Making the Case for Temporary Structures as a Required Course and Recommending an Instructional Design

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Abstract

All construction projects start from the ground up, requiring different enclosures and support systems below grade to keep away earth material and/or water. Constructing from the ground up involves access to elevated areas, requiring the use of platforms, such as scaffolding systems, to get material and labor above ground level. In addition, most construction projects involve concrete, which is the most widely used material in construction, requiring formwork and falsework systems. Also, materials such as rebar cages must be supported temporarily by guying and bracing to avoid collapsing. In some cases, existing underground facilities and appurtenances must be underpinned and supported in place to avoid damages. Additionally, on heavy civil projects requiring heavy construction equipment, there is always the need for trestles and equipment bridges used as temporary access. What is unique about these topical areas is that they fall under the subject area called temporary structures, which happens to fall outside the required curriculum of the CM (construction management) and ConE or CEM (construction engineering or construction engineering management) programs in the US. The objective of this paper is twofold. The first is to make the case for including temporary structures as a required part of the CM, ConE or CEM curriculum, and secondly, to recommend an instructional design approach for a temporary structures class. This study gathered, analyzed and synthesized literature and empirical data on the topic. Considering the failure rate of temporary structures, and the socioeconomic consequences of lack of knowledge and training in the area of temporary structures, the authors call for CM, ConE or CEM programs to re-evaluate the way they view temporary structures. Temporary structures should not be viewed as an optional course; it is an indispensable part of the construction process and should be treated as such. The significance of this research is paramount. It encourages accreditation bodies and academic programs in the area of CM, ConE or CEM to consider making temporary structures a required course. It also provides the programs with an instructional design on how to build the course content for a temporary structures course.

1. Introduction

The fundamental goal of educators in the construction-related program is to focus on developing the abilities of their students, thereby preparing them to embark on their professional journey. The students that come out of construction-related programs should have knowledge in all aspects of construction operations. By so doing, the graduates are able to implement safe, cost-effective, and timely solutions. Thus, to prepare students for the construction profession, they must be educated in the basic, fundamental courses that touch on all aspects of construction. In addition to basic, fundamental courses, such as materials and methods, cost estimating, planning and scheduling, project controls, soils mechanics, structures, surveying, construction equipment, and others, it is important that students learn about the principles and application of temporary structures on construction projects. Hence a great deal of responsibility lies on the shoulders of

construction educators to provide the students with the right tools to make them job ready. Unfortunately, even though it is a well-known fact that temporary structures are an important aspect of most construction projects, the limited number of construction-related programs that offer temporary structures indicates the lack of alignment with reality.

Even as an elective, very few of the CM, ConE or CEM programs have made an effort to introduce temporary structures in their programs. According to Banik in [1], very few ABET (Accreditation Board for Engineering and Technology) and ACCE (Accreditation Council for Construction Education) accredited programs offer temporary structures as part of their curriculum. A few of the programs that are currently teaching temporary structures do so because they see the value and are committed to providing their students with relevant knowledge irrespective of the fact that the course may not be required in their curriculum. According to ACCE in [2], there are 75 baccalaureate degree programs, four master's degree programs, and 13 associate degree programs that are ACCE accredited. A look at ASC (Associated Schools of Construction) membership list reveals that there are 7 regions with a total of 152 programs in the U.S. A search on ABET website on the number of ABET accredited construction engineering programs shows 42 programs. In addition to these programs, there are a good number of construction-related programs that are not accredited by ACCE or ABET, and neither of them holds membership in ASC. Interestingly, of the 75 baccalaureate degree programs accredited by ACCE only 9 of the programs offer temporary structures either as a required course or as an elective. In addition, of all the ABET-accredited civil engineering (CE) programs in the US, only California State University–Chico offers temporary structures as an elective to the students.

One wonders what could be the reason why some of the CM, ConE or CEM programs and the accreditation bodies do not view temporary structures as a must-teach course in these programs. Some of the academic programs make the case why the course is seen as an optional course. The first case that some of the programs make is lack of experts that can develop and teach the course. The second case that has been made is that there is a minimum number of credits external to a major program required by accreditation bodies for graduation. As such, the academic programs are discouraged from subjecting students to additional and unnecessary credits.

Irrespective of the reasons why temporary structures is currently not a required course in the CM, ConE or CEM programs, the objective of this paper is to make the case for temporary structures, and in addition, propose a course format for teaching temporary structures.

2. Literature Review

In construction, the contractor chooses the best construction methodology to get the job done. Those construction methods include resources such as labor, equipment, and material. Temporary structures are part of those tools that a contractor must use in order to construct the permanent structures

In practice, the contractor is responsible for making sure that temporary structures are capable of carrying, supporting and resisting loads that they are exposed to. As such, the contractor is responsible for temporary structures, the design and the selection of a design firm to design the systems.

The question then is why should a student that plans to work for a contractor learn about design and construction of temporary structures when the contractor is not involved in the design of temporary structures? The simple answer is that it is more challenging to coordinate and manage any construction process without grounded knowledge of what is involved in the process. In addition, most construction managers and engineers provide a great deal of input into the design of temporary structures. Also, since some of the contractors may own materials that they ask the design engineers to incorporate into the design, it is important that the contractors have basic knowledge on the capacity, safety and cost-effectiveness of the materials they intend to use.

The term or phrase "practice-ready" is a word that almost every academic program swears by. Yet some of the programs' approach to teaching contradict the goal of practice-ready. Not teaching students the required skill, supports the argument by some of the educators. Those educators say that "students do not need to learn some very important aspects of construction in the classroom in the hope that they will learn them on the job site." However, the reality is that an employer's expectations of a new graduate are that they are practice-ready.

Design and construction failure rates of temporary structures - According to Janney in [3] "construction failure is a failure that occurs during construction and they are considered to be either a collapse or distress of a structural system to such degree that it cannot safely serve its intended purpose." Several factors contribute to the failure of temporary structures, and some of the main causes of construction failures in general as captured by Yates and Lockley in [4] include inadequate bracing, and overloading or impact loading during construction. Ayub in [5] looked at data from OSHA on 96 structural collapses during construction from 1990 to 2008, finding that 80% of those incidents were attributed to construction errors, while the other 20% were attributed to design errors. Such findings are great examples of the consequences resulting from poor training of construction professionals in the area of temporary structures. Regarding scaffolding collapse, a study by Chronowski et al. in [6] points to improper design and construction error as the two main factors. Yates and Lockley in [4] suggest that one way to reduce failures from temporary structures is for construction personnel to be certified in design and construction of temporary structures. This points to the need for training of design engineers and contractors in the principles and applications of temporary structures. Temporary structure failure cases are very common in all parts of the world and even in the US. One of those cases was described by Souder in [7], where pipe and beam falsework bents that were braced using wire rope guying cables collapsed when the cables were released. In this incident the system collapsed onto a passing truck and nearly crushed the driver. The incident also caused one of the construction workers to fall off a nearby bent. The incident resulted from incorrect construction methodology and procedure, and to correct the problem, pipe braces were subsequently introduced in place of guying cables.

Mitigating socioeconomic impacts of construction accidents – According to the U.S. Bureau of Labor Statistics as captured in [8], in 2015, out of 4836 related workplace fatal injuries, 937 of them were in the construction industry. The loss of life and property involved in construction accidents create a huge social and economic impact and much can be done in terms of education to help mitigate such losses. According to Waehrer et al. in [9], costs of occupational injuries and

illnesses include direct and indirect costs, as well as loss in quality of life. Direct costs include first responder services, hospital related services, rehabilitation services, mental health services, burial services, insurance claims, property damages, etc. Indirect costs include wage loss and household production loss, as well as workers' compensation. Quality of life cost includes pain and suffering that victims and their families have to endure. Waehrer et al. in [9] report that the costs of fatal and non-fatal occupational accidents in the construction sectors in 2002 were estimated at $11.5 billion.

Construction safety is everyone's responsibility. The usual construction talk is "never walk past an unsafe act or condition." The reality is when people walk past an unsafe condition, it is not always intentional, but in many cases out of ignorance resulting from one not knowing what an unsafe condition looks like. It is important to give construction professionals the right tools and training that would allow them to do their job safely and efficiently, thereby avoiding accidents.

Considering loss of life and property related to construction collapses, Ayub in [5] found that of the 96 structural collapses the author evaluated, 14 of them were related to scaffolding, three were related to cofferdam construction and 12 related to formwork/falsework. In addition, as a result of the 96 structural collapses, 117 people lost their lives and 235 suffered some sort of injury. Accidents are preventable with the right training and education. Another way to view the impact of construction failures is by looking at the cost of design errors. A study by Lopez and Love in [10] found that, on the average, the cost of design error on a project is about 7% of the contract value. Most CM, ConE and CEM programs have a health and safety course as part of the curriculum. Therefore, temporary structures could be a better way to introduce real-life scenarios to the student.

Exploring practical construction cases through classroom training – The ultimate goal of every project is to deliver a project on time, on budget, and without accidents, which has a lot to do with managing the resources efficiently and effectively. It becomes important that professionals have a good understanding of the projects that they manage and what needs to be done to make sure those projects come in on time, on budget and safely. There is no substitute for having the right knowledge which can be acquired through training or from field experience. Educators are in a position to provide students the right knowledge which empowers them when they encounter real-life situations. Delatter in [11] presents several real-life structural failures and how they relate to design and construction of structural systems. Effective classroom training using real-life cases can help the student prepare for the real-world experience. Classroom training on temporary structures should expose students to:

- Temporary structure failure cases and resulting factors,
- Safety practices related to temporary structures,
- Applicable specification, codes and standards which guide practice,
- Knowledge of design principles and sizing of members,
- Who is responsible for the design of temporary structures?
- Who is responsible for design package review, submittal, and approval?
- Materials and methods for erecting temporary structures,
- Inspection and sign-offs of temporary structures during construction and while in use,
- When to dismantle temporary structures and the sequence of removal,

- Potential loadings and how to evaluate them, and
- Cost drivers that must be considered when estimating the cost to design, fabricate, erect, and dismantle each type temporary structures.

Training students to effectively coordinate Design-Build (DB) projects – The construction industry has seen a huge move from design-bid-build delivery method to design-build delivery method. To support this shift, the industry is now demanding more from ConE and CEM graduates geared towards an integrated approach. Molenaar and Sallar in [12] argue that the current educational environment has seen the separation of architectural, engineering, and construction programs. However, the authors are of the opinion that new educational challenges have been created in need to achieve DB objectives. Irrespective of the construction-related programs that these students graduate from, the reality is that most of them will find themselves working in joint venture companies specifically created for DB projects or for contractors that specialize in DB. A construction engineer charged with coordinating and managing design packages need to have enough knowledge about what goes into the design in order to effectively oversee the design process. Similarly, a design engineer working on a DB project needs to know about the construction process. With more exposure in a course that bridges design and construction, CM, ConE or CEM graduates will no longer feel intimidated or inexperienced, but feel knowledgeable enough to support a DB project. In addition, Molenaar and Saller in [12] suggest that all the players involved in the DB delivery method have unique educational needs. To be "on the same page" and for successful outcomes, the authors state that, in the DB method, each party is forced to educate themselves in how their counterparts think and act. The work by Yates and Battersby in [13] highlight the many types of project delivery methods having fragmented responsibilities and lacking integrated shared knowledge. According to the authors, such a situation has resulted in an environment where the designer's construction knowledge is lacking and so is the contractor's design knowledge.

A point that should be made here is that while ABET programs typically lead to a PE license, ACCE programs do not typically lead to a PE license. While ACCE programs do not lead PE license, it is important that the graduates know enough to obtain the help of a registered engineer in the design of temporary structures. Irrespective of the contractual arrangements between the design firm and the contractor, design liabilities rest on the design engineers, and the liabilities related to construction of the temporary structures rest on the contractor if failure results from construction methods. It is important that ABET and ACCE programs prepare students to understand and mitigate liabilities associated with the design and construction of temporary structures.

Changing students' attitude towards structures courses – Students in the CM, ConE or CEM programs are required to take courses in statics, mechanics of materials, design and analysis of structural steel, timber, and concrete. These subjects are so abstract that some students find them difficult to understand. Students' attitudes toward these courses are akin to their attitude towards mathematics. According to Goldfinch et al. in [14], student failure rates in introductory mechanics and related courses are very high and remains a widespread problem. Karim in [15] states that for many students, courses related to introductory mechanics can be boring because

they contain numerous abstract concepts, principles, and ideas. According to Novak in [16], meaningful learning as compared to rote learning provides a way for learners to think, feel, and act out the concepts learned, through an understanding of how the concepts relate or link to other concepts. Novak points out that all knowledge is comprised of concepts and how they relate to other concepts to create meaning about the world around us, and this is where propositions (principles) evolve. "Propositions are two or more words combined to form a statement about an event, object, or idea" (Novak, in [16]). The richness of understanding an area of study increases when the learner can make sense of the concepts and terminologies, and relate them to other concepts that they can understand. In the book titled the "The art of explanation: Making your ideas, products, and services easier to understand," Lefever in [17], points out that good explanations are built on context, simplification, story, and connections.

Helping students to develop critical thinking skills – In the construction industry, critical thinking is one of the most sought-after qualities that employers look for in job candidates. Critical thinking is about connecting the dots through logical analysis and evaluation. Students in the CM, ConE or CEM programs are taught many design and construction courses and concepts. Those courses and concepts help students to develop knowledge on how to design and manage construction projects. Aigbavboa and Aliu in [18] show that critical thinking is one of the most important skills required by employers in the construction industry. Also, students tend to retain more of what they are taught when the concepts are repeated in several of the courses in their program. Several areas of construction knowledge are related to temporary structures, and temporary structures is an ideal course to reinforce what has been taught in other courses. For example, CM students are taught about various construction materials and methods, they are taught about construction safety, and they are also taught about cost estimating. In addition, they are taught how to plan and schedule construction projects, they learn about construction administration and project engineering practices and they learn about structural design and analysis. Temporary structures would help to reinforce all these subject areas and could help students retain what they are taught in other courses.

3. Temporary Structures from the Viewpoint of Practitioners

The authors conducted a survey which was sent to 110 construction companies in Northern California. Of those companies surveyed, 48 responded (43.6% response rate). Out of those that responded, slightly over 26% of their combined work involved temporary structures. Of these companies, 55% perform predominately commercial construction, 34% perform heavy civil construction and the remaining 11% perform industrial and specialty construction. The data show that even though 55% of the companies are considered commercial contractors, 25% of their work involves temporary structures. The descriptive statistics from the survey show that 54% of the companies that participated in the survey have policies on temporary structure use, 60% of the companies train their employees on temporary structure applications and 79% of the companies believe that temporary structures should be included in a CM, ConE or CEM programs.

4. Proposed Course Format

Educators use various design and delivery methods to transfer knowledge to students, and an effective method is one that achieves the planned objective. According to Dills and Romiszowski in [19], effective instructional design and development are those that provide a model to engage the learner in real-life scenarios and cases. What follows is the proposed course design for temporary structures as it relates to the course objective, content, student assessment and possible textbooks:

4.1 Proposed Course Objective

Most construction projects would not be possible without some form of temporary work. "Temporary Structures" are installations required to provide access, protection, support, or services for workers, equipment and materials during the construction, renovation, retrofit, maintenance, or demolition of permanent structures. Temporary structures are also required to provide temporary service, repair, or support for any part of permanent structures until the permanent structures have achieved a state of completion and self-support, allowing the temporary structures to be removed. As the name implies, temporary structures are short–service-life structures, meaning they are not permanent. On average, a temporary structure is in place for one week to up to six months.

The main objective of this course would be to expose students to the various forms of temporary structures. The areas will include and not be limited to failure cases, safety practices, uses, design and analysis, construction methods and removal, inspection and the behavior of temporary structures. This is done to help avoid structural failures of temporary structures which could lead to loss of life and property.

4.2 Proposed Course Content, Topical Areas, and Learning Outcomes

In general, the topical areas for the course would include topics on statics, strength of materials, loadings, soils mechanics, concrete pressure, scaffolding, support of excavation, formwork and falsework, bracing and guying systems, temporary bridge and platforms, and support of existing structures. From the same survey conducted, the majority of the responding companies indicated high use of the systems listed in Table 1 below. From the survey of practitioners on the state of temporary structures, the results indicate that 66% of the companies surveyed have performed work that requires concrete formwork/falsework, 44% of the companies have performed work that requires shoring, and 62% of the companies have performed work that requires support of existing structures. In addition, 85% of the companies surveyed have performed work that requires scaffolding, 32% have performed work that requires bracing and guying and 19% of the companies have performed work that requires trestles/temporary bridges. Table 1 below provides detail of the course content and the learning outcomes.

Table 1. Student Learning Outcome for Temporary Structures Course

Student Learning Outcome - At the end of the course, students should be able to:
▪ Understand Basic Introductory Concepts of Statics ▪ Discuss Statics and Application to Temporary Structures ▪ Conduct Computation for Reactions, Shear Force, and Bending Moment
▪ Understand Basic Introductory Concepts of Strength of Materials ▪ Discuss Strength of Materials and Application to Temporary Structures ▪ Understand How to Read Design Manuals for Sectional Property Values and Design Values
▪ Discuss Principles of Structural Design and Analysis ▪ Discuss Design and Analysis Philosophy - ASD and LRFD ▪ Understand the Fundamental Stress and Deflection Formulas Used in Structural Design and Analysis ▪ Understand Structural Design Steps ▪ Understand different uses of factors of safety
▪ Understand Different Types of Loadings ▪ Discuss Structural Loadings and Application to Temporary Structures ▪ Conduct Computation of Loadings on Structural Members
▪ Understand Basic Introductory Concepts of Soils and Soil Mechanics ▪ Discuss Soil Mechanics and Application to Temporary Structures ▪ Conduct Computation of Soils Loading on Temporary Structures
▪ Understand Concrete and Factors that affect Concrete Pressure ▪ Discuss Concrete Mix Design ▪ Understand Loading on Formwork and Falsework Systems Resulting from Concreting Operation ▪ Discuss Concrete Pressure and Application to Design of Formwork/Falsework Systems ▪ Conduct Computation of Concrete Pressure Using Set Formulas
For Scaffolding, SOE, Cofferdam, Formwork, Falsework, Bracing & Guying, Trestle, etc. ▪ Understand and Discuss each Unique Temporary Structure System as it Relates to: o Uses and Components o Applicable Case Studies with Emphasis on Structural Failures Causes o Safety Practices, Safety Regulations, and Job Hazard Analysis o How it's Constructed – Means and Methods ▪ Discuss and Conduct Design and Analysis of Structural Components as it Relates to: o Applicable Design Standards o Loadings on Members, and Sizing of Members ▪ Discuss Specifications and Standards that Affect System Choices o Design Submittals, Review, and Approvals o Inspections and Sign-offs of Temporary Structures During Construction and in Use ▪ Cost Drivers/Considerations for Estimating the Cost of each of the Temporary Structures

4.3 Proposed Evaluation of Student Understanding

To evaluate students' understanding of the course, quizzes are given to the students every week, while assignments (problem sets) are also given that correspond to each topical area covered. Two midterm exams, a final exam and a culminating design project should be expected/given to the student

4.4 Proposed Reference Textbook to Prepare and Teach Temporary Structures

There are no comprehensive manuals on temporary structures, but a few textbooks have been published specifically to enhance understanding in this area. Some of the reference textbooks for this course would include:

- Temporary Structures in Construction (Third Edition) by Robert T. Ratay
- Temporary Structure Design by Chris Souder
- Excavation Systems: Planning, Design, and Safety by Joe M. Turner
- Design and Construction Failures: Lessons from Forensic Investigation by Dov Kaminetzky
- Beyond Failure: Forensic Case Studies for Civil Engineers by Norbert J. Delatte
- Scaffolding: The Handbook for Estimating and Product Knowledge by Michael "Terry" Marks
- Formwork for Concrete by M. K. Hurd

5. Conclusion and Recommendations

Most construction projects would not be possible without some form of temporary structures. The use of systems such as scaffolding, support of excavation, cofferdam, formwork, falsework, bracing and guying, equipment platform and trestles, and support of existing structures are required on most projects. Unfortunately, these systems are categorized as temporary structures, which fall outside the required curriculum of most CM, ConE or CEM programs in the US. Temporary structures as a course is viewed as an elective and an optional course in these programs, and the case has been made by some to make temporary structures a required course or to substitute for one of the program's "structural" courses.

The objective of this paper was to make the case for temporary structures to become a required course in the CM, ConE or CEM programs. In addition, the second objective was to present an instructional design for teaching temporary structures. The case was made for temporary structures by looking at the structural failure rate, the socio-economic impact from construction accidents, and the need to mitigate costly real-world mistakes resulting from lack of knowledge. The increasing use of design-build delivery calls for change in students' attitude towards structural design courses. It also calls for students that are capable of coordinating design-build projects. The case was also made that a temporary structure course can help students connect to the other courses taught in their program. As such, temporary structures could be a good fit for a capstone course as well. This research also conducted an industry survey on the use of temporary structures and how practitioners view temporary structures. The findings show that the use and applications of temporary structures in the construction industry are widespread and apply to all sectors. In addition, the findings show that many of the practitioners see the need to teach students in construction-related programs about temporary structures.

The paper also presented an instructional design approach for teaching temporary structures. This is in an effort to make the transition easy for programs that intend to start teaching temporary structures. In addition, for those programs looking to improve how they currently teach temporary structures, the instructional design presented here could be of value.

Considering the failure rate of temporary structures and the socioeconomic consequences from lack of knowledge and training in the area of temporary structures, the authors recommend that CM, ConE or CEM programs re-evaluate the way they view temporary structures. Temporary structures should not be viewed as an optional course; it is an indispensable part of the construction process and should be a required course in the program.

Whether a student's career path takes him or her through the CM path where students are not trained to seek for a PE license, or to the ConE and CEM path where the students are trained to seek a PE license, it is important to teach them about temporary structures. Instead of having students take three structural analysis and design courses, the three courses could be combined into two courses and the third and final structural analysis and design course could then be temporary structures where timber, steel and concrete are used. As such the first structures course could introduce and cover statics, and mechanics of materials. The second structures course could cover principles and basis for design and analysis of structural steel members, wood members, and concrete members. This would allow the third structures course to be temporary structures.

References

[1]. G. Banik, "Course content and outcome of construction temporary structures," Paper presented at *2009 Annual Conference & Exposition*, Austin, Texas, 2009 https://peer.asee.org/5858

[2]. ACCE (n.d). Accredited programs. Retrieved from http://www.acce-hq.org/images/uploads/Programs_0429163.pdf

[3]. J. R. Janney, ed., *Guide to investigation of structural failures*. New York: ASCE, 1986.

[4]. J. K. Yates and E. E. Lockley, "Documenting and analyzing construction failures," *Journal of Construction Engineering and Management*, vol. 128, no. 1, 2002.

[5]. M. Ayub, "Structural collapses during construction." *Structures Magazine*, 2010.

[6]. P. Chronowski, M. Modares, and J. Mohammadi, "Data-driven investigation into causes of collapse in scaffolds," *Practice Periodical on Structural Design and Construction, ASCE*, vol. 22, no. 2, 2017

[7]. C. Souder, *Temporary Structure Design*. Hoboken, New Jersey: Wiley, 2015.

[8]. U.S. Bureau of Labor Statistics (2016). National census of fatal occupational injuries 2015. Available: https://www.bls.gov/news.release/pdf/cfoi.pdf, 2016

[9]. G. M. Waehrer, X. S. Dong, T. Miller, E. Haile and Y. Men, " Costs of occupational injuries in construction in the United States," *Accident; Analysis and Prevention*, vol. 39, no. 6, pp. 1258–1266, 2007.

[10]. R. Lopez, and P. Love, "Design error costs in construction projects," *Journal of Construction Engineering and Management*, vol. 138, no. 5, pp. 585-593, 2012.

[11]. N. Delatte, *Beyond failure: forensic case studies for civil engineers*. Reston, Va: ASCE Press, 2009.

[12]. K. R. Molenaar, and B. J. Saller, "Educational needs assessment for design/build project delivery," *Journal of Professional Issues In Engineering Education and Practice*, vol. 129, no. 2, pp. 106-114, 2003.
[13]. J. K. Yates, and L. C. Battersby, "Master builder project delivery system designer construction knowledge," *Journal of Construction Engineering and Management,* vol. 129, no. 6, pp. 635-644, 2003.
[14]. T. L. Goldfinch, A. L. Carew, and T. J. McCarthy (2008). "Improving Learning in Engineering Mechanics: The Significance of Understanding." Available: http://ro.uow.edu.au/cgi/viewcontent.cgi?article=5557&context=engpapers
[15]. R. Karim, "Teaching and learning of fundamentals of mechanics in an innovative way to maximize students' understanding," *2nd WIETE Annual Conference on Engineering and Technology Education*, Pattaya, Thailand, 25-28 January, 2011
[16]. D. J. Novak, *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*, Mahwah, NJ: Lawrence Erlbaum Associates. 1998.
[17]. L. Lefever, *The art of explanation: Making your ideas, products, and services easier to understand*, Hoboken, NJ: Wiley, 2013.
[18]. C. Aigbavboa, and J. Aliu, "Requisite skills for graduate success: Perceptions of the Nigerian construction industry," *The Scientific Journal for Theory and Practice of Socio-economic Development*, vol. 6, no. 11, pp. 21-42, 2017
[19]. C. Dills, and A. Romiszowski, *Instructional development paradigms*, Englewood Cliffs, N.J: Educational Technology Publications, 1997.