufacturing, transportation / inevitable relationship between science, technology and mathematics and a basic understanding of the earth's physical life and scientific environment and observations / understanding and protecting the environment / historical perspectives / communication devices, such as change of electron to telecommunications waves / digital technology / prediction technology results in community / paying attention to environment and technology
	Practical knowledge required	Product design, industrial design / materials testing / drafting the design / architecture / solid modeling / project implementation / integration of sciences and mathematics, technology and management / familiarity with the process of manufacturing products from initial manufacturing and verification and

		improvement etc. / familiarity with industrial tools and ways of working with them / visual, listening, and electronic communication skills / evaluation of product's design / disciplinary and interdisciplinary design / technological systems management / designing, developing, controlling, using, and evaluating technology systems and processes / analysis and communication skills, knowledge of the underlying assumptions and system components / familiarity with the process of products production
	Economic knowledge required	Technical knowledge / familiarity with business and management principles / ability to use technical knowledge to meet the daily needs / commercialization / familiarity with modern developments in technological systems / identification technologies required in factories, companies and community / market recognition / familiarity with life and attempt to complete projects / familiarity with economic issues, business and management / design, implementation and commercialization
Knowledge management	Problem solving	Problem-solving/ability to combine information and reach new insights / divergent thinking / ability to easily use knowledge and skills in new situations / growth of innovation creativity / development of engineering reasoning and problem-solving / ability to work under restrictions / ability to create / creation and implementation of complex engineering systems in modern environment / multi-dimensional thinking
	Improvement of high-level mental processes	Observation, measurement / interpretation of the data and making informed decisions / strong analytical skills / intelligence in action / reinforcement of judgment and evaluation of systems / / test and discover / classification of information.
Human management	Personal skills	Observing professional ethics / having a strong professional sense, dynamism, cleverness, reaction and flexibility / continuous learning due to the rapid growth of technology / innovation, perseverance, self-knowledge and curiosity / time management / development of metacognition and improvement of internal knowledge structure / self-regulation and self-management / emphasis on self-learning, communication and collaboration / judgment and assessment / strengthening manufacturing approach in people / digital literacy / how to get information and resources
	Group skills	Teamwork spirit and communication skills / leadership principles and their application / group collaboration
Early engineering education	Early engineering education	Awareness of engineering issues since childhood Early engineering education
Meaningful teaching	Meaningful teaching	Emphasizing the design and implementation of projects and considering an attractive design for the laboratory environment in the curriculum/ creating opportunities in teaching to display a good character and freedom of action / being in the experience of brainstorming and production / internship / prototyping / analyzing the product and modeling / participating in brain-storming sessions / exposure of students to several environments / using collaborative education and active strategies, such as peer teaching group / simulations and problem-based learning activities, collective learning activities, inverted or flipped class and other class-centered methods / continuous intertwining of thought and action (retrieving and combining information) / integration of theoretical and practical knowledge / recommendation of writing and thinking, interpreting thoughts and issues on the teaching



Shape 2: Proposed technological standards to be incorporated in the engineering education curriculum

According to the analysis, five technological literacy standards to be incorporated in the objectives, content and teaching methods and techniques of engineering education curriculum evaluation are recommended.

Analysis and exploration of expert opinions in order to determine the weights of components extracted.

At this stage, 20 engineers owning knowledge-driven companies based in South Khorasan Science and Technology Park were asked to indicate the most important factors in fostering a creative engineer. Then, the concepts and their sources were coded based on five components of technological literacy in engineering curriculum. The weight of each factor according to expert opinion was determined through Shannon's entropy.

At the end, five components of technological literacy were proposed for incorporation in the curriculum of engineering education. Based on the findings of shape (2), the five components were, in order of importance, training and knowledge management and HR management skills, presentation of topics leading to technological literacy, significant teaching methods adopted by professors and early engineering education to prepare students for the world of technology ahead.

Table (2): Frequency distribution and normalized data

No.	Knowledge management		Integration of science, technology, art, mathematics and economics		Human management		Early education		Meaningful teaching	
1	10	0.243	8	0.195	10	0.243	5	0.121	8	0.195
2	8	0.285	2	0.071	8	0.285	4	0.142	6	0.214
3	10	0.312	9	0.281	6	0.187	0	0	7	3.218
4	9	0.230	5	0.128	10	0.256	5	0.128	10	0.256
5	10	0.238	4	0.095	10	0.238	8	0.190	10	0.238
6	9	0.225	9	0.225	9	0.255	4	0.1	9	0.225
7	10	0.25	10	0.25	8	0.2	3	0.075	9	0.225
8	10	0.312	6	0.187	7	0.218	0	0	9	0.281
9	10	0.285	10	0.285	7	0.2	2	0.009	6	0.171
10	5	0.16	8	0.25	7	0.22	7	0.22	4	0.129
11	8	0.28	8	0.28	8	0.28	2	0.071	2	0.071
12	9	0.214	10	0.1	10	0.1	8	0.190	5	0.119
13	10	0.29	9	0.26	5	0.041	4	0.117	6	0.176
14	5	0.16	6	0.193	10	0.322	3	0.096	7	0.225
15	10	0.227	7	0.159	9	0.204	9	0.204	9	0.204
16	8	0.222	10	0.277	6	0.166	4	0.111	8	0.222
17	3	0.090	9	0.272	8	0.242	3	0.090	10	0.303
18	10	0.256	10	0.256	7	0.179	2	0.051	10	0.256
19	10	0.4	6	0.24	5	0.2	0	0	4	0.16
20	10	0.263	9	0.236	8	0.21	2	0.052	9	0.236

Table (3): Information load from the significance coefficient of components

Knowledge management	Integration of science, technology, art, mathematics and economics	Human management	Early education	Meaningful teaching	
4.175	4.12	4.22	2.093	3.56	Ej
0.229	0.227	0.232	0.115	0.195	wj

Discussion and Conclusions

This study attempted to investigate the concepts derived from relevant literature on engineering education and technology in order to provide several technological literacy components in engineering education and analyze expert opinions to weight each component through inductive content analysis. The findings yielded the following conclusions.

The first category concerns knowledge management skills training, including excellent mental processes and thinking skills and problem-solving based on findings in Figure (2) and Table (1) and top rating of components in terms of weights based on Table (3). Thinking skills refers to evaluation of different solutions that require recalling the alternatives or inventing new solutions in the development and implementation of engineering projects. At this stage the individual thoughts take various levels and degrees. In the past, creative thinking and divergent thinking were used interchangeably, but it is now believed that creative thinking is an outcome of combined divergent and convergent thinking styles. Before solving a problem, individuals need to first free their mind and find different solutions. Then, they will adopt the convergent thinking to examine the intellectual products from the scientific, practical or utilitarian perspective to achieve the best solution (American Society for Engineering Education, 2008). In this study, experts believed that students will better succeed in the technological arena by acquiring great analytical skills, completing interdisciplinary projects, a spirit of adventure, constructive criticism and resiliency to accept defeat, and optimal use of failed situations. Multi-dimensional thinking can be taught through the application of science, problem-solving, decision-making, planning and organizing, quality management, technology management, knowledge management, management of resources for development, initiative, creativity, search for knowledge, skills to integrate and transform ideas, familiarity with an idea is transformed into action. This concept is known as *engineering design* in the world literature. Engineering design calls for critical thinking, utilization of technical knowledge and creativity. Engineering design revolves around four main pillars to describe technical problems and concentrates on their solutions. (1) semantic-verbal or written description of the problem, (2) graphical and technical outlining of objects, (3) adopting mathematical-analytical equations to devise solutions to technological problems, (4) Physical production of technological artifacts or physical models for testing and analyzing the products (Ullman, 2003).

The second category is human management based on the findings in Figure (2) and Table (2), which ranks second according to data in Table (3). Organizations will not spontaneously become innovative entrepreneurs, unless they are comprised of a team of innovative individuals incorporated into its structure. Collective skills determine to what extent we can manage our relationships with others, while personal skills determine how much we know ourselves and can manage ourselves (Nikrftar, 2013). Engineers require not only specialized knowledge and skill but also competences involving managerial skills (individual and collective) known as *core competencies*. (Lin, Sweet, & Anisef, 2003)classified essential job skills in three categories: personal skills, teamwork skills and academic skills (Momeni, Karami, & Mashhadi, 2012). In this regard, the components of technological literacy are deemed to be team collaboration by Global Alliance for Engineering Education experts from America, Europe, Canada, the UK, Africa, Asia and New Zealand (2014), communication and teamwork skills by the American National Center for Engineering and Technology at Utah State University (2013), a strong sense of professionalism, dynamism, acuteness, resiliency, creativity, interpretation of data and informed decision-making, acuteness in action, proficiency in management, leadership principles and familiarity with ethical principles and its application by the International Institute of Technology Education (2007).

The next category is the integration of science, art, mathematics and economy according to Figure (2) and Table (2), which ranked third in importance based on data in Table (4). One of the tasks of future engineers is to solve the social problems of the 21st century as well as profound needs such as energy, water, food, housing, mobility, health, and demand for sustainable development. Therefore, it is critical to employ the developments in science to further the goals of engineering education(Ambrose, 2013). It is vital to integrate math, science, engineering and art in engineering education. The five areas of knowledge in engineering education based on technological literacy highlight a dependent, interdisciplinary and professional curriculum (2002) similar to Venville et al. (2004) and a model developed by Tryggvason & Apelianin the curriculum of engineering schools. The last link converts knowledge into wealth, while the markets and business will be the final station for engineering students. Hence, knowledge of business, economics and marketing are courses as critical as science, technology, art and mathematics for nourishing the technological competence in students.(Tryggvason & Apelian, 2012)

The fourth category concerns meaningful teaching based on Table (2), which ranked fourth in importance based on data in Table (4). Accordingly, engineering education and learning environment leading to technological engineering practices will be no easy feat. Teaching practices in the fields of science, technology, engineering and mathematics expand far beyond the traditional teaching practices. Curriculum provides opportunities for engineering students to bridge ideas, approaches, experiences and lessons and transform what they learn and transfer them into new complex situations. However, the leading researchers in the field of engineering education have expressed their concern about the current educational model and teaching practices in preparing engineering students as future experts are not sufficient for integration of knowledge, skills and identity (Dall'Alba, 2009; Sheppard, Macatangay, Colby, & Sullivan, 2008) In the engineering education literature, there is a key term called practice, which crystallizes mental involvement, free decision, problem-solving, teamwork and creativity. In Hecker's (cited in Bourgeois & Olds, 2007), practice model, there is similarly a term called degrees of freedom, which implies individual decisions and mental involvement. Hecker (1960) demonstrated that greater degrees of freedom in action will create higher chances of individual success. Creative understanding will enlighten us toward that cause, even though the fact that content-based education focuses on students, it directly deals with them and eliminates any stress due to unawareness. How will students react when facing analytical and decision-making situations? An individual may fail to make a quick decision because no conceivable option comes to mind. Therefore, those students with better analytical and theoretical understanding will be greatly privileged since they barely feel under pressure when doing a task. Specialists have found that such inefficiency can be resolved through practice-based approaches based on competence and participation. In this type of training, most workplace tasks and problems require deeper integration of several disciplines, i.e. various types of procedures and approaches. In the modern global approaches, it is a big mistake to stagnate in one single training procedure (Bourgeois & Olds, 2007; Nikrftar, 2013).

Based on the findings in Table (2) ranked fifth according to data in Table (4**), early engineering education in elementary and secondary schools** will prevent the university-university cycle from resuming in engineering education for many years, while building a new cycle involving experience-university-market. Engineering education based on technological literacy does not overlook the pre-engineering courses, but considers them essential components of the procedure.

Overview of the newly proposed curriculum (technological curriculum in engineering education)

The proposed technological curriculum requires something more than information acquisition, since it needs to be embodied in modern insights. In addition, any content providing technological competence in individuals will outline the essential requirements and intervention in the world so as to make improvement in living standards. In a technological curriculum, engineering education is a two-way process developed through various subjective and objective designs. The activities in this type of curriculum involve illustration, modeling, planning and production. The process of problem-solving and practical learning will prevail the new technological curriculum. Practical activities start off by an idea, which is then designed and fabricated into a structure or product. The technological curriculum is prevailed by constructivism, where individuals develop conceptual frameworks while interacting with the external environment. In a sense, each individual is capable of building their own world. In this paradigm, the main focus of teaching is shifted from knowledge transfer onto learning (Nikrftar, 2013). The new technological curriculum is not about the theory and practice link, but it rather involves leadership by instructors and bringing that link to innovation and solving problems artistically. The reflective teaching practice requires instructors who have realized the nature of technology and never limit it to a particular discipline. Due to costly manufacturing processes, financial incentives have a significant impact on enrichment of learning environments. The technological curriculum is ideal for promotion of technology and information literacy as well as critical thinking, problem-solving and decision-making skills necessary for anyone striving to compete in the ever-evolving world economy. The technological curriculum can enhance the student's conceptual understanding and procedural knowledge skills to solve social problems through technology. This can be realized through multi-dimensional learning environments, smart individualized environments and socially rich environments.

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