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A Study of Determination of Benchmarks during the New Formation of Integrated STEM Leader Preparation Program

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ABSTRACT

Background: Integrated STEM (Science, Technology, Engineering, and Mathematics) education is crucial for teacher preparation programs that provide effective teaching in an interdisciplinary approach to teacher training. There is a need for a novel program to train pre-and in-service STEM teachers as STEM leaders who's moving a passive STEM teacher into an active STEM leader in their schools. The professional development of new STEM leaders in schools is critical so that the benchmarks of a new school program called STEM-LPP can be met. This program is intended to help develop existing STEM teachers to become more experienced and innovative in their usage of interdisciplinary ideas and team-working. An iSTEM approach (Rosicka, 2016) is more than just the skills, competencies, and knowledge of the four (STEM) domains.

Methods: A content analysis method was conducted by benchmarking the top five university master programs and academic committee meetings. The survey method was applied to design a new STEM preparation program for pre-and in-service teachers. This paper reports the benchmark collection and evaluation as a form of meta-analysis by academic meeting processes and views from existing STEM teachers from various schools how do the top five university master programs factor into your considerations? Data was collected by benchmarking and investigating STEM frameworks, models, and principles called benchmarks. Data were discussed and evaluated with academic meeting members, including two experts, two specialists in the department of curriculum development, three STEM teachers, three stakeholders, three staff professors, and two STEM master students from Suleyman Demirel University located in Almaty, Kazakhstan. Besides, 14 STEM teachers participated in evaluating in various schools. Findings: benchmarks and obtained courses were correlated to determine the relations.

Results: The six benchmarks: educational leadership, engineering/project design and integration, technology integration, multiple discipline integration, research-oriented instruction, and practice/experience-based teaching, were determined. Under these benchmarks, courses, competencies, and learning outcomes were also generated. The developing process of STEM-LPP was also confirmed by analyzing the findings from top university master programs with academic meeting studies and STEM teachers' evaluations. The correlations among the benchmarks and between benchmarks and courses were shown to have a strong correlation and their sufficiency for the criteria of LPP was displayed in the data.

Implications: This type of teacher preparation program has two crucial purposes: at first, providing a way of determining benchmarks during the formation of the teacher preparation program for STEM education program designers and developers. Secondly, it was informative on integrating STEM disciplines with STEM student projects and activity work to develop teachers' knowledge and skills. This study contributed to the construction of teacher preparation programs in universities and assisted STEM teachers in developing their teaching skills in the educational sphere. In future, such studies should be re-analyzed and evaluated by a large sample size of STEM teachers, partners, and other contributors.

Keywords: integrated STEM, STEM leader, STEM education, teacher preparation program

INTRODUCTION

The developmental studies of iSTEM (integrated STEM) teaching training programs are just as crucial as pre and in-service teacher training because of effective teaching with an interdisciplinary approach. STEM teachers in schools are rare in terms of iSTEM (iSTEM) knowledge. To be STEM leaders, they need to be supplied with iSTEM knowledge and field-content knowledge to be STEM leaders. When exploring published literature, iSTEM education has been summarily defined as teaching multidisciplinary integrated knowledge to solve transdisciplinary problems (Nadelson and Seifert, 2017; Rosicka, 2016; Wang et al., 2011). Wang et al. (2011) explained STEM integration as an interdisciplinary teaching approach that removes the barriers between the four disciplines. The iSTEM approach involves the application of knowledge and practices from multiple STEM disciplines (Nadelson and Seifert, 2017). Rosicka (2016) noticed that an iSTEM approach is more than the skills, competencies, and knowledge of the four (STEM) domains. iSTEM contains the engineering design (Sanders, 2013; Wells, 2013), problem-based (Roberts, 2013), and project-based approaches (Wells, 2013) to acquire integrated skills in four disciplines. Researchers indicated the benefits and revealed a positive effect on student achievement (Becker and Park, 2011), demonstrated an increased development of creativity, improved social skills and self-efficacy (Roberts, 2013), and allowed teachers to develop interdisciplinary knowledge, its role, and importance in everyday life (Pawilen and Yuzon, 2019) when iSTEM instruction is implemented through instructional strategies.

In most educational systems used by countries, single and specific discipline teaching without interdisciplinary work has been conducted (Burrows and Slater, 2015). The crucial issue in preparing iSTEM teachers is to train qualified teachers with integrative, interdisciplinary knowledge instead of only single discipline knowledge. Borromeo Ferri (2019) noted interdisciplinary learning and teaching require well-prepared teachers and pointed out the need for teachers, who are open-minded enough not to see only their discipline, but who like to connect several disciplines. Most teacher preparation programs include fundamental science courses and pedagogical courses, which have focused on one field of knowledge rather than interdisciplinary knowledge or integration of two or more disciplines. The current K-12 educational system is discipline-based, not problem-based, except for a few (Nadelson and Seifert, 2017). STEM education is still taught more theoretically than practically or project-based, within core disciplines by school syllabi.

The following issues have been identified; insufficient focus on the challenge of having STEM integrated knowledge of teachers (Dagan et al., 2019), the difficulty of incorporating several disciplines together (Kelley et al., 2021), and having the limited utility of isolated science courses and the insufficiency of general teaching method courses to serve integrated knowledge, are being discussed for future science teachers in higher education. Becker and Park (2011) also emphasized that the implementation of the integrative approaches highly depends on STEM teachers' perceptions toward the integrative approach and delivery methods in schools. In this respect, Dagan et al. (2019) pointed out that STEM teachers are vital people and need to be trained as educational leaders aligned with the vision and principles of integrative STEM education in teacher preparation programs.

LITERATURE REVIEW

Research studies on STEM teacher preparation programs by some scholars focused on the features of STEM teacher preparation programs by describing STEM integration programs' principles, frameworks, standards, and other features. Rosengrant et al. (2019) evaluated and developed two existing STEM education programs; the goal is to provide a series of standards to guide the education of STEM teachers. Rosengrant et al. (2019) presented them, and the first two were focused on content knowledge and pedagogy. They said, *"If an educator is not knowledgeable about their topic, they cannot be very effective"* so that the graduate program whose participants should be had content knowledge and pedagogical skills with teaching strategies. According to Rosengrant et al. (2019) research study, the standards directly related to STEM education were 'practice, use of technology, educational research, engineering by design, and STEM content integration'. "The practice standard" provided practical learning on; how to integrate across other disciplines, supplied educational research to find ways to improve teaching. "The technology standard" was aimed to help students with the use of new technologies. "The standard of engineering by design process" empowered easy integration into other STEM fields, and the final standard of iSTEM content helped to teach interdisciplinary content for both educators and students. Hansen and Gonzalez (2014) further described the four instructional principles that are essential for the teaching and learning of STEM as "*(1) integrate technology, (2) reach across disciplines both within and beyond STEM fields, (3) relate to authentic, or real-world, problems, and (4) be based on project-focused tasks.*" Moore et al. (2014) categorized components of the preparation program into subcategories: STEM practices, STEM technology, STEM content integration, real-world problems based learning and lived experience-based learning.

The important facet in the framework for integration STEM is leadership, and this is critically needed in STEM instruction (Bailey, 2020). Leadership may be described as an experienced teacher, researcher, and role model teacher. Sublette (2013) noticed the STEM-I3 model that ensures the teacher leader is a teacher first and is committed to mastering his or her practice for leadership. Ryu et al. (2019), in the study of "challenges for iSTEM teacher preparation existing programs", an integrative master's degree program in STEM, aiming to train educators in Israel, indicated that teachers faced challenges with limited interdisciplinary understanding and a lack of role models when authors developed an iSTEM education methods course which was taught to secondary pre-service teachers in STEM disciplines. In the description of background information by Dagan et al. (2019), they published the relevant objectives: developing leadership with project-based learning experience and advancing the "teacher researcher" approach within STEM teaching through Project-Based Learning (PBL). Research is also needed to prepare STEM teachers to become leaders (Bailey, 2020) and presented this as a standard "accessing research to improve educator development" that was shown in teacher leader standards constructed by Teacher Leadership Exploratory Consortium (TLEC).

Burrows and Slater (2015) illustrated the iSTEM teaching trajectory covered five levels from zero to four, which were 'single discipline, discipline plus mathematics, multiple disciplines, engineering projects, and constant iSTEM' for teachers. They particularly noted that teachers and curriculum designers purposefully included engineering and design projects to help students' learnings while level three engineering project, was described. Project-Based learning with project activities is a key organizing element of STEM programs and curriculum arrangement (Dagan et al., 2019). DiFrancesca et al. (2014) described a STEM-focused elementary teacher preparation program that required pre-service teachers to complete an engineering design process methods class, two mathematics method' courses and two science methods courses. The goal of this program is to cooperate engineering to a single STEM discipline. Pinnell et al. (2013) also presented application engineering design as the framework in the study of STEM education quality over three years of research and literature review.

Pinnell et al. (2013) articulated the framework 'technology integration' which includes instructional computers, robotics, using digital technology tools, technology supported-learning, and technological innovations. Papadakis et al. (2021) noted that educators faced various difficulties in their efforts to include educational robotics (ER) and concluded in their study that teachers need the appropriate training to learn about new forms of educational technology such as ER. The other framework is about practical and experienced teaching that provides the use of theoretical knowledge in practical pedagogical fields. Dailey et al. (2015) examined a program that gives undergraduate candidates by focusing on-field experiences. Corlu et al. (2014) suggested a program that serves practice-based instruction for pre-service teachers and emphasized teaching practice through integrated teaching knowledge may better prepare pre-service mathematics and science teachers for the profession. Another framework is multidiscipline integration that covers effective cooperative studies between science, technology, and math teachers in order to integrate content. Eckman et al. (2016) aimed to evaluate a STEM teacher education model for pre-service teacher preparation which incorporates science or mathematics content and indicate the advantages of the cooperative model that is math-science content cooperation. They focused on the STEM teaching cooperative experiences, which outlined the integration theory and practices for Noyce scholars and concluded that there are important differences, especially confidence of teachers, between the traditional STEM teacher preparation program and the Noyce STEM Scholar Program.

These views underlined by scholars inform about key benchmarks in the teacher preparation program of iSTEM. Each program was focused on various frameworks that consider in accordance with the program goal, objectives, educational standards. All literature reviews and frameworks or approaches reported in the way of fundamental knowledge (Nadelson and Seifert, 2017) for contexts in multiple STEM facets and concepts and opened the way (Burrows and Slater, 2015) to integrate teaching approaches with focusing benchmarks that provide student exploration, learning, clear understanding of how to integrate disciplines, STEM integration. According to the above literature, STEM teachers should be supplied with practical knowledge and teaching strategies in research, project-based, engineering-design oriented, technology knowledge in order to integrate STEM knowledge and implement its knowledge to reflect on design-based projects.

Research Question

It is required to develop a new teacher preparation program within the iSTEM education frameworks, models, and principles (all named benchmarks) which provides inter- and transdisciplinary knowledge and skills at the graduate level in the higher education system. Kirschner et al. (2008) noted that benchmarks had provided informative quantitative markers for annually assessing the implementation of a program. This study addressed the solutions to the following questions:

1. What frameworks, models, principles (all benchmarks) are mainly determined for the well-prepared STEM teacher preparation program?
2. To what degree is the sufficiency of these benchmarks in iSTEM leader preparation program (STEM-LPP)?
3. What is the extent of appropriateness between the benchmarks and courses with competencies and outcomes?

RESEARCH DESIGN

This study was designed in three stages: benchmarking, academic committee meetings, and survey to STEM teachers. STEM programs were examined within the scope of STEM teacher preparation programs by using the content analysis method. According to Trochim (2006), content analysis is the analysis of text documents. As content or document analysis, program information package and program description on university websites were benchmarked by analyzing frameworks, models, and principles. Frameworks, principles, and models (named as benchmarks) related to the STEM teacher preparation program were also investigated from the published relevant literature. In academic community meetings (ACM), 15 community members participated in order to evaluate and discuss the findings of benchmarks and to determine the program's goal with objectives, program outcomes, and courses with competencies. The survey was adapted and conducted in order to evaluate finding benchmarks. The survey was conducted on 14 STEM teachers with teaching experience in schools to gather information about the prepared program (LPP) and learn their opinions. The survey was based on Likert-type research. Creswell (2002) described that Likert-type research is a procedure in quantitative research to describe the attitudes, opinions, behaviours, or characteristics of the population. All variables found from benchmarking, academic meeting evaluations, and survey results were analyzed by using correlations among variables in order to confirm.

Data Collection

The data collection ways were included:

1) benchmarking with document analysis of the STEM teacher or leader preparation programs at the five top universities and investigating related literature,
2) performing academic community meetings during the iSTEM teacher program, and
3) a survey for STEM teachers' views about iSTEM program.

Data was collected by benchmarking content analysis of academic degree programs in the STEM teacher preparation program (n=5) at various universities. The determined benchmarks were considered again by investigating some related literature. The benchmarks were discussed in academic meetings within the participation of academic members. The survey was conducted with STEM teachers in the collaborating high school and professors in universities. The survey was adapted from the suggested frameworks, models, and principles related to STEM to determine the appropriateness of the STEM teacher preparation program. Some items were taken from the published instruments, and some of them were derived from STEM frameworks, principles, and models suggested in the literature. The benchmarks were responded to on a 5-point Likert scale: from strongly agree (5) to strongly disagree (1).

Data Analysis

All STEM-related frameworks, models, principles, and teaching methods from benchmarking various university master program information packages from their websites and the published literature, were documented, investigated, and analyzed. The findings were categorized to recognize as benchmarks that form the STEM-LPP. Qualitative data from the benchmarking results and the community meetings' suggestions were evaluated to identify benchmarks that will form the survey items. Survey item responses were analyzed in considering correlation values among variables. A correlation test was applied to test the relationship among finding benchmarks, program (STEM-LPP) benchmarks, and courses. it was also conducted to assess compatibility between the benchmarks and courses.

RESULTS AND FINDINGS

The first research question was "What frameworks, models, principles (all benchmarks) are mainly determined for the well-prepared STEM teacher preparation program?" For the findings of the first research question, benchmarking was conducted. The second research question was "What degree is the sufficiency of these benchmarks in iSTEM leader preparation program (STEM-LPP)?" For the second research question, the survey was applied to school teachers in order to indicate the sufficiency of the determined benchmarks. The third research question was "What extent of appropriateness between the benchmarks and courses with competencies, and program outcomes?". For the third research question, academic meetings were conducted, and the survey was applied to school teachers in order to indicate appropriateness between the benchmarks and courses with competencies and program outcomes.

Findings of Benchmarking for the First Research Question

The benchmarking method was used as a development process of teacher preparation programs with evaluation and comparison to high-level STEM training programs in five universities. The five programs were the Master of Education - Integrative STEM Education K-12 (California University of Pennsylvania Program), Master of Education in STEM (William Woods University), Master of Science in STEM Education (University of Iowa), Master of Education in Science, Technology, Engineering, Arts & Mathematics (University of San Diego), and Master of Education in Secondary Education with STEM Education program (Southern New Hampshire University). All programs' information was retrieved from the websites of these universities.

The Integrative STEM Education K-12 (California University of Pennsylvania Program) program has focused on training teachers to acquire skills which were teacher leadership skills. These skills are provided to teachers to be acquired in planning, designing, implementing hands-on activities, organizing project-based learning, student-centred learning to become technologically proficient, innovator, and collaborator. Some key benchmarks are interdisciplinary practice, inquiry-based learning, project-based learning, and leadership in educational activities with transforming curriculum, instruction, and assessment. Master of Education in STEM (William Woods University) provides education for researchers, innovators, and leaders teaching these four disciplines. The curriculum integrates technology and project-based learning with real-world problems. It was stated that "students will be able to engage and analyze data, use mathematics and models, and develop solutions." This program leads research, engineering design, integration of computer technology, project-based learning, data analysis, and mathematics. Master of Science in STEM Education (University of Iowa) program combines science and math education that serves research and leadership seminars and experiential learning. Benchmarks were determined as research and leadership, experiential learning, science, and math education combination. Master of Education in STEAM (Science, Technology, Engineering, Arts & Mathematics), (University of San Diego), empowers STEAM integration within a cross-disciplinary approach to employ a project-based learning approach in solving everyday problems. This program provides project-based learning, digital technology-used learning, data analysis, research, leadership, technological innovation. Master of Education in Secondary Education with STEM Education program (Southern New Hampshire University) prepares a teacher to become a secondary school classroom teacher while instilling a transdisciplinary mindset. This program states that it "will help teachers have cross-subject knowledge, authentic assessments, and competency-driven skills for middle and high school level students." Leadership experienced clinical learning, inquiry-based learning, technology-used learning might be accepted as benchmarks.

For findings of the first question, the five programs in indicated universities were investigated to determine the benchmarks covering framework, model, principles, and methodology of STEM education. According to Table 1, the various key benchmarks were determined. They were formulated for the preparation process of STEM- LPP on iSTEM and categorized six directions in order to indicate the main benchmarks (see **Table 1** and **Table 2**). These benchmarks were categorized as leadership, multidiscipline integration, practice/experience-based instruction, research-oriented instruction, engineering design-project-based, and technology integration (**Table 2**).

Table 1. The benchmarking of University STEM teacher preparation programs

Program name	Program aim & objectives	Key benchmarks	Courses
(CUP) California University of Pennsylvania Program: Master of Education-Integrative STEM Education K-12	To learn innovative, relevant, and engaging practices for incorporating STEM principles across disciplines in grades K-12.	Interdisciplinary practice, inquiry-based learning, project-based learning, and leadership in educational activities: transforming curriculum, instruction, and assessment.	Teachers as Leader, Methods of Research, Mathematics as Problem Solving, Foundations of Integrative STEM Education K-12, Integrating Technology in Elementary/Middle School STEM Curriculum, Integrative STEM Pedagogy and Instructional Design, Integrative Project in STEM Education, Building Scientific Literacy and Understanding Through Inquiry
(WWU) William Woods University Master of Education in STEM	The aim is to teach STEM concepts, to remove barriers that separate these four disciplines, integrating them into real-world, rigorous, and relevant learning experiences.	Research, engineering design, integration Computer technology, Project-based learning, STEM education leadership	STEM: Science, Technology, Engineering and Math–An Introduction Research Design Integrating Technology into the Curriculum, STEM: Engineering Design Software Applications for Academic Programs, STEM: Technology and Coding, STEM: Citizen Science-Project Based Learning Appraisal of Student Learning Action Research Capstone
(UI) University of Iowa Master of Science in STEM Education	The aim is to prepare educators to equip the next generation to solve challenging problems, gather and evaluate data, and apply critical thinking skills to make sound decisions.	Research and leadership, experiential learning, science, and math combining education	STEM Research and Leadership Seminar, STEM Experiential Learning, STEM Through Mathematical Modeling Science or Math Graduate-Level Courses, STEM Independent Research, STEM Extracurricular Experience and Capstone Coursework

Table 1 (Continued).

Program name	Program aim & objectives	Key benchmarks	Courses
(USD) University of San Diego Master of Education in Science, Technology, Engineering, Arts & Mathematics	to help your students critically analyze information and to compose, create and collaborate using the latest digital technology	STEAM project-based learning, digital technology-used learning, Analytics, research, leadership, technology innovation	Social Justice and Educational Equity Cognition and Learning Educational Research Methodology Qualitative Methods in Educational Research Capstone Seminar Inclusive Learning: Special Education and Universal Design Literacy and Digital Learning Curriculum and Instruction School Leadership Technology and Innovation
(SNHU) Southern New Hampshire University, Master of Education in Secondary Education with STEM Education Program	The aim is to teach in the growing number of schools that have adopted a competency-based approach to teaching and learning.	Leadership, experienced clinical learning, inquiry-based learning, technology-used learning.	Theoretical Foundations Classroom and Behavior Management Initial STEM Clinical Students with Exceptionalities Secondary Instructional Methods I-II Professional Clinical Experience I-II Assessment for and of Learning Learning through Technology Advanced STEM Clinical Educational Leadership and Change

Table 2. The categorized benchmarks and frequency

Category name	Description	Universities					Frequency
		CUP	WWU	UI	USD	SNHU	(*f*)
Leadership	Leadership in educational activities, inquiry-based learning, digital technology-used learning	+	+	+	+	+	5
Practice/experience-based	Interdisciplinary practise, experiential learning, clinical experienced learning, science, and engineering practices	+		+		+	3
Engineering/project design-based	Engineering integration and design projects, project-based teaching (STEM & STEAM)	+	+		+		3
Research-oriented	Research-oriented instruction		+	+	+		3
Multiple discipline integration	Multiple discipline integration, science and math education combination, data analysis and mathematics			+			1
Technology integration	Technology integration and computer use, technological innovation		+		+		2

Findings of Survey for the Second Research Question

The second question, "To what degree is the sufficiency of prepared iSTEM-LPP in terms of the following benchmark?" gave information about the sufficiency of categorized benchmarks that followed as educational leadership, multidiscipline integration, research-oriented instruction, practice/experience-based teaching, engineering/project design-based teaching, and technology integration. Before the survey, the information of iSTEM-LPP was introduced to 14 STEM teachers by exploring the program aim, objectives, competencies, and target outcomes. At that time, the indicated teaching courses with contents and course purposes were also presented to STEM teachers. To this, together, the preparation stages of the iSTEM-LPP were mentioned to give information about the program. Two main questions were answered by the Likert type, five-point scale with the following scale type: 1–most insufficient; 2–insufficient; 3–uncertain; 4–sufficient; 5–most sufficient.

The results with frequencies and percentages are shown in Table 2 and Table 3.

According to Table 3, for question 1 that asked the sufficiency of benchmarks STEM leader preparation program, the highest-rated sufficient benchmark at 64% of total sufficient and most sufficient choice was "Engineering integration and design projects". The lowest rated sufficient benchmark at 43% of total sufficient and most sufficient choice was "Multiple discipline integration". The middle level rated benchmarks at 57% of total sufficient, and the most a sufficient choice was "educational leadership, practice/experience-based teaching, research-oriented instruction, and technology integration".

Table 3. STEM teachers' opinions about the sufficiency of iSTEM-program benchmarks

Benchmarks	Survey responses						
	1	**2**	**3**	**4**	**5**	***f***	**%**
Leadership in educational activities, including instruction of problem/project-based, inquiry-based, digital technology-used	0	2	4	6	2	8	57
Interdisciplinary practice, experiential learning, clinical experienced learning, science, and engineering practices	0	2	4	6	2	8	57
Engineering integration and design projects	0	2	3	6	3	9	64
Research work, thesis/project work	0	1	5	5	3	8	57
Multiple discipline integration within science and math combination, data analysis and mathematics	0	3	5	3	3	6	43
Technology integration and computer use, technological innovation	0	1	5	4	4	8	57

Notes: The sufficiency rate for benchmarks was calculated by the percentage of the total sum of sufficient and most sufficient choice number (*f*). Responses: 1-most insufficient; 2-insufficient; 3-uncertain; 4-sufficient; 5-most sufficient.

Findings of Academic Committee Meetings' Evaluations and STEM Teachers' Survey for the Third Research Question

The Academic Committee Meeting (ACM) was recommended on formative components of the academic program for adding, expanding, or deleting benchmarks and determining courses within competencies/learning outcomes. The ACM included 15 community members who were two program experts, two university program developers, three staff professors from the science and math education department, two STEM master students, three STEM teachers, and three stakeholders. The participants' years of experience in the field of education ranged from 2 to 51 years, with a mean of 43.58 years. Committee members pointed out university strategy and academic policy during the preparation of STEM-LPP with aim, objectives, competencies, outcomes, and principles. In the light of the mentioned information, the iSTEM frameworks, models, and principles were particularly discussed. The participants recommended and discussed some stated benchmarks in determining target courses within competencies and learning outcomes. Committee members noticed that courses should be contributed to pre-service STEM teachers to be iSTEM leaders in terms of the stated benchmarks and recommendations. They are also assigned to the courses with prerequisites or corequisites and their lecture, practice, and laboratory hours that treat core knowledge and the knowledge of the iSTEM disciplines. The student performance assessment criteria were specified in the all-course outline by the faculty members during the meeting. ACM indicated that the program should be included practical works, hands-on activities and minds-on projects that support the skills of school teachers to be a good STEM leader. This program should be based upon practices, activities, and projects that assist teachers in becoming qualified iSTEM teachers in their schools. STEM-LPP should also be offered in the fields of engineering and computer science education. In the results of ACM study, some principles and objectives were accepted. In the frameworks of the recommendations, ACM studies and the six categorized benchmarks about STEM integration education, the competencies, courses, outcomes, and matrix of formation of the program was determined and presented in **Table 4**.

Table 4. Matrix of formation of teaching courses, outcomes on competency models

Recommended courses	Competence	Outcomes	Propositional learning outcomes
Nature of Science & Science History, Managerial Psychology, Higher Pedagogy, Cyber Pedagogy, STEM Teaching Methods, STEM Education Technology	Professional skills	1, 2, 5, 6, 7, 8	1-Demonstrates in-depth knowledge of professional disciplines of STEM 2-Uses modern information and digital technologies to solve specific and applied problems 3- Critically analyzes research studies in STEM, as well as organizes and conducts independent research 4-Design projects for professional problem-solving using STEM interdisciplinary research results 5-Organizes STEM training courses and programs in a formal and online format 6-Develops fundamental scientific and practical innovations aimed at the systematic solution of problems of inter and transdisciplinary education 7-Communicates effectively in professional and social environments to solve problems and make decisions 8-Carries out reflection and self-assessment of the research and project activity defines directions of further professional development
Robotics, Electronic Technologies, 3-D Design and Modelling, Cyber Pedagogy, IT Technology in STEM Education	Digital skills	2, 4, 5, 6	
STEM research, Pedagogical Diagnostics, Research Methods & Data Analysis, Statistical Mathematics, Big Data, Graduation Thesis	Research skills	1, 2, 3, 4, 6, 7, 8	
Commercialization, Patenting	Entrepreneurial skills	3, 8	
Managerial Psychology, Industrial Design	Managerial skills	1, 2, 4, 6, 7	
Industrial Design, 3-D Design and Modelling, Science Projects, Analysis of Eco- Projects, Data Analysis, Statistical Mathematics, Big Data	Personal skills: Creativity, analytical thinking, decision making, designing	1, 2, 3, 4, 5, 6, 7, 8	

The third question "Is it appropriate for the following courses to perform the indicated benchmarks to get knowledge among STEM disciplines integration." The question-3 asked the STEM teachers (n=14) to indicate the appropriateness between presented courses and iSTEM-program benchmarks.

According to **Table 5**, the highest-rated sufficiency at 64% of total sufficient was "research-oriented courses". The lowest rated sufficiency at 43% of total sufficient and most sufficient choice was "Multiple discipline integration". The other of the rated sufficient courses at 57% of total sufficient choice was "educational leadership and engineering/project design courses, and the middle-order rated sufficient courses at 50% of total sufficient choices were practice/experience-based teaching and technology integration courses". The results with frequencies and percentages are shown in **Table 5**.

Table 5. STEM teachers' opinions about the sufficiency between courses and benchmarks

Coursework variables related to benchmarks	Courses	Survey responses (n=14)						
		1	2	3	4	5	*f*	%
Fundamental and educational leadership courses	Nature of Science & Science History, Managerial Psychology, Higher Pedagogy, Cyber Pedagogy, STEM Methods, STEM Education	0	1	5	4	4	8	57
Interdisciplinary practice-based teaching courses	ISTEM Lab Works, Science Projects, Analysis of Eco-Projects, Internship	0	2	5	5	2	7	50
Engineering/project design courses	Industrial Design, 3-D Design and Modelling, Science Projects, Eco- Projects, Patenting Commercialization,	0	2	4	6	2	8	57
Research-oriented courses	STEM Research, Pedagogical Diagnostic, Research Methods & Data Analysis, Statistical Mathematics, Big Data, Graduation Thesis	0	1	4	7	2	9	64
Multi disciplines integration courses	Robotics, Electronic Technologies, 3-D Design and Modelling, Cyber Pedagogy, IT Technology	0	2	6	4	2	6	43
Technology integration courses	Robotics, Electronic Technologies, 3-D Design & Modelling	0	2	5	5	2	7	50

Notes: Teachers responded with more than one choice. The rate of sufficiency *frequency (f)* was calculated by the percentage of the total sum of sufficient and most sufficient one. Responses: 1-most insufficient; 2-insufficient; 3-uncertain; 4-sufficient; 5-most sufficient.

All findings and results were also confirmed by analysis of correlation results. Correlation values were checked to understand the adequacy relationship of the benchmarks. Correlation values were analyzed among FUP (Frequency from University STEM programs), PRSB (Percentage of responses of the sufficiency benchmarks), and PRSC (Percentage of responses of the sufficiency of courses). Correlations between FUP and PRSB, FUP and PRSC, PRSB and PRSC are equal to 0.59, 0.65, and 0.68, respectively (see **Table 6**).

Table 6. Evaluation values and correlations among FUB, PRSB, and PRSC values

Benchmarks	FUP	Evaluation values by STEM teachers		Correlation values among variables
		PRSB	PRSC	
Leadership in educational activities	5	57	57	*Correlation between
Practice/experience-based teaching	3	57	50	FUP and PRSB-0.59
Engineering-design and project-based teaching	3	64	57	*Correlation between
Research-oriented teaching	3	57	64	FUP and PRSC-0.65
Multidisciplinary integration	1	43	43	*Correlation between
Technology integration	2	57	50	PRSB and PRSC

Notes: FUP: Frequency from university STEM programs; PRSB: Percentage of responses from the sufficiency benchmarks; PRSC: Percentage of responses from the sufficiency of courses.

Accordingly, values between 0.49 and 1.0 indicate a strong relationship between the benchmarks made as a result of the comparisons with the programs in different universities and the evaluation values from STEM teachers.

DISCUSSION

In the light of findings of benchmarking, literature reviews, academic meetings, and surveying data, this study presented the determination benchmarks by the formation of a new program (STEM-LPP) for teachers. The benchmarks are as follows: leadership, engineering/project design, technology integration, practice/experience-based, research-oriented, and multiple discipline integration. According to the findings of the benchmarking frequency (see **Table 1**) from five university programs, the benchmark with the highest frequency was "leadership", and the benchmark with the lowest frequency was "multidiscipline integration". According to surveying STEM teachers (see **Table 3**), the highest-rated sufficient benchmark at 64% of total sufficient was "Engineering integration and design projects". The lowest rated sufficient benchmark at 43% of total sufficient was again "Multiple discipline integration". According to the STEM teachers' evaluations about courses, the highest-rated sufficiency at 64% of total sufficient was "research-oriented courses". When we look at the sufficiency rate of courses of the engineering/project design and educational leadership, they are in the second rate but close to the first. The lowest rated sufficiency at 43% of total sufficient courses was about "Multiple discipline integration".

Despite the sequencing difference, the most prominent benchmarks were engineering design, leadership, and research. Technology integration and practice-based teaching were at an intermediate level. Multidisciplinary integration is seen at the lowest level. The program certainly seemed inadequate in terms of multidiscipline integration. Accordingly, STEM-LPP benchmarks and courses together had been discussed.

Leadership

Leader preparation is a central purpose of developing STEM educators (Wells, 2013). As "the inspiring component of the model" by Sublette (2013), STEM teacher leaders should inspire through coaching and/or mentoring other teachers, leaders, and students with skills of collaboration, communication, and assistance in establishing a relationship. The inquiry component of the Sublette (2013) model recommended that STEM teacher leaders should maintain ongoing learning and development as resource providers to other teachers by maintaining an ongoing teacher leader network professional learning community. STEM leaders also should be the actors to establish the relationship between industry leaders and the school and classroom. This allows the teacher leaders to stay connected as well as critique and develop through one another and further develop the practice of the STEM teacher leader. In this respect, the courses of "STEM education", "STEM teaching methods", "managerial psychology", and "Internship" help to promote leadership for STEM teachers in STEM-LPP. These courses are more beneficial for making connections, collaboration, and communication with partners, industrial places, and other related communities in order to train teachers (Francis et al., 2018). "STEM Education" course also emphasized an integrative approach for pre-service teachers in order to improve STEM education. Honey et al. (2014) supported the idea that STEM education programs frequently aim to build teachers' subject-matter and pedagogical content knowledge relevant to individual STEM subjects and to make connections between and among them. Besides, STEM educational knowledge provides connections among STEM disciplines in preparation for teachers as project leaders in schools (Dagan et al., 2019).

Engineering/Project-Design

An industrial design or engineering design course was placed on STEM-LPP to enable teachers in developing solutions to problems, items or products of projects that will be beneficial for teachers' design skills, hands-on ability, creativity, and engineering knowledge. The engineering design course will involve defining problems, modelling, planning, analyzing, interpreting, designing, and managing information. Engineering design was provided that the learners would experience planning, doing projects, solving problems, communicating ideas, constructing models, and designing and creating in engineering (Pawilen and Yuzon, 2019). Aydin-Gunbatar et al. (2018), in their study the results revealed that the design-based STEM courses helped pre-service teachers deepen their content knowledge. Lin et al. (2021) also believe that incorporating the engineering design process into the training of pre-service technology teachers is beneficial for developing pre-service technology teachers' schema of design thinking. Morgan et al. (2013) concluded that the design process provides a structure for approaching complex problems while encouraging creativity in achieving project goals. As the way of science and engineering integration, engineering-based projects that could solve industrial problems were considered as the essential issue for iSTEM teaching. Because engineering-based or science technology-based projects will provide STEM teachers to gain engineering-based content knowledge, Hudson et al. (2014) stated the importance of this that the teaching of engineering contents could not yet be sufficiently included in STEM curricula although it provides meaningful learning, makes connections with other scientific fields easier and understood scientifically. Strimel and Grubbs (2016) also indicated this for the technology and engineering education profession and suggested that teachers must be properly prepared to teach engineering content. Therefore, STEM-LPP included the courses of "Engineering design", "STEM science projects", "Ecological projects analysis" that support teachers to establish the science and engineering content integration. The crucial educational way of engineering knowledge is to do engineering and science projects because of the strong relevancy of the actual collaboration within the STEM fields. STEM is particularly suited for project/problem-based learning (PBL) because of the natural overlap between the fields of science, technology, engineering, and mathematics (Capraro and Jones, 2013). Solving problems of society and environment within the boundaries of STEM fields is also possible with STEM projects focused on real-world issues (Capraro and Jones, 2013). Morgan et al. (2013) also notified that engineering PBL inherently addresses the connections of knowledge and skills in one topic area to another area and in real-life applications to the knowledge learned.

Research-Oriented

The research-oriented courses were central for developing STEM educators and scholars (Wells, 2013). The STEM-LPP courses: STEM research, statistical mathematics, research methods, data analysis, big data, pedagogical diagnostic, internship, and graduation thesis assist in acquiring research skills, analytical thinking, scientific literacy, and data analysis skills. The course of "STEM research" provides to teachers STEM literacy, novel research background and give information about future studies of the iSTEM disciplines and STEM career. Milner-Bolotin (2018) recommended that teacher candidates should have an opportunity to experience the value of education research for their teaching practice and engage in designing and implementing research-based pedagogies. The courses also promote the integrative knowledge of teachers to become STEM leaders. One of these was the "Pedagogical Diagnostic" course that provides to evaluate the achievements of STEM activities projects on the teaching-learning process and gives feedback to STEM teachers.

Technology Integration

Berson et al. (2000) noted that appropriate training focuses on integrating various types of technology to make lessons better, rather than learning technology simply to get technological skills. Milner-Bolotin (2018) exampled this idea that the courses of technological pedagogical STEM teaching methods such as video records focused on specific STEM concepts, pedagogy, and educational technology, promote the growth of teacher candidates' knowledge for STEM teaching. The technology courses: Electronic technologies, Robotics, 3-D Design and Modelling, Cyber pedagogy and doing some STEM projects help teachers how to integrate technology tools: basic mechanical, electrical tools, sensors, computer programming, educational robotics, and daily-life objects. Francis et al. (2018) focused the developmental challenges of the course of "STEM Education" on their study, and the course assignments include design, robotics and coding, and STEM integration. Robotics helps to develop STEM technology knowledge and practical skills that were noted by Honey et al. (2014) as one of the learning competencies providing combination practices from two or more STEM disciplines to solve a problem or complete a project. Robotics also help to increase scientific, mathematical, and technological competencies (Leonard et al., *2016*). Papadakis et al. (2021) defined educational robotics (ER) as knowledge-based approaches within activities using simple and standard electronic components in their study. They informed the benefits of ER that it could help teachers expand their interest in STEM concepts and contribute more to a student's emotional and intellectual engagement than other commonly used educational tools. Learning with robots can integrate all the STEM elements, as well as teach problem solving and teamwork.

Practice/Experience-Based

STEM-LPP includes lab works, design-based and eco-projects, research activities, and internships that serve practice-based and experienced learning to be STEM practice-leader. Anderson et al. (2019) concluded that students were particularly engaged by the "hands-on" activities in the STEM projects by students' responses. These practical activities also promote teacher experience by generating integrated projects to solve real-life problems. Bailey (2020) noted that effective practices for STEM teachers include creativity, collaboration, inquiry through real-world problems, and reflection. The pedagogical internship also supplied pedagogical experience that contributed to STEM pedagogy and teaching in schools.

Multiple Discipline Integration

The combination of STEM disciplines provides opportunities for understanding four STEM disciplines, collaborative-integrative knowledge production, problem-solving, and decision making. Kelley et al. (2021) indicated that the STEM Content and Practices Integration model is a trans-disciplinary model that focuses on science and engineering practices in schools. They implemented the collaborative model to implement iSTEM lessons using engineering design and science inquiry practices, biomimicry, and 3D printing to enhance learning STEM content. As an appearance to the above courses, the multidiscipline connection within practices and projects have a positive impact. Honey et al. (2014) argued the teaching STEM in a more connected manner and then notified that the connection can be made the disciplinary practices within the individual STEM disciplines. Accordingly, it is possible to connect disciplines with experienced teachers who have content matter knowledge and pedagogical skills. The specific integrated course is difficult and problematic in a single program because of limited course credit and teacher. Thus, there should be integrated content instead of specific courses by cooperative studies of content teachers with practical activities, projects, and lab works on the curriculum. Nadelson and Seifert (2017) promote a greater mixture of the segregated foundational knowledge STEM with integrated project-based STEM to effectively apply the STEM knowledge and practices. Eckman et al. (2016) indicate that the STEM pre-service teachers in the cooperative teaching model were more confident about their teaching skills, more comfortable with their content knowledge, and prepared to work effectively with high-needs students. In LPP, it was seen that it was also sufficient to conduct practice, problem-led, and various project learning activities supplied courses such as STEM education, STEM methods, projects, electronic technologies, and robotics.

CONCLUSION

This study concludes the experiences, frameworks, principles, models, and approaches named all as benchmarks for the STEM teacher preparation program for pre-and in-service teachers to be iSTEM leaders in the school. The preparation of a new STEM leader program presented as the way of determination of benchmarks while designing? a teacher preparation program. The forming process of LPP was conducted by analyzing benchmarks from top university master programs and STEM teachers' evaluations and correlating these benchmarks and courses. The correlations (greater than 0.49) among benchmarks and between benchmarks and courses were shown as a strong relationship and their sufficiency of benchmarks for the criteria of LPP. The correlations among benchmarks and courses have shown there is a strong relationship and the sufficiency of benchmarks for the LPP. After the graduate of LPP, for teachers or leaders, it was guided to implement STEM integration activities, the various integrated projects, and STEM courses in their schools. Participant teachers to STEM-LPP will help to accept iSTEM knowledge and literacy. In this program, pre-service and in-service teachers perform to design knowledge for STEM instructional activities, courses, works, and projects in schools. Weinberg et al. (2021) noted that transformations to STEM educators could be traced by the following activities: problem-solving, individually preparing to teach and developing courses, and collaborating on STEM education with writing projects proposals. In future, such studies will be replicated to determine benchmarks in detail and evaluate benchmarks for the existing programs in the various implementation of STEM teacher preparation.

Implementations

This type of teacher preparation program is provided to inform program designers and developers about program formation steps and program formation practices. In most schools, the crucial issue is how to integrate four disciplines. The prepared program study illustrates how to prepare a program to contain effective communication, collaboration, and novel teaching approach such as research-oriented, practice-based, project-based instruction. It also provided general information to school teachers, administrators, and faculty members for program improvement and development.

This study contributes to studies of the design of teacher preparation programs in universities and the existing research on STEM leader or teacher development programs. Roberts (2013) noted that efforts to create models of teacher preparation for integrated instruction might serve as key examples for developing STEM teacher preparation programs. The program designer has identified the iSTEM leader preparation model as an effective model that assists the existing teachers to become a leader in the integration of disciplines, subjects, and topics. This leader preparation model can present ideas about the preparation methods of teacher programs, the role of leaders, and the process of developing STEM teacher leaders. STEM-LPP has contributed for pre-service and in-service school teachers in STEM disciplines to learn new STEM projects, technology/engineering design practices, STEM teaching methods and techniques, and some integrative courses such as robotics electronic technologies.

Limitations

The main limitation of this study was regarding sample size of the STEM teachers (n=14). This may be re-evaluated with a large sample size of STEM teachers, and not only teachers but school administrators, university academic members, researchers, and stakeholders should assess the whole program in terms of benchmarks, courses, and other teaching activities. Besides, The STEM-LPP was re-evaluated in terms of school needs and STEM capacities of existing teachers. It appeared that the benchmark "multidisciplinary integration" was slightly questioned by STEM teachers. It was mostly considered as curriculum integration during the instruction of each discipline with strong collaboration for each grade in school. However, it can be diversified into integration methods such as design projects, research studies, problem-based assignments. In future research studies, the alternative methods to provide integration disciplines should be investigated. Generally, all benchmarks, especially multidiscipline integration that seemed less rated, should be needed to raise to a sufficient level re-analysis and re-evaluating with a large sample size of STEM teachers, other members of STEM education such as stakeholders, graduates, administers, researchers, academicians, and graduate students in future studies

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