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TECHNICAL REPORT

MARIE PAZ E. MORALES, PH.D.
Principal Investigator

Philippine Normal University

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EXECUTIVE SUMMARY

Aimed at creating the Philippine Workforce 4.0, ideally skilled to flourish in the Fourth Revolution era (FIRe), we gear our efforts to revolutionize the country's STEAM (Science, Technology, Engineering, Agri/Fisheries, Mathematics) Education. The country's firm stand on improving the human capital, and its science, technology and innovation (Philippine Development Plan [PDP], 2017) is our way towards concretizing Education 4.0, to help bridge us to the FIRe phenomenon (featuring technological revolution to converge and fuse human and the cyber world [Van Duuren 2017] through analytics, artificial intelligence, cognitive technologies and the internet of things [IoT] Renjen 2018]to design interconnected digital enterprises capable of more informed decision making tasks [Mars et al., 2014]). We also confirm that a strong STEAM (professionals, and education) will contribute to the knowledge society and economy of the country (Government Office of the Slovak Republic 2018; Morales, 2017), as well as improve its economic competence and competitiveness (English, 2016).

The Philippine context STEAM (where "A" refers to Agri/fisheries) in higher and advanced learning focuses on several aspects of teaching and learning, and on the merging of the disciplines to teach a particular STEAM content (Morales et al., 2019), thus, we explore the possibility of generating the Philippine STEAM Education model as our blueprint for STEAM higher and advanced learning and our way towards realizing the country's development plan themed as *AmbisyonNatin 2040* (PDP, 2017). We theorize that weaving all concepts and principles drawn from the nation's policies, standards, and guidelines defined by its Commission on Higher Education (CHED) for the individual STEAM programs, tempered by the principles of the Philippine Professional Standards for Teachers, and looking at these extracted principles, ideas and concepts from the lens of TPACK may help define a contextualized model for the Philippines, which the current study, "*TPACK in Philippine STEAM Education,"* shares.

The current study's key findings include:

1. A self-rating tool with a built-in scoring program to determine the Philippine Higher STEAM educator proficiency in enacting the STEAM disciplines.

2. Philippine Higher STEAM educators' perceived proficiency ranges from 'Highly Proficient to Distinguished leaning on the ``Distinguished' self-perception as STEAM educators.

3. Notably, male and female educators do not register significant differences on how they perceive themselves except in one or two (i.e., learning environment, diversity of learners, pedagogy) domains and dimensions, which by nature favor the female gender.

4. School type (private and government-owned) do not index significant difference either, except on Community Linkages and TPACK as a whole.

5. The Philippine STEAM Education models visually present three major constructs: variables (characteristic that expresses the feature or parameter of the practices of STEAM educators in terms of the three domains of teaching and learning: Pedagogy, Assessment, and Technology Integration); dimensions (route of the actions covering the distinctive feature of the whole, as an integrated piece that seizes a single aspect of STEAM), and indicators (as set of features or characteristics that allow or establish the description and evaluation of certain dimensions of a variable).

6. The generated STEAM pedagogical model of the current Philippine Higher Education Institutions (HEIs) demonstrates an interdependence between Institutional Pedagogical Culture (which drives its STEAM pedagogical processes [*planning, facilitating, and monitoring learning, mentoring mechanism for learners]*, and shapes the pedagogical character [*teacher's epistemological beliefs and teaching practices*], and STEAM Pedagogical Processes to deliver the fourth variable known as outcomes (competent STEAM professional, critical thinker, productive citizen).

7. Significant inputs from STEAM experts crafted the emerging Philippine STEAM (PSEPM) Pedagogical Model emphasizing the inclusion of new indicators of the expected outcomes of STEAM Education (21st century-skilled STEAM professionals, productive citizens, and competent and innovative STEAM professionals).

8. The engendered Assessment Model of the current Philippine STEAM education features four variables (Enablers [*with two dimensions: institutional affordances and sustainability*], Drivers [*with three dimensions: equity and diversity, collaboration and modality*], Processes [*with five dimensions: planning and preparation, implementation, rating, reporting and reflection*], and Outcomes [w*ith three dimensions: innovative STEAM professional/learner, critical thinker, and productive citizen*]).

9. The crafted emerging Philippine STEAM Education Assessment Model (PSEAM) covers "*innovation*" as part of the dimensions of the Drivers, and a shift from critical thinker to "*21st century-skilled STEAM learner."*

10. The generated Technology Integration Model builds on three variables: Teacher Technological Knowledge *[with two dimensions: lesson structure and content-driven],* Institutional support [*with two dimensions: capacity building and quality of technology, architecture, system and design*], and Outcomes [*with three dimensions: innovative, productive citizen, critical thinker*], and heavily supported by the Triple E framework: Engagement, Enhancement, Extension.

11. The emerging Technology Integration Model (TIM) embraces "context-based" as part of the Teacher Technological Knowledge, restructures the Institutional support to include research in technology development, and shift from critical thinker to "*21st century-skilled STEAM learner".*

12. The Philippine STEAM Education Model (PSEM) generated from the model analysis and synthesis exudes four variables: outcomes [*represented as innovative STEAM learner or professional, critical thinker, productive citizen*], drivers [with three dimensions: *teacher technological knowledge, teacher pedagogical character, and providing modality*], institutional support *[with five dimensions: capacity building, provision for appropriate architecture, administrative support, provision for collaboration and ensuring equity and diversity],* and processes *[with three dimensions: planning and preparation, implementation, monitoring, mentoring]* exemplifying innovative, appropriate, and contextualized **pedagogy, assessment,** and **technology integration** in educating the Filipino learners.

13. The emerging PSEM includes "platform for innovation" in its institutional support, and "core values" in its drivers, and shift from critical thinker to "*21st century-skilled STEAM learner".*

14. The developed Lesson Exemplars concretize how Philippine STEAM Educators may yet help realize the PSEM and achieve the goals for STEAM education.

These aforecited key findings were detailed in sections or chapters of this document. In its entirety, the book format research report extends to six chapters described as follows:

Chapter 1: Philippine STEAM Proficiency
This chapter expounds on the Philippine Higher STEAM educators proficiency in enacting the STEAM disciplines. It further describes the stages in determining the national measure: developing the self-rating tool (Proficiency Indicators for Philippine Higher Education STEAM Educators [PIPSE]), developing the scoring framework, and determining the national proficiency of the Philippine Higher Education STEAM educators.

Chapter 2: The Pedagogical Model
The chapter presents the entirety of the Philippine Higher STEAM Education Pedagogical Model (descriptions, salient features, domains, variables, dimensions, indicators, continuum of practice and illustration of practice). It also informs readers/users on how the model may align to the identified frameworks (e.g., Policies, Standards and Guideline, Philippine Professional Standards for Teachers, Technological Pedagogical Content Knowledge). Furthermore, the chapter clarifies the methodology used in crafting the model and the generated, validated and emerging models.

Chapter 3: The Technology Integration Model

The chapter pictures the range of the Philippine Higher STEAM Education Technology Integration Model (descriptions, salient features, domains, variables, dimensions, indicators, and illustration of practice). It also provides information on how the model aligns to the identified frameworks (e.g., Policies, Standards and Guideline, Philippine Professional Standards for Teachers, Technological Pedagogical Content Knowledge). Furthermore, the chapter explains the methodology used in crafting the model and the generated validated and emerging models. It also presents the proficiency continuum of STEAM teachers.

Chapter 4: The Assessment Model

The chapter deals with the entire gamut of the Philippine Higher STEAM Education Assessment Model (descriptions, salient features, domains, variables, dimensions, indicators, suggested resources and illustration of practice). It also offers considerable insights into how the model may align to the identified frameworks (e.g., Policies, Standards and Guideline, Philippine Professional Standards for Teachers, Technological Pedagogical Content Knowledge). Moreover, the chapter accounts the methodology used in crafting the model and the generated, validated and emerging models.

Chapter 5: The Philippine STEAM Education Model

The chapter discusses how the team developed the Philippine Higher STEAM Education Model. In detailed descriptions of the methodology used in crafting the model and the generated validated and emerging models, it specified and distinguished all the indicators mapped in the different TPACK dimensions to generate the country's TPACK model for Philippine STEAM Education. This section also features the attributes of the Career Stages of a Philippine Higher Education STEAM Educator, as verified in the required documents for each Career Stage.

Chapter 6: STEAM Educators Professional Development

The chapter explains the team's intentions and actions in synthesizing all the phases of the STEAM education program titled, TPACK in Philippine STEAM Education, through the professional development of the STEAM teachers. Lastly, it details all the activities and participants deliverables staged in two parts: capacity building program and National forum in STEAM education.

Initially, the STEAM education program crafted through this CHED-funded research endeavor of the researchers' part, together with selected university collaborators attempt in clearing the path for the Philippine STEAM education towards realizing its goals spelt in PDP 2017-2022. Together, we envision that by using the Philippine Commission on Higher Education model, other related agencies (e.g., Department of Science and Technology), and professional organizations, may follow STEAM education or may yet succeed in providing the country with Filipino Workforce 4.0 who are able to maneuver in FIRe.

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CHAPTER 1

ABSTRACT

CHAPTER 1
Philippine STEAM Proficiency

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This chapter discusses the determination of the Philippine Higher Education STEAM Educators' proficiency level in delivering STEAM disciplines. Its national measure of proficiency includes three major stages: developing the self-rating tool (Proficiency Indicators for Philippine Higher Education STEAM Educators [PIPSE]), developing the scoring framework, and determining the national proficiency of Philippine Higher Education (PHE) STEAM educators using the aforementioned developed measures. The online survey of the sampled (Tier 1: stratified random sampling for 156 Philippine Higher Education Institutions [HEIs] distributed in 17 regions, and Tier 2: complete enumeration of STEAM educators in the sampled HEIs) 1940 STEAM educators in January to December 2018 provided enough data to predict the general proficiency level of PHE STEAM educators. Analyzed data (i.e., programmed scoring framework, descriptive statistics, percentile rank, and t-test) revealed that self-rated proficiency defines their teaching and learning competence.

In terms of the domains of the Philippine Professional Standards for Teachers (PPST) and the dimensions of the Technological Pedagogical Content Knowledge (TPACK) framework, PHE STEAM educators viewed themselves as within the range of "Highly Proficient to Distinguished", leaning on the "Distinguished" self-perception as STEAM educators. Males and females do not register significant differences on how they perceive themselves except in one or two (i.e., learning environment, diversity of learners, pedagogy) domains and dimensions, which by nature favor females. Neither, school type (private and government-owned) indexes significant difference, except on Community Linkages and TPACK as a whole. These findings may inform policy creation to improve and/or sustain these proficiency levels and help build stronger Philippine Workforce 4.0.

Keywords: Education 4.0, Industrial Revolution 4.0, proficiency indicators, STEAM Education, TPACK, Philippine Professional Standards for Teachers (PPST), workforce 4.0

1 Introduction

Driven by the demands and paradigms of the Industrial Revolutions 4.0 (IR 4.0), which requires a "global workforce transformation" (Goldsberry, 2018; Harkins, 2008), countries largely invest in developing their future manpower to transition to the new skill sets required in the job market. Industries and companies in this new era (IR4.0) would seek and expect a workforce capable of harnessing the emerging digital operations waves with the use of artificial intelligence, cognitive computing, robotics, and Industrial Internet of Things (IOT) (Alias, Hikmi, Puteh, Tapsir, 2017). Tagged as the "new collar workforce" or Workforce 4.0 (Biosvert, 2018), this buzz word aptly describes the new skill set that our Generation z (present tertiary students aged 18 to 23 years old) should develop (Fisk, 2017), along critical and creative thinking, design and selective thinking, productive and problem-solving thinking, entrepreneurial thinking, responsible thinking, social consciousness thinking, scenario thinking.

Seemingly, the expected human resource terrain foreseen to man IR 4.0 requires a shift in the current education paradigm (Education 3.0) that addresses the needs of the "technology era" (Harkins, 2008) to the envisioned education archetype (Education 4.0) to fully cater to the needs of the "innovative era" (Hussin, 2018; Sinlarat, 2016). Education 4.0 perpetuates quality, globalization, and enhancement of knowledge economy and economic growth by emphasizing development through technological innovations, research and innovation, and acceleration of human capital leaning on well-established and nourished qualities and attributes of its major outcomes (the learners). Corollarily, it has been observed that most first world countries believe in STEM education to provide them these needed skilled-(re-skilled and up-skilled) human resource to bring them economic prowess (Wise 2015; Oberoi 2016; Fiddis 2017), thus their efforts focus on re-skilling and upskilling the future workforce through highly competent and quality STEM teachers.

A countrywide campaign to accelerate human resource spelt out in the Philippine Development Plan (PDP, 2017-2022) drives all sectors of the government to strategize to progress. Specifically, the government also largely invests in assessing, re-skilling, and monitoring the STEAM (Science, Technology, Engineering, Agri/Fisheries [as defined in the Philippines], Mathematics) teaching force to attune them to the new STEAM learning landscape. Thus, the state focuses on programs and reforms that can help provide quality and distinguished STEAM (in terms of competence and proficiency in STEAM Education) teachers to train and future proof the Filipino Workforce 4.0 (the Philippine pride) (Morales, 2017).

This chapter presents the Philippine Higher Education STEAM Educators' proficiency in STEAM Education, as it gravitates wholly on developing the self-rating tool for STEAM educators grounded on three major theories and principles (Philippine Policies, Standards and Guidelines [PSGs], Philippine Professional Standards for Teachers [PPST], and Technological, Pedagogical Content Knowledge [TPACK]. This self-rating tool comes with a programmed scoring framework and a manual counterpart for interpreting proficiency self-reports. Finally,

reports on self-rating of STEAM teachers determined their proficiency in STEAM Education in terms of the domains and dimensions of the cited theories and principles.

1.1. Philippine Proficiency of STEAM Teachers

1.1.1. The Framework of Philippine Proficiency

The Philippine Higher Education STEAM educators' proficiency grounds on three major policies, standards, and theories: Philippine Policies, Standards and Guidelines [PSGs], Philippine Professional Standards for Teachers [PPST], and Technological, Pedagogical Content Knowledge [TPACK] framework.

1.1.1.a. Policies, Standards, and Guidelines (PSG's)

To ensure security of information within organization while specifying operations and control details, agencies (government-owned or privately-supervised) institute Policies, Standards, and Guidelines (Policies, Standards and Guidelines, 2009). Typically, organizations valorize four major types of documents in this aspect: 1) Policies, considered as a high-level document signed by a person of significant authority [e.g. corporate officer, president, or vice president, commissioner], which generally accepts that a particular high-level control objective is indispensable to the agency's success, requiring mandatory compliance; 2) Standards, mid-level documents ensuring uniform application and implementation of a policy, with obligatory acquiescence; and 3) Guidelines, a document to determine the course of action containing non-compulsory controls defined to support the standards. Furthermore, guidelines are meant to provide advice pertaining to how organizational objectives might be obtained in the absence of a standard, and are commonly known as strongly recommended best practices.

Currently, the call for quality has propelled the Philippine Commission on Higher Education (CHED) to adopt the Outcomes-based education (Biglete, 2018) in Philippine Higher Education (Commission on Higher Education Memorandum Order [CMO], No. 46, 2012). Consequently, CHED's call for quality demanded the revisions instituted in all PSG's of the commission to stress: 1) fusion of minimum required general education subjects, core subjects, professional or major subjects including electives, 2) work or experiential learning as part of the curriculum, and 3) ranges of the minimum required total number of credit units for undergraduate programs. In fairness, though, almost all programs of the Commission required revision of their respective PSGs which should include the following key elements: program specifications, curriculum and minimum required resources.

1.1. 1.b. Philippine Professional Standards for Teachers (PPST)

While PSGs define quality in all the Commissions' program, the Philippine Qualifications Framework (PQF, 2012) (a competency-based and labor-market driven national policy) assures quality of development, recognition and award of qualifications based on standards of knowledge, skills and values acquired in different ways and methods by learners and workers of the country. The framework influences actions and strategies (spelt in PDP 2017-2022) to achieve globalization, internationalization, industrial revolution 4.0, and the country's economic growth through technological innovations, research and innovation, and the acceleration of human capital. More pointedly, these two national policies (PDP & PQF) define the qualities of the Philippine human capital, specifically extracting elaborations of these policies in teacher quality, which the Philippine Professional Standards of Teachers defines (PPST, 2017).

PPST (2017) defines the needed competencies and skills of quality teachers to enable them to maneuver in the technological era. Specifically, PPST's aims include: "1) setting clear expectations of teachers along well-defined career stages of professional development from beginning to distinguished practice; 2) engaging teachers to actively embrace a continuing effort in attaining proficiency; and 3) applying a uniform measure to assess teacher performance, identify needs, and provide support for professional development" (PPST, 2017). Such Philippine standard covers seven (7) domains, which collectively comprise 37 strands that refer to more specific dimensions of teacher practices: Domain 1 (Content Knowledge and Pedagogy [with 7 strands]), Domain 2 (Learning Environment [with 6 strands]), Domain 3 (Diversity of Learners [with 5 strands]), Domain 4 (Curriculum and Planning [with 5 strands]), Domain 5 (Assessment and Reporting [with 5 strands]), Domain 6 (Community Linkages and Professional Engagement [with 4 strands]), and Domain 7 (Professional Growth and Professional Development [with 5 strands]).

1.1.1.c.Technological, Pedagogical, Content Knowledge (TPACK)

Tracing TPACK, the framework is highly influenced by Shulman's idea that the teacher's PCK makes quality and effective teaching (Karaman, 2012; Park & Oliver, 2007; Shulman, 1987). Societal progress, however, led the dramatic technology revolution in the 21st century, influencing Clark (2010) to hold that integrating technology in the curriculum and instruction will bring about significant student achievement leading to deep understanding of concepts. Meaningful integration of technology, as Clark (2010) avers, refers to the process of matching the most effective tool with the most appropriate pedagogy to achieve the learning goals of a particular lesson. The idea of integration matched the desired goals of Mishra and Koehler (2006) of introducing technology on Shulman's (1986) concept of pedagogical content knowledge (PCK) to address the growing prominence of digital technologies in instructional settings, describing the integration of technology into the teaching and learning system as Technological Pedagogical Content Knowledge (TPCK). As a complete bundle of principles

to drive teaching and learning, the framework was later renamed as TPACK for Total PACKage (Thompson & Mishra, 2008).

TPACK focuses on the complex interactions between teacher's knowledge of the content (CK), pedagogy (PK), and technology (TK). Apparently, Mishra and Koehler (2006) further claimed that a teacher who can navigate between these interrelations acts as an expert far different than a lone subject matter, pedagogy, or technology expert. Moreover, probable categories and profiling of STEAM educators through their TPACK competencies may provide better capacity building.

The Philippine proficiency of STEAM teachers is part and parcel of the vision to design Quality Tertiary Education aligned to the Philippine and Asian quality standards for quality assurance; and to the themes of "AMBISYONNATIN 2040:" "*Matatag, Maginhawa, at Panatag na Buhay* (Philippine Development Plan [PDP], 2017)." With the country's foreknowledge, PDP puts STEAM and STEAM workforce as among the cores to achieving the 2040 goals as concretized in three priority areas: 1) *malasakit* (enhancing social fabric); 2) *pagbabago* (reducing inequality); and 3) *patuloy na pag-unlad* (sustaining growth potential). Thus, compelling the CHED to collaborate with universities and other agencies to develop innovative strategies, which may be derived from quality STEAM education for the Filipinos. Such vision calls for assessing and strengthening the competence and proficiencies of all stakeholders in Philippine STEAM education, specifically STEAM educators to deliver the new and improved STEAM professional to man the Philippine Workforce 4.0

1.1.2. The Indicators of Proficiency

The STEAM Educators Proficiency Indicators is a self-rating tool to determine the proficiency level of Philippine Higher Education (PHE) STEAM Educators. The crafting of the instrument used design and development research. Extensive literature review was conducted to trace all the preliminary information on tertiary teachers' teaching proficiency in which all available indicators of teaching proficiency for STEM and STEAM were reviewed. Likewise, the PSGs of 46 STEAM (science -22, technology – 7, engineering – 10, agriculture – 5, and mathematics – 2) degree programs were revisited. These PSGs contain the core competencies expected of every graduate in the country. The review deduced the common competency standards across all programs. Another important document that helped in drafting the proficiency indicators is the PPST that provided vital information outlining the needed competencies and skills of quality teachers across and in all levels, as well as the general attributes of teacher quality, proficiency and career stages.

The development of the STEAM Educators proficiency indicators started by identifying all common tertiary teacher competencies based on the PSGs of all the STEAM programs. Comparison and alignment of the PSGs and teacher standards based on PPST were also performed. Scrutinizing the indicators against the PPST domains resulted in revising some items. That yielded the 90-item initial draft of the instrument (version 1). The initial draft

underwent two-tier validation. Comments and the mean scores of the committee of experts were tallied and results yielded the 86-items (version 2). The 86-item self-rating proficiency tool was pilot tested to 102 STEAM teachers to privately-owned colleges and government-supervised universities. The results of the Principal Axis Factor analysis and Principal Component Analysis yielded 60 items (version 3), while the self-rating proficiency tool deduced seven factors. The TPCK framework is highlighted in the designed and developed proficiency indicators, particularly the dynamic interrelation and interactions on teachers' knowledge of pedagogy (PK), content (CK), and technology (TK). The seven factors are identified parallel to the TPCK seven dimensions: Factor 1 (TPACK), Factor 2 (TPK), Factor 3 (TCK), Factor 4 (PCK), factor 5 (TK), Factor 6 (PK), and Factor 7 (CK). Equally, the self-rating proficiency indicator highlights the specific domains anchored on PPST. The domains are D1 – Content Knowledge and Pedagogy; Domain 2 – Learning Environment; Domain 3 – Diversity of Learners; Domain 4 – Curriculum and Planning; Domain 5 – Assessment and Reporting; Domain 6 – Community Linkages and Professional Engagement; and Domain 7 – Personal Growth and Professional Development. Domains have 4-6 assigned factors. The indicators of proficiency clustered in the seven factors match the seven TPACK dimensions as well as recognize the intentions of the domains in the PPST.

The STEAM Educators Proficiency indicators were intended to describe the proficiency level of the PHE STEAM Educator. To achieve this goal, the self-rating tool (version 3) was administered to 1940 STEAM teachers from the identified colleges and universities throughout the country. Survey results showed that STEAM teachers perceived their respective career stages as Beginner, Proficient, Highly Proficient, and Distinguished. Furthermore, the self-rating tool can also predict the perceived proficiency level of the STEAM teachers in the dimensions of PPST and TPCK implying that the self-rating proficiency indicators may be an appropriate self-assessment tool mapped within the dimensions of TPCK suited to PHE STEAM educators. Lastly, the self-rating tool may be used by the STEAM Educators for reflective practice in higher and advanced learning.

1.1.3. Scoring at a Glance

1.1.3.a. National Higher Education Institution Proficiency Profile

Using the developed survey discussed in the previous subsection, the research sought to determine the STEAM educator's proficiency in a) the seven (7) domains of the Philippine Professional Standard for Teachers (PPST), and b) the seven (7) TPACK dimensions, without any external assumption. The PPST's seven domains centered on 1) content knowledge and pedagogy, 2) learning environment, 3) diversity of learners, 4) curriculum and planning, 5) assessment and reporting, 6) community linkages and professional engagement, and 7) personal growth and professional development. In like manner the TPACK themes covered 1) pedagogical content knowledge (PCK), 2) technological pedagogical knowledge (TPK), 3) technological pedagogical content knowledge (TPCK), 4) technological content knowledge (TCK), 5) technological knowledge (TK), 6) pedagogical knowledge (PK), and 7) content

knowledge (CK). To this end, the study expressed the STEAM educator's proficiency in detail as a) beginner, b) proficient, c) highly proficient, and d) distinguished in each of the seven domains and seven dimensions. The study found out as well the proficiency in the overall domain, as it surveyed a total of $n = 1507$ respondents.

Let R_{ijk} stand for the ratio

$$R_{ijk} = \frac{\text{the total number of } i^{th} \text{ choice the } j^{th} \text{ respondent have chosen in items within the } k^{th} \text{ domain}}{\text{total number of items in the } k^{th} \text{ domain}}, \quad (1)$$

where $i = 0, 1, 2, 3, 4,\ \ j = 1, 2, \dots, n,$ and $k = 1, 2, \dots, 7$. Similarly, we define

$$T_{ijk} = \frac{\text{the total number of } i^{th} \text{ choice the } j^{th} \text{ respondent have chosen in items within the } k^{th} \text{ dimension}}{\text{total number of items in the } k^{th} \text{ dimension}}. \quad (2)$$

R_{ijk} and T_{ijk} obey the normalization property

$$\sum_{i=0}^{4} R_{ijk} = \sum_{i=0}^{4} T_{ijk} = I_{jk} = 1. \quad (3)$$

The proficiency level of the sample population corresponding to the i^{th} choice in the k^{th} domain and k^{th} dimension are measured with the following means given by

$$\overline{R}_{ik} = \frac{1}{n}\sum_{j=1}^{n} R_{ijk}, \qquad \overline{T}_{ik} = \frac{1}{n}\sum_{j=1}^{n} T_{ijk}. \quad (4)$$

Each domain contribute equally to the overall proficiency of the sample population. The domain-based overall proficiency level then is

$$\overline{G}_i = \frac{1}{7}\sum_{k=1}^{7} \overline{R}_{ik}. \quad (5)$$

The measures in eq. (4) and eq. (5) satisfy the normalization conditions

$$\sum_{i=0}^{4} \overline{R}_{ik} = \sum_{i=0}^{4} \overline{T}_{ik} = I_k = 1, \text{ and } \sum_{i=0}^{4} \overline{G}_i = 1. \quad (6)$$

1.1.3.b. Scoring Program and Validation

The derived mathematical equations (4) and (5) directed the development of the scoring programs using Microsoft excel and Fortran. Three tier validation (quantitative and qualitative) through participant responses determined the robustness and soundness of the scoring programs. For the quantitative validation, the sampling ensured nationwide coverage. Respondents replied to the survey online using google form. Once all prospective replies in google form were retrieved, these were converted into Excel file for the convenient and automatic calculation of the a) ratios in eq. (1) and (2); and b) means in eq. (4) and (5). Also, the measures in eq. (4) and (5) were calculated independently using Fortran codes that produced and saved as .f95 file with respondents' replies converted into input txt file. These compiled files helped produce the measures. Comparison and equivalence of the measures determined through the scoring programs using Microsoft Excel and Fortran identified the first tier quantitative validation of the programs.

The second tier compared the measures determined through the Fortran program using the online survey and the classroom observation rating of a particularly pre-determine career stage of a respondent. Validity is established once the program shows the presence of agreement in the proficiency level of teachers according to oneself and from an observer in the classroom. This tier chose participants in each career stage (distinguished, highly proficient, proficient, and beginner) who took the online survey, were interviewed and observed later.

The third tier accented a qualitative validation by comparing generated codes in the interview transcript and observation notes of the participant in each career stage emerging as incurring the same measure in the online survey and in the classroom rating scale (2nd tier) and the significant attributes underscored in all PPST domains and TPACK dimensions. Once the proponents established the validity or equivalence of quantitative and qualitative measures (codes), they designed the unique attributes of each career stage in all the seven domains, and the overall attribute in each career stage. Five experts in the field established the validity (descriptive validation) of the generated attributes.

1.1.3.c. Knowing One's Profile and Proficiency

Individual teachers wishing to check their level of proficiency may take the survey. Once completed, the individual teacher's results are calculated using eq. (1) and (2), by setting, corresponding to a single respondent, and then compared to the measures in eq. (4). Eq. (3) and eq. (6) to help ensure that any one of the four proficiency characteristics will stand out the most in the comparison, corresponding to the teacher's proficiency level. Print out or email generated by the program spells out the general attributes and the per domain attributes of the teacher's proficiency level.

For example, the survey data says that the national STEAM proficiency profile of higher education institution corresponding to PPST's domain on content knowledge and pedagogy, calculated using eq. (4) with $k = 1, n = 1507$, are as follows explicitly: Distinguished $(i = 4)$, $\overline{R}_{41} = 0.37$; Highly Proficient $(i = 3)$, $\overline{R}_{31} = 0.44$; Proficient $(i = 2)$, $\overline{R}_{21} = 0.14$, Beginner $(i = 1)$, $\overline{R}_{11} = 0.03$, Not Observed $(i = 0)$, $\overline{R}_{01} = 0.02$. Now, suppose a higher education institution STEAM teacher who has taken the 60-item survey have a proficiency profile in the PPST's content knowledge and pedagogy domain given explicitly by: Distinguished$(i = 4), R_{41} = 0.21$, Highly Proficient$(i = 3), R_{31} = 0.32$, Proficient$(i = 2), R_{21} = 0.26$, Beginner$(i = 1), R_{11} = 0.16$, Not Observed$(i = 0), R_{01} = 0.05$. The scoring framework says that when the teacher's proficiency profile is compared to the national proficiency profile, we determine the teacher's proficiency level. In the example, the teacher is a beginning STEAM teacher.

1.1.4. The Philippine STEAM Proficiency

1.1.1.4.a. Sample and Procedure

The research used descriptive-survey design to gather the necessary data to describe the proficiency of the Philippine Higher Education (PHE) Science, Technology, Engineering,

Agri/Fisheries, and Mathematics (STEAM) Educators. A national level survey that included a total of 123 institutions (56% of sample HEIs) representing various regions in the archipelago provided a thorough documentation, if not rich details of the PHE STEAM educators' proficiency, through a complete enumeration (N=1,940) of STEAM educators in the identified schools. Specifically, public HEIs included 46 Levels 1 and 2 State Universities and Colleges (SUCs) and 20 Local Universities and Colleges (LUCs); while 57 private institutions of higher learning were considered. The sample comprised of 936 males and 1,000 females (implausible responses were omitted). In terms of school type, 1,219 STEAM educators connected with the government owned (SUCs and LUCs) HEIs and 635 from private colleges and universities participated.

The 60-item self-rating tool (Philippine Indicators for STEAM Educators) was administered through Google form from January 30, 2018 to December 30, 2018. The consolidated results of the survey were subjected to the scoring program to determine the STEAM educator's proficiency both in the PPST and TPACK domains. Our computations indicated that on the average, there emerged 3.1% beginning, 8.1% proficient, 38.4% highly proficient, and 50.4% distinguished STEAM teachers.

For comparison purposes, each proficiency scores were converted into Standardized Scores (S) using the linear transformation formula S = (SR - LPR) x (100 / HPR); where SR, LPR, and HPR represent Sum of Ratings, Lowest Possible Rating, and Highest Possible Rating. To further simplify the process of determining the proficiency of STEAM teachers, the researchers deemed it proper to use the identified percent count of teachers in the career stages to derive the score range for each level of proficiency. Using percentile ranking, we identified $P_{3.1}$ = 57.48, $P_{11.2}$ = 69.91, and $P_{49.6}$ = 85.28, to derive the following STEAM proficiency scale: Beginner (0 <= S <= 57.78), Proficient (57.48 < S <= 69.91), Highly Proficient (69.91 < S <= 85.28), and Distinguished (85.28 < S <= 100). The summary of the results is presented in Appendix I. A.

Further analyses of the data set and draw some more information in describing the PPST and TPACK proficiency level of the PHE STEAM educators. Then they were categorized according to gender and school type, next applied t-test for independent samples to test if the significant differences in the self-professed proficiency of STEAM educators between the groups. The summary of computations and comparisons are found in Appendix I.B.

1.1.4.b. Proficiency in Terms of PPST Domains

The self-professed proficiency of PHE STEAM Educators drawn from their responses indicates that the majority (f = 978, 50.4%) of the participants perceive their overall level of proficiency in the PPST domains as "Distinguished"; while many (f = 745, 38.4%) view themselves as "Highly Proficient". On the other hand, about 157 (8.1%) teachers rated themselves as "Proficient" and 60 (3.1%) as "Beginner", in terms of PPST. Apparently, most PHE STEAM educators appraised themselves highly in terms of competence in delivering STEAM

disciplines to Filipino learners. This finding shows that they tend to have a positive self-concept that may boost their self-confidence and self-esteem (Collie, Shapka, Perry, 2012; Glotovaa & Wilhelmb, 2014) building positive attitude towards STEAM teaching and learning. In fact, more than 50% of surveyed STEAM educators manifested high concept of "Me as an effective teacher" (Glotovaa & Wilhelmb, 2014), as evidenced by the number of "Distinguished" ratings, in PPST Domain 2 (Learning Environment), Domain 3 (Diversity of Learners), Domain 4 (Curriculum and Planning), and Domain 6 (Community Linkages and Professional Engagement); with the highest registered percentages in Domains 3 (68.1%) and 6 (58.8%), emphasizing the STEAM teachers' high regard for student diversity and the community. Their positive self-concept of STEAM teaching and learning may be sourced from their dominant Filipino trait of being caring and loving (Stauss, 2011) and valuing the *pakikisama* [fellowship] or *bayanihan* [mutual cooperation] tradition (Pinoy Life: 8 Classic Filipino Traits and Characteristics, 2016). These results highlight the role of PHE institutions as the hub of learners from various academic, social, personal, and regional backgrounds, where educators may further improve the paradigms of inclusivity (UNESCO, 2017, 2019) in education, particularly STEAM.

Surprisingly, even though nearing half of the sample STEAM educators saw themselves as distinguished, more than half conveyed otherwise (rated themselves as beginner to highly proficient) in Domain 5 (Assessment and Reporting) and Domain 7 (Personal Growth and Professional Development). Accordingly, the majority appraised assessment and reporting, specifically the formative assessment (El-Kafafi, 2016) as not well explored probably due to the teacher difficulties in this domain (Bahous & Nabhani, 2015; Havilan, 2009), thus needing enhancement through professional trainings, which might probably address improving STEAM teachers self-concept of Domain 7. Lastly, unlike the other six domains, the highest percentage distribution (f = 739, 38.1%) in Domain 1 (Content Knowledge and Pedagogy) falls under the "Highly Proficient" career level, although notably, in general, STEAM teachers still score a high self-concept in this particular domain since the percentage of teachers who rated themselves "Distinguished" in this domain registered only 2% less (f = 701, 36.1%).

1.1.4.c. Proficiency in Terms of TPACK Domains

Their perception of proper blend and balance to sustain quality STEAM education manifested in their self-concept in terms of TPACK dimensions, where they regard themselves as "Distinguished" in its core and highest level, the TPCK domain, with strong consideration of the "Distinguished" appraisal in TK and PK domains too. Reworded, PHE STEAM educators believe that good teaching with technology involves a seamless integration of the three (3) fundamental components: CK, PK, and TK; and inclusive of the relationships (PCK, TPK, and TCK) between and among them (Fisher & Tondeur, 2013; Koehler & Mishra, 2006). These findings imply that STEAM educators put premium to TPCK than the other dimensions, considering that most of them only view themselves as "Highly Proficient" in the other dimensions (TPK, PCK, and TCK).

1.1.4.d. Gender Influence

In terms of PPST, data analysis shows that in general, there is no significant difference in STEAM educators' proficiency in terms of gender (p = .142). Specifically, five of the seven (71.4%) domains note no significant difference in the proficiency scores of males and females [Domain 1 (p = .562), Domain 4 (p = .567), Domain 5 (p = .863), Domain 6 (p = .199), and Domain 7 (p = .459)]. Additionally, the comparison also reveals that the mean score of females appears consistently higher than that of the males, with a deviation in Domain 1. Although a significant difference shows in the proficiency scores of male and female STEAM educators in Domain 2 (p = .033) and Domain 3 (p = .000) in favor of the female. The mark difference of self-concept of males and females in Domain 2 (Learning Environment) emphasizes the teachers' role in providing comfortable, conducive, secure, fair and supportive educational atmosphere to promote learner responsibility and achievement. It is assumed that Filipino STEAM women teachers exhibit better emotional empathy than men (in general), that cultivates better relationship with students (Goleman, 2011). For Domain 3 (Diversity of Learners), the advantage of female STEAM teachers lies on underscoring their responsibility in effectively differentiating the classroom and in ensuring that students are in a responsive, conducive environment that admits diverse characteristics (DepEd, 2017).

By contrast, observably the mean self-rated proficiency scores in the TPACK dimensions of male STEAM educators proves higher in TCK, TK, and CK; while the mean proficiency scores of female STEAM educators yields higher on the domains TPCK, TPK, PCK, and PK. Notably, there is no significant difference in the proficiency scores of male and female STEAM teachers in TPCK (p = .093), TCK (p = .160), PCK (p = .385), TK (p = .150), and CK (p = .196) domains; whereas a significant difference is found in TPK (p = .018) and PK (p = .000) domains. While PK involves the teachers' knowledge and understanding of the teaching and learning processes and methods, TPK describes the interactions between PK and technological tools (Mishra & Koehler, 20092006). The higher self-concept of Philippine female STEAM may be probably traced to their femininity and motherly nature (caring and nurturing) (Drudy, 2008; Wood 2012), as women are widely thought of to be natural caregivers (Martino & Rezai-Rashti, 2010). Previous reports indicate that women teachers are generally more expressive, supportive (Rashidi & Naderi, 2012; Islahi & Nasreen, 2013), and open towards students (Islahi & Nasreen, 2013). Besides, studies suggest that women teachers tend to share authority and manage classrooms while keeping teacher-student relationship intact (Statham, Richardson, & Cook, 1991; Islahi & Nasreen, 2013) that might also explain why female STEAM teachers demonstrate a higher-concept in Domains 2 and 3 of PPST.

1.1.4.e. School Influence

Data analyses reveal vital information in describing STEAM educators' proficiency in terms of school affiliation. The comparison shows that in terms of PPST domains, private HEIs mark higher than the government-owned HEIs. However, there is no significant difference in the STEAM educators' proficiency in terms of the type of school (p = .151) despite the perceived

score advantage of private HEIs. Reworded, their self-professed proficiencies may not be influenced by their school affiliation (whether they work in private or government-owned HEIs). Specifically, a similar trend appears in all the PPST domains, except in Domain 6 (Community linkages and Professional engagement), which reports a significant difference (p=.003). Accordingly, Community Linkages accomplish personal and social development with the community (Rubio, et al., 2016), a finding that may lean on the fact that in financial aspects, the expenditure on extension activities in State Universities and Colleges (SUCs: government-owned HEIs) reaches only about two percent from the total spending in 2012 (Manasan & Revilla, 2015). Furthermore, the average tuition (AY 2017-2018) for SUCs is P216.01 and P174.33 in Local Universities and Colleges (LUCs), while in the same academic year, the average tuition for private HEI ranges P644.14 (CHED, 2018). Assuming that the private HEIs utilize the same percentage, then, their budget will be about thrice the amount of SUCs and LUCs, which makes extension activities the least of the problem of a private HEI, as compared to the SUCs and LUCs (Rubio et al., 2016).

Similarly, only one TPACK dimension (TPCK [p = .002]) registers significant difference in terms of school type in favor of private HEIs. In fact, analysis shows that private schools pose higher means in the three (TPCK, TPK & TK) of the four domains with technology (TPCK, TPK, TCK & TK). This result may hint on institutional affordability sourced from better funds appropriations (for related technology procurement) in private HEIs, as compared to those of SUCs and LUCs (CHED, 2018; Romero, 2018; Rubio et al., 2016). Relatively, better faculty to student ratio may also influence the lean on private institutions perceiving quite well (Distinguished) in the core of TPACK dimension. Seemingly, large class size poses a negative correlation with student performance (Koc & Celik, 2015) and less quality of instruction by the teacher (Mueller, 2013). In fact, SUCs in the National Capital Region (NCR) report an average faculty to student ratio in AY 2017-18 as 1:26 compared to 1:19 in the private HEIs (CHED, 2018). In this connection, the same trend (Central Visayas [1:29 for SUCs and LUCs, as compared to 1:19 for private HEIs, and Mindanao region [1:35 for SUCs and LUCs compared to 1:21 in private HEIs] in the other parts of the archipelago (CHED, 2018).

1.1.5. Conclusion and Recommendation

The developed and validated self-rating tool (Proficiency Indicators for STEAM Educators) coupled with a developed and validated programmed scoring system equips the country with a means to determine the Philippine Higher Education STEAM Educators' proficiency in enacting STEAM education to deliver quality outputs for Workforce 4.0. In general, they (sampled STEAM Educators) perceive themselves as "Highly Proficient to Distinguished" in terms PPST and TPACK framework oozing a high level of self-confidence in STEAM education. With a positive self-esteem, they view themselves as the good and the confident "Me as a STEAM Teacher." Vital outcomes using other data representations (mean and median, other than frequency and percentages) established their high self-appraisal in terms of competence in delivering STEAM disciplines to Filipino learners. They accentuate on the convergence of TPACK dimensions, specifically featuring "TPCK" as the main and key

element in delivering STEAM disciplines. Their positive self-concept shepherds a practical, enthusiastic, productive and confident view of teaching and learning of STEAM disciplines. This current condition helps motivate more students to the STEAM pipeline and sustain a pool of STEAM professionals as a navigable path to further improvement the Human Capital Resource, from which the country relies on for its bullish economic growth and well-being. Thus, it may be inferred that good and confident self-concept as STEAM educators may both contribute and serve as the key to bringing the country in a better rank (compared to being below average in Southeast Asia and rank 73rd in the world) in terms of GII (Global Innovation Index, 2018).

Self-reports of STEAM educators confirm the non-influence of gender and school affiliation of STEAM educators to their positive self-concept, although specific domains and dimensions (e.g., diversity of learners, learning environment, and TPCK) show female-ascendancy and private school affiliation-hegemony. Although, some minute but significant differences in gender surveyed in Learning Environment and Diversity of Learners emphasize uniqueness of the Filipino women in this aspect. Culturally-influenced, the Filipina is known to be hospitable and caring aside from the fact that in general, she exhibits better empathy than her male counterpart. In our attempt to envision full gender equality in all domains and dimensions, however, in the process we do away with the uniqueness of the Philippine culture. This means that our country may attest the reports that in general, the Philippines, a matriarchal society more than patriarchal, ranks the world's 8th best in gender equality and Asia's top (Tomacruz, 2018) with our reports on high level of gender equality in the STEAM field (5 out of 7 in both PPST and TPACK).

Non-acceptance of deficiency in proficiency in certain aspects and domains of STEAM teaching and learning may be one of the possible drawbacks of a very positive outlook, though. This disadvantage deludes STEAM educators to affirm that they do not need professional development to improve themselves. We reaffirm, though, that STEAM educators' low research engagement may be a contributing factor to a number professed low proficiency in specific domains (content knowledge and pedagogy; and assessment and reporting). Thus, we recommend that such data be confirmed by providing another means of assessing Philippine Higher Education STEAM Educators' Proficiency other than self-rating. This way forward may inevitably come with a needs assessment tool to determine areas of professional development, that may call for larger appropriation of funds for professional development, research and publication capacity building, as much as research opportunities and grants to improve content knowledge and dissemination. Such means may also address gender and school affiliation ascendancy, if efforts gear to which equality in fund appropriation. Furthermore, the government with the education agencies for higher learning may tinker on programs to push for STEAM Education-University-Industry partnership and policies on regular proficiency assessment of STEAM educators as well.

APPENDICES

Appendix I. A. Frequency of STEAM educators in each career stage of the PPST and TPACK domains (n = 1940)

Domain	Beginner	Proficient	Highly Proficient	Distinguished
	f (%)	*f (%)*	*f (%)*	*f (%)*
Domain 1: Content Knowledge, and Pedagogy	146 (7.5)	354 (18.2)	739 (38.1)	701 (36.1)
Domain 2: Learning Environment	56 (2.9)	144 (14.4)	700 (36.1)	1040 (53.6)
Domain 3: Diversity of Learners	62 (3.2)	82 (4.2)	474 (24.4)	1322 (68.1)
Domain 4: Curriculum and Planning	74 (3.8)	191 (9.8)	585 (30.2)	1090 (56.2)
Domain 5: Assessment and Reporting	135 (7.0)	241 (12.4)	728 (37.5)	836 (43.1)
Domain 6: Community Linkages and Professional Engagement	97 (5.0)	120 (6.2)	582 (30.0)	1141 (58.8)
Domain 7: Personal Growth and Professional Development	122 (6.3)	120 (6.2)	780 (40.2)	918 (47.3)
Overall	**60 (3.1)**	**157 (8.1)**	**745 (38.4)**	**978 (50.4)**
TPACK Dimensions	**Beginner**	**Proficient**	**Highly Proficient**	**Distinguished**
TPCK	66 (3.4)	138 (7.1)	582 (30.0)	1154 (59.5)
TPK	56 (2.9)	124 (6.4)	720 (37.1)	1040 (3.6)
TCK	355 (18.3)	416 (21.4)	657 (33.9)	512 (26.4)
PCK	104 (5.4)	208 (10.7)	765 (39.4)	863 (44.5)
TK	184 (9.5)	214 (11.0)	501 (25.8)	1041 (53.7)
PK	33 (1.7)	112 (5.8)	570 (29.4)	1225 (63.1)
CK	83 (4.3)	240 (12.4)	724 (37.3)	893 (46.0)

Appendix I. B. t-Test Results of the Comparison of STEAM Educators Proficiency in Terms of Gender and School Type

PPST and TPCK proficiency comparison between gender using t-test for independent variables

PPST Domains		Mean (SD)		t	df	*p*
		Male (n = 936)	Female (n = 1,000)			
PPST Domains	Domain 1: Content, Knowledge, and Pedagogy	78.46 (14.56)	78.09 (14.00)	.581	1934	.562
	Domain 2: Learning Environment	84.35 (13.57)	85.61 (12.45)	-2.131*	1890.33[a]	.033
	Domain 3: Diversity of Learners	86.35 (13.32)	89.21 (11.69)	-5.008***	1862.80[a]	.000
	Domain 4: Curriculum and Planning	84.36 (13.71)	84.70 (12.32)	-.573[a]	1878.24	.567
	Domain 5: Assessment and Reporting	81.94 (16.93)	82.07 (16.42)	-.173	1934	.863
	Domain 6: Community Linkages and Professional Engagement	84.04 (14.34)	84.85 (13.53)	-1.285	1934	.199
	Domain 7: Personal Growth and Professional Development	83.41 (16.13)	83.92 (14.51)	-.740[a]	1878.76	.459
	Overall Proficiency Indicator	83.27 (12.46)	84.06 (11.20)	-1.469[a]	1878.26	.142
TPCK Dimensions	TPCK	84.87 (12.95)	85.83 (11.88)	-1.679	1890.651[a]	.093
	TPK	84.01 (13.00)	85.35 (11.74)	-2.374*	1881.275[a]	.018
	TCK	73.19 (18.12)	72.06 (17.40)	1.405	1934	.160
	PCK	81.37 (13.67)	81.90 (12.77)	-.868	1934	.385
	TK	82.45 (17.02)	81.29 (18.09)	1.440	1934	.150

	PK	86.32 (12.19)	88.46 (10.65)	-4.088***	1859.45[a]	.000
	CK	83.62 (15.64)	82.70 (15.56)	1.294	1934	.196

*Note: *=p≤.05, ***=p≤.001, [a]Equal variances not assumed.*

PPST and TPCK proficiency comparison between type of schools using t-test for independent variables

	PPST Domains	Mean (SD)		t	df	p
		Public (n = 1,219)	Private (n = 635)			
PPST Domains	Domain 1: Content, Knowledge, and Pedagogy	78.10 (14.35)	78.53 (13.98)	-.616	1852	.538
	Domain 2: Learning Environment	84.65 (13.04)	85.74 (12.82)	-1.719	1852	.086
	Domain 3: Diversity of Learners	87.55 (12.76)	88.25 (12.21)	-1.146	1852	.252
	Domain 4: Curriculum and Planning	84.38 (13.16)	84.73 (12.72)	-.552	1852	.581
	Domain 5: Assessment and Reporting	81.77 (16.34)	82.27 (17.42)	-.606	1852	.545
	Domain 6: Community Linkages and Professional Engagement	83.76 (14.44)	85.71 (12.59)	-3.008**	1446.883[a]	.003
	Domain 7: Personal Growth and Professional Development	83.29 (15.29)	84.07 (15.35)	-1.048	1852	.295
	Overall Proficiency Indicator	83.36 (11.92)	84.19 (11.61)	-1.435	1852	.151
TPCK Dimensions	TPCK	84.67 (12.70)	86.58 (11.67)	-3.165*	1852	.002
	TPK	84.29 (12.57)	85.40 (11.90)	-1.825	1852	.068
	TCK	72.62 (17.49)	72.30 (18.09)	.377	1852	.706
	PCK	81.54 (13.28)	81.68 (13.19)	-.213	1852	.831
	TK	81.29 (17.55)	82.89 (17.59)	-1.870	1852	.062
	PK	87.25 (11.72)	87.80 (10.88)	-.990	1852	.322
	CK	83.19 (15.84)	83.39 (14.73)	-.259	1852	.796

*Note: *** =p≤.01, [a]Equal variances not assumed.*

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CHAPTER 2

ABSTRACT

CHAPTER 2
The Pedagogical Model

Marie Paz E. Morales, Jovito C. Anito Jr., Caesar P. Palisoc

A model of Philippine STEAM education was developed following a three-tier qualitative data analysis of interview transcripts and observation notes. In-depth interviews with school administrators and teachers, reinforced data gathered from classroom observations in various STEAM classes conducted across 33 Higher Education Institutions (HEIs) all over the country. Findings showed that the STEAM Pedagogical Model in Philippine HEIs demonstrates an interdependence between Institutional Pedagogical Culture and STEAM Pedagogical Processes. The pedagogical culture of an HEI pertains to its framework and mechanism for planning, disseminating, and evaluating the pedagogical processes and the extent by which research and teaching nexus is advanced in all these processes. The pedagogical culture of an HEI drives its STEAM pedagogical processes, specifically the teaching practices, and shapes the pedagogical character of its teachers. A teacher's epistemological beliefs and teaching practices comprise, better yet, reflect his/her pedagogical character. STEAM teachers acknowledge the absence of perfect teaching strategy to suggest that appropriateness of teaching approach must be given attention in planning the pedagogical processes. Hence, STEAM teachers are skilled in various teaching strategies and adept in switching across strategies whenever appropriate and necessary. Equally, STEAM teachers model learning by linking practice and teaching, and demonstrating critical and reflective thinking. The Pedagogical model of Philippine STEAM Education explicates that the synergy between an institution's pedagogical culture and its pedagogical processes is gauged by the quality of its learners and teachers. Specifically, Philippine STEAM education aims at nurturing critical thinkers, productive citizens, and competent STEAM professionals.

Keywords: epistemological beliefs, illustration of practice, pedagogical model, pedagogical culture, proficiency continuum

2.1. The Model Defined

This section articulates the compelling reasons why a study on Philippine model of STEAM education is cogent and relevant to current times. It also provides a general background of the model, what the model is all about and what it is not, its salient features, what is new in the model, and its very purpose.

2.1.1. Why the Model

The multi/inter/transdisciplinary nature of Science, Technology, Engineering, Agri-Fisheries, and Mathematics (STEAM) advances understanding of the world as a whole rather than as fragments of isolated realms. STEAM Education then necessitates teachers to have a multi/inter/transdisciplinary grasp of STEAM. This entails loosening one's exclusive disciplinary identity, going out of one's comfort zone, and demonstrating holistic understanding of how Science, Technology, Engineering, Agri-Fisheries, and Mathematics shape each other. Translating the holistic view of STEAM into STEAM pedagogical processes results in products and outcomes that drive the global economy and industry. We owe most of the innovations and inventions to STEAM thinkers (e.g. practitioners, educators). In demand skills and jobs are all in STEAM - data science, software engineering, robotics, etc... This interconnection suggests that STEAM-competent teachers are in high demand.

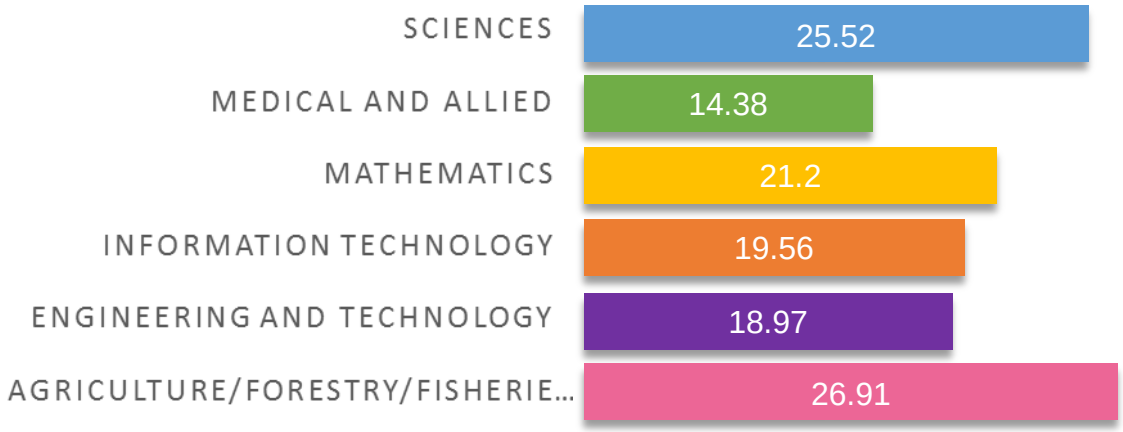

Figure 2.1. Completion rate (%) across STEAM areas calculated from a 5-year data until SY 2016-2017. Source of Data: Commission on Higher Education

However, the Philippines falls short of STEAM graduates. CHED data (Commission on Higher Education, 2019) on completion rates (Figure 2.1) across STEAM areas show that STEAM programs indexed an average completion rate of 21%. In 2016, for example, of the 645,973 university graduates, only 12% obtained a degree in engineering, mere 1% in science and dismal 0.4% in mathematics. The dearth of STEAM graduates manifests as shortage of scientists. At 189 scientists per million, the Philippines lags behind the UNESCO

recommendation of 380 per million (Jalea, 2018), a figure way lower than that of its neighboring ASEAN countries - Vietnam at 674 per million, Thailand at 974 per million, and Malaysia at 2,100 per million.

The scarcity of scientists in the Philippines is greatly felt in various productivity metrics. In agriculture, for example, the total factor productivity of the Philippines registers 1.87%, way much lower than that of Vietnam at 2.53% and Malaysia at 2.85% (Jalea, 2018). The total factor productivity or agricultural productivity is a comparative measure between agricultural resources (e.g. land, labor, materials) and total crop and livestock production. In terms of agricultural trade (export versus import), the latest UN Trade Map data, as cited in Jalea (2018) showed that the Philippines registered a deficit of $5B versus the $9.3B and $26.5B respective surplus of Malaysia and Thailand. All these point to the unfavorable conditions obtaining in STEAM education in the country, particularly on the quality of STEAM teachers. Research shows that an increase in the number of STEAM-competent teachers raises the number of students going into STEAM fields (Business-Higher Education Forum, 2010). Studies further show that STEAM proficiency of teachers affects students' STEAM proficiency (Gordon, Kane, & Staiger, 2006; Hanushek, 2002). Data from World Economic Forum, as cited in Oxford Business Group (2018), also reveal that the quality of Mathematics and Science Education in the Philippines ranks among the lowest regionally, resulting in relatively low number of STEM graduates. Responding to this deficiency, the Philippine Commission on Higher Education (CHED) identified Education for STEAM as one of its Research priority areas. Such realities necessitate a study that models the current practices of STEAM education in the country to develop or amend relevant policies and standards, as regards the country's STEAM programs.

2.1.2. The Model is…

The Pedagogical Model for Philippine STEAM Education (PMPSE) represents the current pedagogical perspectives and practices of Philippine STEAM administrators and teachers. Specifically, the analysis focused on exploring the various domains of STEAM pedagogical processes, as practiced by Philippine higher education institutions (HEIs). The PMPSE represents the antiquated view of Philippine HEIs on STEAM education.

2.1.3. The Model is NOT…

The PMPSE may not model an ideal STEAM pedagogy in the Fourth Industrial Revolution (4IR). An examination of literature on the possibilities, opportunities, and disruptions brought about by the 4IR on business and industry points to the acute need for HEIs to have a relatively radical shift in the educational contour. Also, literature review conducted attempted to extrapolate the PMPSE domains into the conditions and requirements of the 4IR.

2.1.4. What is new about the Pedagogical Model?

The PMPSE intensifies the nexus between institutional pedagogical culture and pedagogical practices. The model emphasizes how institutions shape the outcomes of learning via their pedagogical ideals and practices. It also underscores the tripartite synergy among HEIs, industry, and community.

2.1.5. Salient Features of the Model

The PMPSE represents the current pedagogical perspectives and practices of Philippine STEAM administrators and teachers. More deeply, the model:

- articulates the various epistemological and ontological perspectives drawn from the data sources (i.e. HEI administrators, STEAM Program Coordinators, STEAM Teachers), as shown in their beliefs, ideas, and practices;
- accentuates the interdependence between an institution's pedagogical culture and STEAM pedagogical processes;
- explicates the synergy between an institution's pedagogical culture and its pedagogical processes as gauged by the quality of its learners and teachers; and
- revisits the STEAM pedagogical practices of HEIs to identify gaps with the requirements of the 4IR.

2.1.6. What is the Pedagogical Model

The Pedagogical Model of Philippine STEAM Education (PMPSE) articulates the various epistemological and ontological perspectives drawn from the data sources (i.e. HEI administrators, STEAM Program Coordinators, STEAM Teachers), as manifested in their beliefs, ideas, and practices. It accentuates the interdependence between an institution's pedagogical culture and STEAM pedagogical processes. The pedagogical culture of a Higher Education Institution (HEI) refers to its framework and mechanism for planning, disseminating, and evaluating the pedagogical processes and the extent by which research and teaching nexus is advanced in all these processes. Planning the pedagogical processes specifically ensures alignment of learning objectives with activities, alignment of faculty specialization with content taught, partnership between school and industry, and emphasis of the relevance of STEAM to the community. An institutional pedagogical culture equally demands disseminating institutional pedagogical policies and curricular reforms, programs, and innovations. Evaluation of pedagogical processes entails not only periodic institutional review of curriculum but also of teachers' pedagogical processes and consequently drawing implications for ranking, promotion, and continuing professional development. Pedagogical culture further promotes mentoring among faculty members, tenders continuing professional development opportunities for teachers.

The pedagogical culture of an HEI drives its STEAM pedagogical processes, specifically the teaching practices, and shapes the pedagogical character of its teachers. As illustrated by the **yin-yang** construct, the institutional pedagogical processes and teachers' pedagogical character exemplify the institution's pedagogical culture. This stance suggests that pedagogical processes exact planning, facilitating, and monitoring learning, as well as establish a mentoring mechanism for learners. More importantly, the Philippine STEAM pedagogical model emphasizes inquiry-based and output/product-based learning and teaching and a spectrum of related teaching practices. By extension, it promotes ethical conduct of STEAM pedagogical processes and research for continuous improvement of STEAM pedagogy.

A teacher's epistemological beliefs and teaching practices reflect more than his/her pedagogical character. STEAM teachers acknowledge that there is no such thing as a perfect teaching strategy. This axiom suggests that appropriateness of teaching approach must be given attention in planning the pedagogical processes. Hence, STEAM teachers are skilled in various teaching strategies and adept in switching across strategies whenever appropriate and necessary. Ideally, STEAM teachers model learning by linking practice and teaching and demonstrating critical and reflective thinking that redound to the learners' benefit.

The Pedagogical model of Philippine STEAM Education explicates that the synergy between an institution's pedagogical culture and its pedagogical processes is gauged by the quality of its learners and teachers. In particular, Philippine STEAM education aims at nurturing critical thinkers, productive citizens, and competent STEAM professionals. The circular frame of the model depicts sustainability of every relationship demonstrated by its variables and dimensions.

2.2. Alignment of the Pedagogical Model to TPACK, PPST and PSG

Crafting the Pedagogical Model for Philippine STEAM Education attunes to Quality Tertiary Education consequently aligned to the Philippine and Asian quality standards for quality assurance; and to the themes of *"AMBISYON NATIN 2040:" "Matatag, Maginhawa, at Panatag na Buhay* (Philippine Development Plan [PDP], 2017)." The country holds that the 2040 goal may be concretized through the three priority areas of the crafted Philippine Development Plan which includes: 1) *malasakit* (enhancing social fabric); 2) *pagbabago* (reducing inequality); and 3) *patuloy na pag-unlad* (sustaining growth potential). These three priority areas stress, among other things, the promotion and awareness of Philippine culture, acceleration of human capital development, promotion of technology, and stimulation of innovation. Seemingly, the vision of PDP framework underscores the need for pedagogical model to direct all pedagogical workings within the envisioned quality Philippine STEAM education as among the cores to achieving the 2040 goals.

Apparently, the Philippine Pedagogical Model defines quality in the envisioned Philippine STEAM Education by being aligned to and defined by the three major frameworks that inform the Philippine Higher Education: TPACK Framework, Policies, Standards, and Guidelines, and the Philippine Professional Standards for Teachers. In details, TPACK defines the pedagogical processes of STEAM teachers through technology integration, innovative pedagogical approaches, appropriate assessment tools, and content standards and competencies, covered by the sub-leveled dimensions such as teaching practices and pedagogical character of STEAM teachers. The Institutional Pedagogical Culture variable of the PMPSE informs how the reviewed 46 PSGs influenced crafting of the PSME to suit almost all possible and unique attributes of all the STEAM programs laid in the PSGs. Finally, PPST heavily influenced the other variables (STEAM Teaching Practices and Outcomes of STEAM Education).

2.3. Purposes of the Pedagogical Model

The PMPSE was developed to document the current practices of Philippine HEIs as regards STEAM education. Primarily, the PMPSE aims to inform the higher education institutions on the current practices beliefs among its administrators and teachers on specific aspects of STEAM education. The model also seeks to inform the Commission on Higher Education on the position of Philippine STEAM education in the 4IR.

2.4. The Model Explained

This section expounds each domain of the model through descriptions, explanations, illustrations of practice, and continuum of practice.

2.4.1. Domain Overview

2.4.1.a. The Institutional Pedagogical Culture

The institutional pedagogical culture refers to the institutional policies, infrastructure, and practices that support the pedagogical processes and requirements of the faculty and staff. The Pedagogical Model of Philippine STEAM Education (PMPSE) valorizes the need for an institutional mechanism in planning, disseminating, and evaluating the pedagogical processes.

Planning the pedagogical processes entails instituting a mechanism that engages the faculty and staff across all departments and units in a periodic review of the curriculum, specifically on the alignment of learning objectives, activities, and assessment. Planning involves developing a system to maximize involvement of the faculty and staff across disciplines in all institutional initiatives to fine tune the curriculum. In this regard, curriculum here is seen as an overarching element that encompasses the pedagogical processes such that understanding the pedagogy first requires a good grasp of the curriculum. Curriculum review constitutes

alignment of the learning objectives with activities, course requirements, and alignment of the STEAM content with the teachers' field of specialization. As revealed during school visits and interviews, some Philippine HEIs task teachers to teach content areas which are outside their field of specialization. A case in point is that of a licensed nurse teaching modern Physics in a school in a Teacher Education cohort. While this incident may not be a concern in a STEAM-based curriculum, the problem arises when some teachers lack the necessary competencies to teach the course as a result of a highly discipline-based curriculum. For instance, while we envision our graduates of a Physics degree to be considerably competent in other STEAM disciplines, when harsh reality reminds us that these graduates were trained in a highly Physics-based curriculum thereby possessing the competencies exclusively identified in a Physics degree. Planning the pedagogical processes also necessitates HEIs to ensure that the STEAM curriculum advances school-industry partnership and stresses the relevance of STEAM to the society. This motion suggests that HEIs establish strong linkages with industry partners as well as with the community. The PMPSE underscores the need to involve these stakeholders in all major curricular modifications or innovations of an HEI. For example, shifting to an outcomes-based curriculum must necessarily involve the industry partners and the community in every stage of the transition to suggest that HEIs fairly institute a mechanism where pedagogical decisions are properly communicated to all probable stakeholders.

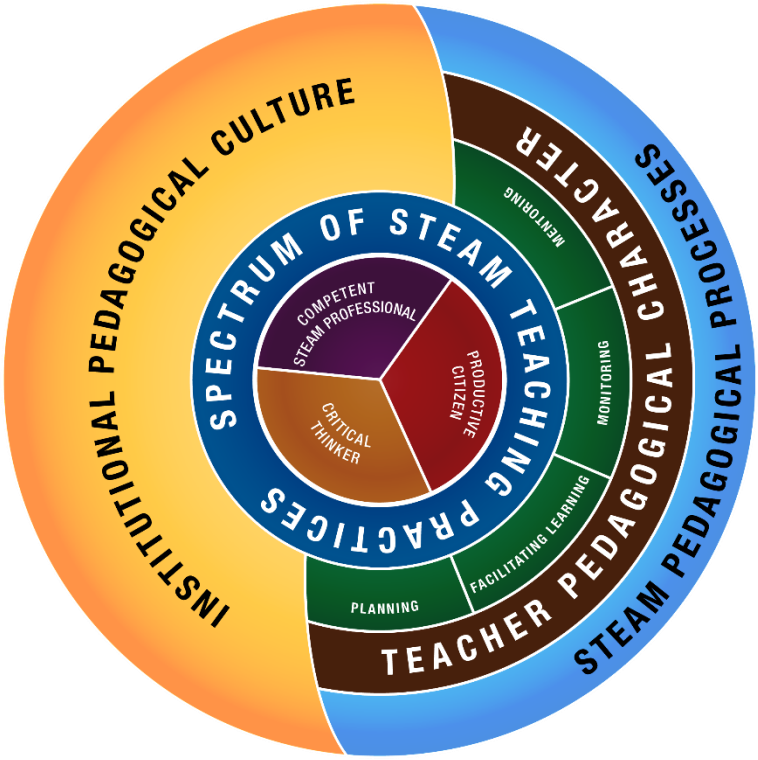

Figure 2.2 The Pedagogical Model of Philippine STEAM Education

Disseminating pedagogical processes relates to an institutional mechanism to diffuse pedagogical innovations, programs, and policies to all stakeholders. It entails making sure that

pedagogical policies and standards are communicated and understood by its main implementers. This function further means that faculty and staff, the industry partners, and the community are not only fully aware of the pedagogical goals of the HEI, but also stress their responsibility and accountability towards quality STEAM education. It also implies that evaluation of the pedagogical processes involves the stakeholders as well.

Evaluating pedagogical processes means that an institutional mechanism has taken its rightful place in monitoring and assessing planned pedagogical processes. It involves regular institutional review of the curriculum, which serves as basis for further planning of pedagogical processes, and evaluation of teachers' pedagogical plans and their implementation. HEIs must see to it that evaluation data are significantly considered for any relevant academic and administrative decisions including teachers' continuing professional development and ranking, promotion, and retention.

The pedagogical culture of an institution further extends its scope to institutional support to pedagogical processes, primarily in the area of professional development. Such institutional support–moral or financial–to professional development demands allocating funds for professional development programs and activities such as trainings and capacity building workshops and benchmarking of best practices from other HEIs with reputable STEAM programs. Support to professional development also includes establishing an institutional mentoring mechanism among faculty and staff such as Senior-Junior Faculty mentoring program.

2.4.1.b. The Teacher's Pedagogical Character

As the PMPSE posits that the pedagogical culture of an institution shapes the pedagogical character of STEAM teachers, the latter consequently upholds the former and vice versa. This dualist interaction manifests as STEAM pedagogical processes where a spectrum of STEAM teaching practices is grounded. The pedagogical character of a STEAM teacher specifically refers to his epistemological beliefs and teaching practices. For instance, as noted earlier, Philippine STEAM teachers acknowledge that there is no such thing as perfect teaching strategy so that the effectiveness of a strategy can never be replicated. This idea implies that a teaching strategy is effective only at the very moment it was proven effective. It is imperative then that every STEAM teacher becomes adept in employing a strategy that suits the content and the context of learners and learning circumstances.

The teachers' pedagogical character is also demonstrated through modeling of learning that entails conducting STEAM research, sharing one's experiences, linking practice to teaching, and demonstrating critical and reflective thinking. The collected data revealed that STEAM practitioners, or those with industry experiences, are preferred to teach the STEAM courses, as they are able to integrate application of concepts to real industry processes by invoking their own experience. Questioning skills also indicate one's pedagogical character. STEAM teachers are assumed to be skilled considerably in straddling through questions across different

difficulty levels that entail skillful use of, and management of reply to, probing questions, converging questions, impromptu questions, and queries that require higher order thinking skills. Data also yielded that increasing the complexity of questions during recitations significantly helps students grasp and appreciate the lesson's nuances. It can be deduced that a teacher's pedagogical character translates into actual teaching practices. The succeeding section models the teaching strategies of Philippine STEAM teachers.

2.4.1.c. STEAM Teaching Practices

Consistent with pedagogical character, STEAM teachers are assumed to be skilled in various teaching strategies and adept in switching across approaches and techniques whenever appropriate and necessary. This study looked into the current teaching practices of Philippine STEAM teachers. Data showed that generally, teaching STEAM courses is characterized by inquiry-based and collaborative learning with more weight placed on students' outputs or products. STEAM teaching as an inquiry-based learning process particularly suggests that modeling learning must manifest in the learning process. Building from what has been discussed in the previous section, modeling learning underscores the teachers' ability to provide live applications of STEAM concepts. This practice includes (1) simulations of actual applications, (2) illustration of real-life examples, (3) facilitation of a life-like experiences, (4) integration of values, and (5) application of concepts in solving problems in the raw. Specifically, such a scheme involves (1) virtual modeling and computer simulations, (2) site visits to industries, and (3) problem-based and project-based learning, and the (4) development of values and life skills in such processes. Apparently, teaching STEAM is characterized by a wide spectrum of output-based and collaborative teaching strategies. Hence, teachers must be skilled in facilitating group activities which may demand establishment of grouping policies and guidelines.

Collaborative learning is preferred in teaching STEAM because students share knowledge and demonstrate skills to fellow students rather than to their teachers. Interestingly, PMPSE deems the lecture method an important teaching strategy for STEAM. It is believed that it gives teachers the opportunity to underscore (repeat) the least learned concepts.

Teaching STEAM is also characterized by the conscious incorporation of the learners' prior knowledge in the pedagogy. STEAM teachers elicit prior knowledge primarily to draw out the learners' conceptual background as an input to any possible deviation from the planned lesson scope, pacing, and strategy. Specifically, eliciting prior knowledge or schema entails dealing with alternative conceptions with respect and utilizing the learners' naive ideas as springboard to the discussion. Data further showed that STEAM pedagogical processes must provide learners opportunities to develop and strengthen their communication skills. In particular, learners are goaded to express their grasp and appreciation of concepts in their own words, better yet, grapple with the bull's horn, so to speak.

Emerging as an essential pedagogical process for STEAM, research in STEAM is two-pronged. PMPSE posits that STEAM teachers must be actively doing researches both in STEAM field and in STEAM Education. While research on STEAM (multidisciplinary, inter/intradisciplinary, transdisciplinary) is deemed vital in modeling learning, research on STEAM pedagogy bridges the perceived pedagogical gap among STEAM specialists (i.e., graduates of STEAM degrees and not of STEAM education degrees) who are commonly stereotyped to be poorly wanting in pedagogical strategies, as they tend to be highly conceptual and theoretical in their approach. If at all, they are perceived to show little concern about the learners' context (e.g., conceptual background, schema or prior knowledge, learning preferences) and the learning circumstances. PMPSE postulates that conducting iterative researches about STEAM teaching, as well as integrating the outputs of STEAM research in the pedagogy, conjointly establish the foundation of quality STEAM education.

Planning the Learning Process

The PMPSE highlights the support of teachers to institutional mechanism in planning the STEAM pedagogical processes. It calls for active involvement of STEAM teachers to institutional efforts in curriculum development and review thereby ensuring strong school-industry-community partnerships. Specifically, STEAM teachers plan the teaching strategies, approaches, and methods vis-a-vis the course objectives, competencies required, and institutional pedagogical goals. STEAM teachers likewise plan the learning process to ensure that teaching strategies are responsive to the diverse learning contexts. The PMPSE also finds it crucial to ensure that the teacher assigned to handle a particular STEAM course possesses the competencies that the course aims to develop among the learners. This implication suggests that more than the possession of the competencies, PMPSE prefers teachers who have experienced the practical application of STEAM concepts such as in industries and services sectors.

Facilitating the Learning Process

The PMPSE emphasizes the significance of facilitating learning in ensuring success in the learning of STEAM. Facilitating learning is seen as an integral component of STEAM learning such that planning the pedagogical processes must duly consider how learning may be maximized, a desideratum implying that facilitating learning has to be embedded in every STEAM teacher's pedagogical processes.

Facilitating learning primarily seeks to promote a positive relationship with learners and maintain a positive learning environment in creating a friendly environment with learners while maintaining authority over them. This notion may involve dealing with struggling learners with patience and being considerate in giving course requirements and projects, especially those that involve expenses. Promoting a positive relationship with learners also means helping the learners build self-confidence and motivating them to learn how to learn, to use Dellor’s phraseology. STEAM teachers must inspire their learners. They impose high, great

expectations on learners and encourage them to do more and to be better achievers. Teachers inspire learners to appreciate learning for its own sake, as John Dewey aptly puts it. The PMPSE affirms that in a STEAM classroom, teachers are keen at appreciating efforts and academic milestones of learners. This quality entails giving credits whenever due and appropriate. It also requires appreciating learners' curiosity. Facilitating learning also involves classroom organization where students in every class assume specific responsibilities such as disseminating information and announcements. It also requires imposing classroom rules and regulations, observing class routine, and monitoring learners during discussions and class activities. For example, STEAM teachers must ensure that laboratory rules and guidelines are considerably observed during laboratory classes to avoid untoward incidents.

Monitoring the Learning Process

STEAM teachers very consciously monitor the learning process and learning circumstances. This suggests that teachers follow up on the classroom processes and the learners' acquisition of knowledge and development of skills and values, entailing development of assessment tools. Monitoring learning advances that learners must be fully aware and conscious of the assessment standards. Expectedly, the assessment tools must provide learners the opportunity to explore the various applications of STEAM concepts through varied problems. This need implies that assessment tools for STEAM ought to simulate solving actual problems in the field. STEAM teachers must be keen in making sense of the assessment results that inform the mentoring mechanism, the subsequent learning processes such as lesson pacing and scope, and more important, even the institutional STEAM pedagogical processes.

Mentoring the Learners

Mentoring is deemed crucial in the success of teaching STEAM. Besides mentoring among faculty and staff, the PMPSE advocates establishing an institutional mentoring mechanism for students. It specifically demands having rooms dedicated for mentoring activities as well as including the mentoring sessions as official function of every faculty whereby certain number of mentoring hours will be dedicated or considered as official time. Mentoring is viewed as seamless and borderless such that students may sign up for a mentoring session with any faculty he/she deems fitting and proper to address his/her concerns. The mentoring process in PMPSE primarily aims to address students' difficulty in understanding the lessons.

2.4.1.d. The Outcomes of STEAM Education

The PMPSE advances the stance that the mutual support between institutional pedagogical culture and the teachers' pedagogical character, as demonstrated by the STEAM pedagogical processes, nurtures learners expected to graduate as life-long critical thinkers, competent STEAM professionals, and productive citizens. Specifically, STEAM graduates are trained to planning and executing probable solutions to pressing societal problems which involve

modeling and communicating ideas. A competent professional is able to achieve the discipline-based requirements such as passing the licensure examination and relevant accreditations. Competent STEAM professionals primarily are those who tender significant contributions to programs and initiative that improve the quality of life. This spectrum involves research, production, and application of useful knowledge, products and services.

The Pedagogical Model of Philippine STEAM Education illustrates the interdependence between an institution's pedagogical culture and STEAM pedagogical processes. Specifically, the institutional pedagogical culture is considered the key driver to STEAM pedagogical processes, which consequently shape the former. The model elucidates that STEAM teachers and teaching practices play a critical role in ensuring quality of STEAM education in the country. The succeeding section presents the proficiency indicators of STEAM teachers, as drawn from the model.

2.4.2. Continuum of Practice

The model articulates the characteristics of STEAM educators based on the analysis of generated responses and observed practices among data sources. Specifically, the model clarifies four proficiency levels of STEAM educators - the Novice (Awareness) level, the Proficient (Proactive Awareness) level, the Highly Proficient (Modeling) level, and the Distinguished (Inspiring/Mentoring) level. A sample elaboration of proficiency among STEAM teachers is presented in Table 2.1., the full description of each level of the continuum presented in Appendix II.A.

Table 2.1. Proficiency continuum for STEAM Educators in the area of Monitoring of Learning

Novice (Awareness)	Proficient (Proactive Awareness)	Highly Proficient (Modeling)	Distinguished (Inspiring/Mentoring)
Novice STEAM Educators possess knowledge of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement; manifest capability of using	Proficient STEAM Educators promote the effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement; and promote the effective use of assessment data to address challenges	Highly Proficient STEAM Educators model effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement; and model the	Distinguished STEAM Educators mentor other STEAM Educators on the effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement, as well as the effective use of assessment data to

assessment data to address challenges in implementing effective teaching and learning practices.	in implementing effective teaching and learning practices	effective use of assessment data to address challenges in implementing effective teaching and learning practices	address challenges in implementing effective teaching and learning practices

2.4.3. Suggested Resources

The PMPSE advances a synergy among administrators, faculty, and staff within HEIs and among HEIs, Industry, and Community. Like any other synergistic approach to change and improve services, the model implies allocating sufficient budget for the advancement of STEM. To illustrate, in terms of teacher professional development, HEIs must ensure that sufficient budget is set aside for the training, reskilling, and upgrading of faculty members' competencies.

2.4.4. Illustration of Practice

STEAM education practices among administrators and teachers are modeled in a form of proficiency continuum (see Appendix II.A). The specific practices and indicators are also captured in Appendix II.B.

APPENDICES

Appendix II. A. Proficiency Continuum for STEAM Educators

Novice (Awareness)	Proficient (Proactive Awareness)	Highly Proficient (Modeling)	Distinguished (Inspiring/Mentoring)
Novice STEAM Educators acknowledge the need for a culture of support to institutional mechanism in planning, implementing, and evaluating pedagogical processes, ensure alignment of learning objectives and activities, advancing school and industry partnerships, emphasizing the relevance of STEAM to society, and instituting continuous improvement in curricular policies and practices.	Proficient STEAM Educators promote a culture of support to institutional mechanism in planning, implementing, and evaluating pedagogical processes, ensure alignment of learning objectives and activities, advancing school and industry partnerships, stressing the relevance of STEAM to society, and instituting continuous improvement in curricular policies and practices.	Highly Proficient STEAM Educators exemplify a culture of support to institutional mechanism in planning, implementing, and evaluating pedagogical processes, ensure alignment of learning objectives and activities, advancing school and industry partnerships, focusing on the relevance of STEAM to society, and instituting continuous improvement in curricular policies and practices.	Distinguished STEAM Educators nurture a culture of support to institutional mechanism in planning, implementing, and evaluating pedagogical processes, ensure alignment of learning objectives and activities, advancing school and industry partnerships, accenting the relevance of STEAM to society, and instituting continuous improvement in curricular policies and practices.
Novice STEAM Educators acknowledge the need to model learning, and to demonstrate critical and reflective thinking.	Proficient STEAM Educators promote learning-by-modeling and demonstrate critical and reflective thinking.	Highly Proficient STEAM Educators exemplify learning-by-modeling and demonstrate critical and reflective thinking.	Distinguished STEAM Educators lead and inspire other STEAM educators in exemplifying learning-by-modeling, and demonstrating critical and reflective thinking.
Novice STEAM Educators possess knowledge of teaching strategies and manifest capacity to manage learning activities that promote learning based on learners' needs.	Proficient STEAM Educators manifest the use of wide range of teaching strategies that promote STEAM literacy and other skills by actively engaging in collaborative learning with the professional community and other stakeholders for mutual	Highly proficient STEAM Educators collaborate with colleagues in applying research-based pedagogy that promote inquiry, problem- and product-based learning, curriculum planning, management of learning, and valuable use of technology to create lifelong impact in the lives of other STEAM	Distinguished STEAM Educators champion modelling and mentoring of research-based pedagogy that promote inquiry, problem- and product-based learning, curriculum planning, management of learning, and valuable use of technology to create lifelong impact in the lives of other STEAM

	growth and advancement.	professionals, colleagues, diverse learners/students and the community.	professionals, colleagues, diverse learners/students and the community.
Novice STEAM Educators possess knowledge of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement, manifest capability in using assessment data to address challenges in implementing effective teaching and learning practices.	Proficient STEAM Educators promote the effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement, as well as promote the effective use of assessment data to address challenges in implementing effective teaching and learning practices	Highly Proficient STEAM Educators model effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement, as well as model the effective use of assessment data to address challenges in implementing effective teaching and learning practices	Distinguished STEAM Educators mentor other STEAM Educators on the effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement, as well as the effective use of assessment data to address challenges in implementing effective teaching and learning practices
Novice STEAM Educators acknowledge the need to develop a structured academic consultation mechanism to address learners' difficulty.	Proficient STEAM Educators promote having a structured academic consultation mechanism to address learners' difficulty.	Highly Proficient STEAM Educators model effective conduct of academic consultation as evidenced by the learners' improvement.	Distinguished STEAM Educators mentor colleagues on the effective conduct of academic consultation, as evidenced by the learners' improvement.
Novice STEAM Educators recognize the need to promote positive relationship with learners in an environment conducive to learning, thereby inspiring learners to aim for excellence.	Proficient STEAM Educators promote positive relationship with learners in an environment conducive to learning, thereby inspiring learners to aim for excellence.	Proficient STEAM Educators model positive relationship with learners in an environment conducive to learning, thereby inspiring learners to aim for excellence.	Proficient STEAM Educators inspire other STEAM educators to promote positive relationship with learners in an environment conducive to learning, thereby inspiring learners to aim for excellence.
Novice STEAM Educators acknowledge the need to conscientiously plan the pedagogical processes towards effective use of knowledge, skills and values to support the STEAM teaching and learning process.	Proficient STEAM Educators promote conscientious planning of pedagogical processes towards effective use of knowledge, skills and values to support the STEAM teaching and learning process.	Highly Proficient STEAM Educators models conscientious planning of pedagogical processes towards effective use of knowledge, skills and values to support the STEAM teaching and learning process.	Distinguished STEAM Educators inspires colleagues to conscientiously plan the pedagogical processes towards effective use of knowledge, skills and values to support the STEAM teaching and learning process.
Novice STEAM Educators understand that critical thinking	Proficient STEAM Educators promote acquisition,	Highly Proficient STEAM Educators model pedagogical processes	Distinguished STEAM Educators inspire other STEAM educators to

among learners characterizes quality education and that STEAM pedagogical process must provide learners the opportunity to acquire, demonstrate, and evaluate critical thinking.	demonstration, and evaluation of critical thinking among learners in all pedagogical process.	that put premium on acquisition, demonstration, and evaluation of critical thinking among learners.	model pedagogical processes that put premium on acquisition, demonstration, and evaluation of critical thinking among learners.
Novice STEAM Educators acknowledge the need to consciously integrate in the pedagogical processes, whenever cogent and relevant, the development of knowledge, skills, and values that could help prepare learners pass the licensure examination.	Proficient STEAM Educators promote the conscious integration in the pedagogical processes, whenever cogent and relevant, the development of knowledge, skills, and values that could help prepare learners pass the licensure examination.	Highly Proficient STEAM Educators model the conscious integration in the pedagogical processes, whenever cogent and relevant, the development of knowledge, skills, and values that could help prepare learners pass the licensure examination.	Distinguished STEAM Educators mentor other STEAM educators the conscious integration in the pedagogical processes, whenever cogent and relevant, the development of knowledge, skills, and values that could help prepare learners pass the licensure examination.
Novice STEAM Educators acknowledge the need to prioritize in all pedagogical processes the development of skills, knowledge, and values required of the profession thereby enhancing employability and work success of graduates.	Proficient STEAM Educators promote prioritizing the development of skills, knowledge, and values required of the profession thereby enhancing employability and work success of graduates.	Highly Proficient STEAM Educators model prioritizing the development of skills, knowledge, and values required of the profession thereby enhancing employability and work success of graduates.	Distinguished STEAM Educators mentor other STEAM educators on prioritizing the development of skills, knowledge, and values required of the profession thereby enhancing employability and work success of graduates.

Appendix II.B. Indicators of Practices for STEAM Domains

Domain	Elaboration	Illustration of Practice
Institutional Pedagogical Culture	Institutional Pedagogical Culture refers to institutional practices that support the pedagogical process and requirements of faculty and staff. The model proposes an institutional mechanism in planning, disseminating, and evaluating pedagogical processes. Planning the pedagogical processes entails the following: 1. Involvement of faculty and staff across all disciplines to align learning objectives and activities. 2. Alignment of teacher's field of specialization and course content to teach. 3. Ensuring that pedagogical processes advance school-industry partnership. 4. Ensuring that pedagogical processes stress the relevance of STEAM Education to community. Evaluating pedagogical processes means that an institutional mechanism is in place for monitoring and evaluation of planned pedagogical processes. It entails: 1. Regular institutional evaluation of curriculum 2. Evaluation of teachers' pedagogical plans – A staff (e.g. coordinator) is assigned. 3. Evaluation of teachers' implementation of pedagogical plans. 4. Results of evaluation serve as basis for ranking, promotion, and retention. 5. Results of evaluation serve as basis for teacher professional development programs The institutional support to pedagogical processes primarily refers to institutional support for faculty development. Support for faculty development means the institution: 1. provides funds for teacher professional development such as attendance to trainings 2. has a mentoring program between senior and junior faculty members 3. collaborates with other HEIs with reputable STEAM programs	Institutional Annual Review and Calibration of Curriculum Regular Meeting with Industry Partners and Community Leaders Classroom Observation Specialization Mapping Orientation, Convocation, and Symposium Faculty Development Programs Ranking and Promotion Faculty Mentoring Program Collaboration - Twinning
Teacher Pedagogical Character	This refers to the teachers' epistemological beliefs and pedagogical practices. 1. teacher acknowledges the diversity of teaching strategies. Anchored on the idea that "there is no perfect teaching strategy", suggesting that appropriateness of strategy must be considered: "it's not always because sometimes it's not the most appropriate to use" 2. teacher models learning *a.* shares his/her experiences *b.* links practice and teaching *c.* demonstrates critical and reflective thinking. Questioning skills are also observed.	Survey of Student needs and preferences Conducts Action Research Educational Trips Recitation

STEAM Teaching Practices	The pedagogical processes currently employed by Philippine STEAM teachers in teaching STEAM courses, primarily the teaching approaches and corresponding teaching techniques. The following emerged as current practices of STEAM teachers: 1. Inquiry-Based Learning – teachers employ inquiry-based learning a. Real-life applications - Teacher's pedagogical processes provide life-like applications of lessons 2. Output-Based Learning – Whenever appropriate (there are disciplines like engineering that are highly output-driven), the teacher gives more weight to learner's output than the process. 3. Lecture Method. The teacher's pedagogical processes include use of lecture method deemed important in teaching STEAM courses, specifically in the tertiary level. It gives teachers the opportunity to repeat (underscore) important topics 4. Collaborative Learning. Facilitating group activities is evident in the teacher's pedagogical processes. a. Grouping policies and guidelines b. Collaborative learning is employed because students tend to share knowledge more to fellow students than to the teacher. General: 1. Elicits prior knowledge. Teacher's pedagogical processes include dealing with prior knowledge appropriately. Primarily, eliciting schema means drawing out the learner's background or previous knowledge and conducting a short review before proceeding to the next topic. 2. Strengthens learners communication skills. The teacher's pedagogical processes strengthen the learner's communication skills (English and Filipino) 3. Teacher does action research to ensure that pedagogical practices are relevant and effective. Teacher's pedagogical processes include monitoring learner's acquisition of knowledge. 1. warns students who get low scores in test 2. seeks learner's commitment to do well in class 3. adjusts teaching techniques based on learner's progress Monitoring of learners' acquisition of knowledge also entails ability to develop assessment tools. Teacher develops test items not lifted directly from the materials used in class. Crucial also in monitoring acquisition of knowledge is making the learners aware of the assessment standards. Teacher's pedagogical processes include a regular consultation schedule to address learners' difficulty. 1. a room is dedicated for mentoring sessions 2. teacher is open to mentor any student in the school, anytime 3. consultation time is structured Management of classroom processes is embedded in the teacher's pedagogical processes. It entails classroom organization where the teacher delegates tasks and responsibilities to class officers as in disseminating information or announcements, imposing classroom	Use of Scaffolding and GRR Employs Learning by Modeling Employs Simulations Employs problem-based, output-based, project-based, outcome-based learning Employs Lecture Method Provides group tasks Conducts Review prior to lesson Code switching in using language Recitation Conduct of Action Research Consultation and Conference with Students Employs Authentic Assessment Conducts structured mentoring and consultation Class Organization (with Class Officers) Imposes classroom and laboratory rules

	rules and regulations, observing class routine, and monitoring learners during discussion and class activities.	
Outcomes of STEAM Education	STEAM teachers treat critical thinking as an outcome of STEAM pedagogical processes 1. graduates are trained to offer solutions to any problem 2. learners must know how to explain solution to a problem 3. learners are able to model a problem e.g. diagrams, pictures, grid, etc. 4. learners learn the concept that is applicable to solve a problem, not the specific formula appropriate to a specific problem 5. learners are exposed to many possible solutions to a problem Teacher's pedagogical processes prepare students for the licensure examination Teachers underscore employability of graduates as outcomes of the pedagogical processes	Field Trips Employing models Apprenticeship [Students] Passing the licensure examination Conducting a Tracer Study

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CHAPTER 3

ABSTRACT

CHAPTER 3
The Technology Integration Model

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The technology integration model unifies or consolidates technology in STEAM Education, its framework developed from the collected and analyzed qualitative data retrieved from the STEAM teachers across the country. The results derived three variables: *teacher technological knowledge (TTK), institutional support (IS)* and *outcomes*. Teacher technological knowledge has two dimensions: *lesson structure and content-driven*; just as the institutional support comes in tandem: *capacity building and quality of technology, architecture, design system*. The model gears up to realize three outcomes: to produce *innovative STEAM learner/professional, critical learner, and productive citizen*. The model theorizes using the TPACK, SAMR and Triple E framework with emphasis on Triple E: *engagement, enhancement and extension*. The two-tier validation to which the model was subjected helps create an emerging model. The emerging technology integration model has an additional dimension under TTK *(content-based)* and IS *(research in technology development*) and possessing 21st century skills as one of the outcomes of being a STEAM learner/professional. The technology integration model is believed to agree with the PSGs, assist with the PPST and strengthen the TPCK framework. The technology integration model may provide insights into reforms and policies to further technology integration in STEAM education.

Keywords: STEAM Education, technology integration, technology integration model

3.1. The Model Defined

3.1.1. Why the Technology Integration Model

Admittedly, Technology always has a special part in education. The use of technology such as tools, equipment and even nonphysical equipment like software and computer applications helps the teachers and students in teaching and learning STEAM disciplines. These roles are evident in the different components of teaching and learning; hence technology integration is essential in education. Technology integration refers to the use of technology resources (e.g., computers, mobile devices like smartphones and tablets, digital cameras, social media platforms and networks, software applications, the Internet, etc. in learning, in daily classroom practices, in teachers' major and other duties, and in the management of a school (Edutopia, 2007; Education4site, 2011).

In the teaching-learning process, innovative teaching approaches are so essential in the students' learning experiences, that they provide learners with the necessary learning competence and experiences. Furthermore, in a STEAM classroom where learners are dynamic and diverse, these teaching innovations must be practiced by teachers to address the learners' multi-faceted needs. Consequently, these innovative teaching strategies could be best demonstrated with the integration of technology. The *21st Century skills* explicitly indicate the need for integrating the use of technology inside the classroom. Similarly, with the kind of students we have at present, they more often than not, learn best with the aid of technology such as educational software, audio-visual presentation, equipment and other related technology utilized inside a STEAM classroom.

Moreover, Education 4.0 directs all the teaching and learning processes in pursuit of all the demands of Industrial Revolution 4.0. It promotes a new learning vision and novel ways of learning that capitalize on collaboration of humans and machines (also known as cyber-physical system) (Atkinson, 2018). In the same view, it recalibrates the new learning terrain that centers on blending virtual and cyber-physical worlds into the realms of reality. Technology integration has a vital role in addressing the demands of Education 4.0, especially for STEAM education.

With the tenets of a quality STEAM education upheld, technology integration needs to be taken into so much consideration that technology integration model is developed. The current study looks into the domains of the model. Furthermore, the model proposes the emergence and importance of teacher technological knowledge and institutional support being used inside a dynamic STEAM classroom to produce quality STEAM leaners and professional.

3.1.2. The Technology Integration Model…

- Aims to describe the technology integration in quality STEAM education

- Has three major variables
  - **Teacher technological knowledge**
    - Lesson structure
    - Content-based
  - **Institutional support**
    - Capacity building
    - Quality of technology architecture, systems and design
  - **Outcomes**
    - Innovative professional
    - Productive citizen
    - Critical thinker
- Intends to address
  - Teacher quality
  - Students' learning
- Incorporates how technology integration is measured
  - Engagement
  - Enhancement
  - Extension

3.1.3. The Technology Integration Model is NOT...

- The model does not prescribe how technology is integrated in STEAM education.
- The model does not show the extent of integrating technology inside a STEAM classroom.
- The model does not reflect the current state of technology integration in the Philippine STEAM education, as it merely describes technology integration based on available data.

3.1.4. What is new about the Technology Integration Model?

- The model includes how technology integration is measured.
- It shows how institutional support is placed in technology integration.
- It describes the intention of technology integration and shows the outcomes of technology integration.
- It highlights the role and significance of STEAM teachers in the model as much as their impact on the students.
- It agrees with the PSGs, assists PPST, and strengthens TPCK.

3.1.5. Salient Features of the Technology Integration Model

- The model features the three major variables of technology integration.
- It also shows the processes of each variable essential in integrating technology to achieve quality STEAM education.

- It integrates the Triple E Framework (Engagement, Enhancement and Extension).
- It looks into the alignment to TPACK Framework, PSGs and PPST.
- The outcomes of the model are clearly defined.

3.1.6. What is the Technology Integration Model?

The technology integration model is a framework of how technology integration is reflected to achieve quality STEAM Education. Technology integration refers to the use of technology resources (computers, mobile devices like smartphones and tablets, digital cameras, social media platforms and networks, software applications, the Internet, etc.) in learning, in daily classroom practices, in teachers' major and other duties, and in the management of a school (Edutopia, 2007; Education4site, 2011). The technology integration model for STEAM education shows three variables: *teacher technological knowledge (TTK), institutional support (IS) and outcomes*.

The **Teacher technological knowledge (TTK)** refers to the teachers' understanding about technology including familiarity to various technology, understanding how to make and use specific technology in identified lessons, even assess when technology assists or impedes lesson delivery. Teacher technology knowledge has two dimensions: lesson structure and content-driven. The former refers to the integration of technology in specific parts of the lesson, at most, for faster lesson delivery and better presentation, the latter to the use of technology in instruction, specifically applicable to courses on which the content of the course is bound to technology use. Contrastingly, **Institutional Support (IS)** has two dimensions: capacity building and quality of technology, architecture, system and design. *Capacity building* seeks to enhance technological literacy of teachers in the appropriate use of technology for specific purpose. It includes trainings and workshops for teachers in the proper use of technology. *Quality of technology, architecture, design and system* refers to various software, applications, devices and other instruments that the teachers need to carry out the teaching-learning process, as approximated by the affordability, availability, and appropriacy of the technology used in instruction and/or assessment. Current and modern designs to ensure the comfortable use of technology in teaching and learning are essential to produce *critical thinkers, productive citizens, and innovative STEAM professionals* in promoting quality STEAM education.

3.2. Alignment of the Technology Integration Model to TPACK and Other Theories (PPST and PSG)

The technology integration model agrees with the TPACK model, Philippine Professional Standards for Teachers (PPST), Policy Standard to Enhance Quality Assurance and Policies, Standards and Guidelines (PSG).

3.2. 1. TPACK Model and Technology Integration Model

The core components of teaching with technology are content, pedagogy and technology, and their fusion (Koehler & Mishra, 2009). In the technology integration model, these components were all observed in the theme *teacher technological knowledge* and subthemes *lesson structure* and *content-driven*. In lesson structure, TPCK can be seen in the teaching and learning experience, while TPK focuses on Teacher's understanding of the affordability of Technology. TCK is observed in the laboratory and simulation activities, applicability to the topic and lesson objectives. Single core components TK, CK, PK are shown in teachers' Knowledge on the different types of technology, productive discussions and teaching objectives respectively.

In the variable, institutional support, only TPK, TCK and TK are evident in both *capacity building* and *quality of technology architecture, systems and design* sub-themes. In TCK, the administration supports the training on the effective use of technology inside the classroom. Provision of laboratory room for instruction and research, installation of LCD TVs, or LED TVs, for instruction and setting-up of LMS to aid instruction are evident in TPK. In TK, protocol on the use of laboratory and available technologies are in effect.

3.2.2. PPST and Model in Technology Integration

PPST intends to help teachers reflect and assess their own practices (Department of Education - Teacher Education Council, 2017). The model in technology integration can assist PPST in this aspect. Specifically, the model responds to Domains 1 and 4.

Domain 1 states that skill in the use of technologies is needed to promote high quality learning outcomes. Specifically, strand 1.3 states that there should be a positive use of ICT. In contrast, domain 4 states that teacher should be able to use their professional knowledge and curriculum content to a well -structured and sequenced lessons. Strand 4.5 points out that ICT should be part of the teaching and learning.

In the model, teacher technological knowledge accords with the teachers' need for adequate skills. They should be willing, ready and able to use technology in structuring the lesson, in delivering the subject content, and in evaluating its efficacy. To ensure that teachers meet the skills expected of them, administration supports such by capacity building and providing the technology architecture, systems and design. In terms of the technology to be used, it should be affordable, available and appropriate.

3.2.3. Policy Standard to Enhance Quality Assurance and Model in Technology Integration

Quality assurance provides mechanisms, procedures and processes to get the desired quality. When translated to actions, professional institutions ought to have learning resources and support structures appropriate in developing professional knowledge and skills (CHED, 2012). In the integration model, administrative support is clearly included, with subthemes of providing the technologies and the intricacies of using such technologies.

3.2.4. Policies, Standards and Guidelines (PSG) and Model in Technology Integration

PSG is a program-based quality assurance mechanism set by CHED (Pijano, 2010). A specific PSG is set for every particular program. The model in technology integration agrees with the PSGs inclusion of technology in many aspects. Virtually, it states that general education courses should have basic computer literacy, which is needed in the current technological society (PSGs in Accountancy, Library and Information Science, Nursing, Pharmacy Education & Respiratory Therapy). Learning resources are a must for the delivery of the curriculum (PSGs in Library and Information Science). BESED Math & Computer Engineering in different formats (PSGs in Library and Information Science & Respiratory Therapy). Laboratories, in turn, are indispensable to supplement and complement the attainment of learning outcomes before actual experience (PSG in Library and Information Science, all Science & Engineering programs). These requirements translate to technologies enhancing instruction (PSGs in Nursing & Pharmacy Education) in classroom. That said, in various PSGs, it behooves that STEAM educators possess technological knowledge to effectively deliver the goals stated in the PSGs. At best, the technology may be provided by the administration.

3.3. Purposes of the Technology Integration Model

The technology integration model may address the teacher quality and the students' learning, particularly in the cognitive and affective components. The model intends to provide opportunities for the STEAM educators to update or adapt to new technology used in the classroom and provide opportunities to make STEAM educators highly qualified. Moreover, this will lead to integration of technology in innovative teaching strategy to enhance teaching. Notably, the model outlines the significance of technology integration to produce quality STEAM learners.

In effect, the model attempts to address students' learning. When teachers demonstrate innovative teaching approaches with the integration of technology, students tend to experience meaningful learning evident in a more interactive and effective discussion, which may

gradually lead to improvement of their academic achievement, as they enhance their active participation in the classroom, not discounting their increased motivation and attention span.

3.4. The Model Explained

The Technology Integration Model has three major variables: teacher technological knowledge, institutional support, and the outcomes. Figure 3.1 shows the validated technology integration model.

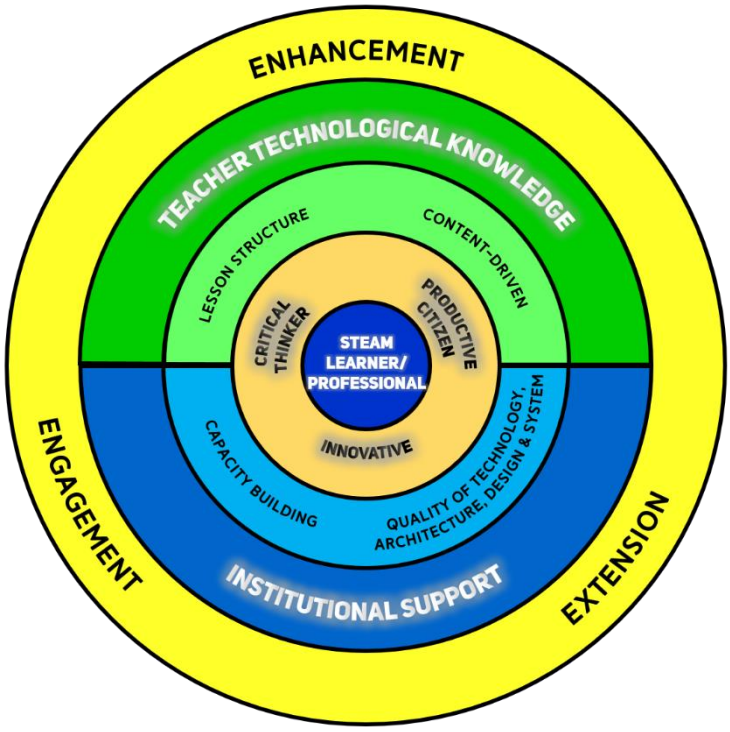

Figure 3.1. Validated technology integration model

Etymologically, the word technology comes from the Greek word *tekhnologia* or systematic treatment of an art or craft, i.e., *tekhne,* skill (American Heritage Dictionary, 1997). "It is the scientific method and material used to achieve a commercial or industrial objective." In the context of the given framework above, technology refers to scientific materials used in support of teaching. This can be classified into analog and digital. Analog technology consists of materials used in teaching that does not require the use of computers, internet, software and the likes. It includes chalkboard, whiteboard, and improvised apparatus or equipment. According to Koehler and Mishra (2009), this type of technology is characterized by specificity, stability, and transparency of function. By contrast, digital technology is protean, unstable and opaque. It includes computers, tablets, SMART board, projectors, PowerPoint or digital slides, clicker response system, movies, software applications, laboratory equipment, and websites.

3.4.1. Teacher Technological Knowledge (TTK) refers to the teachers' understanding about technology, as well as familiarity to various technology, making sense of how to devise and use specific technology to identified lessons, and how to assess when technology assists or impedes lesson delivery (Koehler & Mishra, 2009). Essentially, teachers with technological knowledge should know their basic intentions in using or integrating these technologies, or in considering the choice of a specific technology and when and what part of the lesson technology is used. In this regard, the National Research Council (NRC, 1999) coined the term Fluency of Information Technology (FITness) that goes beyond were technological literacy, requiring an adequate grasp of the best technology to be used in achieving set goals and objectives.

Lesson Structure means the integration of technology in specific parts of the lesson, at most, for faster lesson delivery and better presentation. Primarily, it enhances the learning experience of students by increasing their interest in the lesson using technology that is otherwise impossible or time-consuming when done manually. *Content-Driven* is the use of technology in instruction and only applicable for specific courses where the content of the course is bound to technology use. This aspect may include Information Technology subjects, subjects with laboratory and practical works among others.

Teacher knowledge of technology either for lesson delivery or as required by the course content must be engaging, enhancing, and extending to maximize the teaching and learning experience.

3.4.2. Institutional Support (IS) refers to the assistance and other forms of support given by the institutions and its administration. It has two dimensions: capacity building and quality of technology, architecture, design and system.

Capacity building means the act enhancing technological literacy of teachers in the appropriate use of technology for specific purpose. It includes trainings and workshops for teachers in the proper use of technology. *Quality of technology, architecture, design and systems* refers to various software, applications, devices and other instruments that the teachers need to carry out the teaching-learning process. This scope can be approximated by the affordability, availability and appropriacy of the technology used in instruction and/or assessment and design of the school. Technology that is available in schools for teaching and learning are greatly affected by how much the technology costs and the institution's financial capacity. Such demands for software and subscriptions need budgetary allotment from the institution. In other instance, availability of technology is another consideration, it being connected to affordability some schools fall short of funds with which to operate. Appropriacy bespeaks the teacher's choice of technology to enhance the teaching of specific topics, as affected by

what technology is readily available for teachers to choose from which, in turn, is affected by technology affordability.

Current and modern designs to assure the comfortable use of technology in teaching and learning are called for to produce *critical thinkers*, *productive citizens* and *innovative STEAM professionals* in promoting quality STEAM education.

The technology integration model theorizes using the TPACK, SAMR and Triple E framework with emphasis on Triple E: *engagement, enhancement, and extension*. The model shows no barriers enough to divide the dimensions of the variables to signify that these dimensions are related to one another. Similarly, the Triple E Framework are observed in the outermost circle to denote that technology integration can be a way to evaluate the choice of tools to meet the learning goals, and design learning episodes using tools that impact students to deduce the desired learning outcome.

The technology integration model underwent two-tier validation process that revealed the existence of some emerging concepts considered part and parcel of the model. These concepts somehow may reflect the current and future technology integration model. Figure 3.2 presents the emerging technology integration model

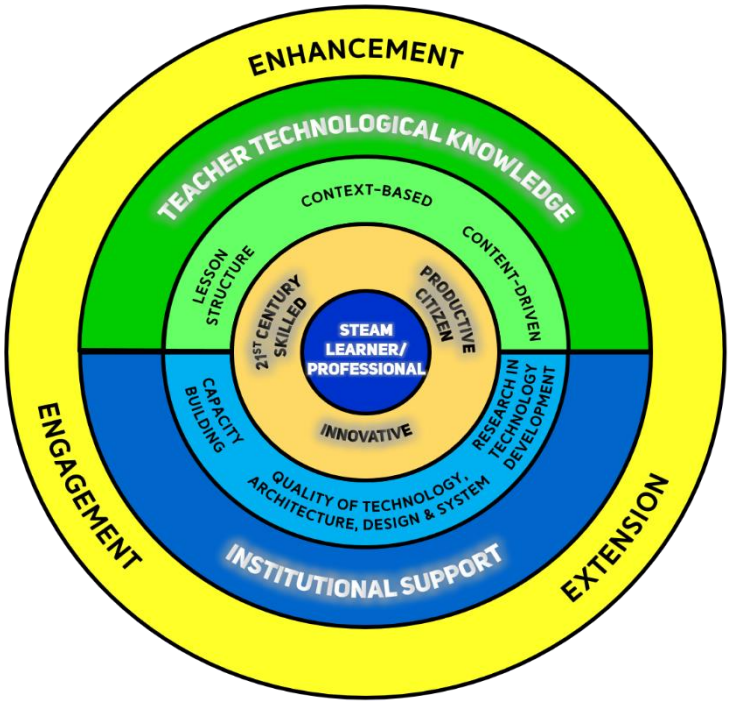

Figure 3.2. Emerging technology integration model

The emerging technology integration model resulted from the two-tier validation. The same variables are present in the model: *teacher technological knowledge, institutional support* and *outcomes.* The emerging model has an additional dimension each falling under teacher technological knowledge and institutional support. *Context-based* under the teacher technological knowledge refers to the conditions, physical, economic or cultural, of the school,

teachers and the students. Under institutional support the added dimension refers to research in technology development that creates opportunities to innovate and develop technology related to STEAM disciplines. The utmost outcomes of being a STEAM learner/profession is to possess *21st century skills* that could help learners thrive well in a competitive, highly technological world.

3.4.3. Domain Overview

3.4.3.a. Teacher technological knowledge (TTK)

Teacher technological knowledge (TTK) refers to the understanding of teachers about technology. This aspect includes familiarity to various technology, understanding how to make and use specific technology to identified lessons, and how to assess when technology assists or impedes lesson delivery. Under the validated technology integration model, TTK has two dimensions: lesson structure and content-driven while in the emerging technology integration model, context-based is an added dimension.

3.4.3.b. Institutional Support (IS)

Institutional support refers to the assistance and other forms of support given by the institution and administration. Under the validated technology integration model, IS has two dimensions: Capacity building and quality of technology, architecture, design and system, while in the merging technology integration model, research in technology development is an added dimension.

3.4.3.c. Outcomes

Outcome is the third variable in the technology integration model. The model attempts to produce quality STEAM learners and professionals who are critical thinker, productive citizen and innovative. On the other hand, the emerging model includes possessing 21st Century skills as one outcome in producing quality STEAM learners and professionals.

3.4.4. Illustration of Practice

Table 3.1 shows the technology integration practices of the STEAM teachers grouped according to their respective STEAM disciplines.

Table 3.1. Technology integration practices among the STEAM teachers

STEAM	Technology Integration Practices	SAMR (Substitute, Augment, Modify, Redefine)	Triple E (E1-Engage, E2-Enhance, E3-Extend)	TPACK (TK, PK, CK, TCK, TPK, PCK, TPCK)

Science	Use of PowerPoint presentation in presenting and delivering the lesson.	S	E1	TPCK
	Models of a cell, other improvised models are used to enhance learning.	A	E2	TPCK
	Use of PowerPoint in presenting and delivering the lesson.	A	E1	TPK
	Use laptops, computers, speakers, LCD projector as an aid in teaching.	A	E1	TK
	Use flash, clicker response, android dictionary and computer software to deliver a lesson.	A	E3	TPCK
	Blended learning and computer-aided learning are used to augment learning.	A	E1	TK
	Technology is integrated with the use of PowerPoint, flash, videos, models, internet and the use of technology tools such as whiteboard, LCD projector, and computer software to delivering lessons.	M	E3	TPCK
	These technology tools are used as part of the teachers' pedagogical practices such as content-based instruction, lecture, laboratory and to integrate to other disciplines.			
Technology	Use animation with integration to other disciplines.	R	E3	TPCK
	Aided with simulation and computer graphics and computer software to enhance learning activity.	A	E1	TCK
	Read online materials	A	E1	TCK
	Integrate human anatomy in teaching body animation.	R	E2	TPCK
	Aided with Use simulation and computer graphics and computer software.	A	E1	TCK
	Use of PowerPoint in presenting and delivering the lesson.	A	E1	TPK
	Use laptops, computers, speakers, LCD projector, smart TV as an aid in teaching.	S	E1	TK
	Immediate feedbacks with the use of computer.	A	E2	TPK
	Hands-on with computer activities.	A	E2	TPCK
	Technology is integrated with the use of PowerPoint, flash, videos, models, internet and the use of technology tools such as whiteboard, LCD projector, computer software to delivering lessons.	A	E1	TPK

Engineering	Integration of Galton Board.	M	E2	TPCK
	Use visualization like graph/dot matrix.	S	E2	TPK
		A	E1	TPK
	Use laptops, computers, speakers, LCD projector as an aid in teaching.	A	E1	TPK
	Use of PowerPoint in presenting and delivering the lesson.	A	E2	TPK
	Equipment and tools are used to enhance lesson delivery.	A	E2	TPK
	Technology integrated activities like a strategy game, graph activities interactive video are used.	A	E1	TPK
	Lecture-discussion coupled with PowerPoint, video.			
Agri-Fisheries	Use PowerPoint (computer aided learning) **but limits teacher's interaction with* students.	A	E1	TPK
	Use of PowerPoint in presenting and delivering the lesson.	A	E1	TPK
	Teaching lesson is aided with a PowerPoint.	A	E1	TPK
Mathematics	Use flash quiz.	A	E2	TK
	Use excel in solving matrices/linear problems.	S	E2	TCK
	Use computer-aided learning	A	E2	TK
	Software like SPSS is used.	S	E2	TK
	Visualization of graph function.	S	E2	TK
	Use laptops, computers, speakers, LCD projector as an aid in teaching.	A	E1	TPK
		A	E1	TPK
	Teaching tools such as whiteboard, PowerPoint, videos, LCD projector, calculators, computers.	R	E3	TPCK
	Integration of the topic to the real-world and to other related disciplines using technology integration.			

Table 3.1 shows the technology integration practices of the STEAM teachers when grouped according to their respective disciplines of specialization. These practices were coded based on classroom observation notes, interview transcripts and teachers' responses to the open-ended questions in the survey. Using SAMR framework, augmentation is found to exhibit in the technology practices demonstrated among the STEAM teachers. In augmentation, teachers often use technology as a direct tool substitute with functional improvement to enhance learning, and the least goes to modification, which would allow use of technology for significant task redesign to configure learning transformation (Microsoft Asia News Center, 2018). This phase is followed by substitution in which technology acts as a direct tool substitute without functional change (Microsoft Asia News Center, 2018). As per STEAM discipline, the most number of practices is in Technology and the least in Agri/Fisheries. Various technology integration practices based on SAMR in all STEAM disciplines except in Agri/Fisheries

dominate augmentation level. Seemingly, STEAM teachers exhibit a vision for higher level of technology integration to provide transformational atmosphere of learning to bring the Filipino learners to a level of self-directed learning (Heick, 2018) which the students need in this era.

Triple E framework provides the model for educators to measure how well technology tools integrated into lessons are helping students to meet the learning goals (Triple E Framework, .n.d.). The framework is based on three components: Engagement, Enhancement, and Extension. In terms of Triple E framework, the majority of the technology integration practices exhibited by the STEAM teachers show engagement in learning in which these technology integration practices allow the students to focus on the learning activity and motivate learning. Some technology integration practices are observed to enhance learning goals, as particularly observed in Engineering, Technology and Mathematics disciplines. Additionally, technology integration intends to reinforce the STEAM teachers' pedagogical practices by integrating technology on the common teaching methods such as lecture-discussion, laboratory, and inquiry-based approach, among others. In the Science discipline, notably technology integration is practiced to extend students' learning to other disciplines. The results may give STEAM teachers insights into advancing or furthering the integration of technology to increase students' engagement in learning, better yet, enhance and extend learning to connect and apply to the real world.

The technology integration practices of the STEAM teachers are also described using the TPACK framework that mostly concentrated on TPK, TK, and TPCK among all the the dimensions of TPACK framework. Considering that STEAM teachers are disciplined-based professionals all experts in their respective disciplines—they use technology as part of their pedagogical approach in the delivery and presentation of their STEAM lessons. Meanwhile, TCK is the least identified dimension in the technology integration practices of the STEAM teachers. This finding may mean that discipline-based is a basic consideration in integrating technology and that content knowledge influences the development of TPCK (Cetin-Berber & Erdem, 2015). Among the STEAM disciplines, science teachers seem to have more TPCK practices in their technology integration while all other disciplines are taking their skills to integrate technology further enough to prompt them to enhance their professional development to further explore technology integration as part of their pedagogical practices.

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CHAPTER 4

ABSTRACT

CHAPTER 4
The Assessment Model

Celina P. Sarmiento, Levi E.Elipane, Brando C. Palomar, Marie Paz E. Morales

Fundamental to STEAM education is quality assessment in that it promotes student learning and confirms students' conceptual understanding, learning progress, and achievement throughout the teaching-learning discourse. It is a dynamic and cyclical process wherein teachers learn about their students, as they also learn with their students, that may provide greater positive impact on students' learning. This chapter presents the details and features of the Philippine STEAM Assessment model developed through an exploration study, observing a three-tiered analysis of interview transcriptions, observation notes, and existing documents from sampled HEIs (SUC levels 1 and 2, LUCs and non-autonomous private schools) all over the country.

Furthermore, a two-tiered validation process by experts, administrators, and practitioners was done to establish the suitability and appropriacy of the model for STEAM education and its alignment to the dimensions of the Technological Pedagogical and Content Knowledge (TPACK), domains and strands of the Philippine Professional Standards for Teachers (PPST), and the Policies, Standards, and Goals (PSG) set by the Commission on Higher Education (CHED). Two models were derived from the validation process, the Validated and the Emerging Models of STEAM assessment. The Validated Model represents the exact and observed assessment practices that transpired in the collected data. The Emerging Model was created to incorporate the suggestions of the validators, many of whom come from SUC levels 3 and 4 and autonomous private schools.

In both models, the first three variables: Enablers, Drivers, and Processes of STEAM assessment encapsulates the fourth, that defines the target STEAM outcomes: Critical Thinker (21st Century Skills in the Emerging Model), Productive Citizen, and Innovative STEAM Professional or Learner. The models represent the framework that ensures the quality of assessment in STEAM education. It may guide the different educational stakeholders in grasping the many aspects of assessment in STEAM. It also offers a series of TPACK aligned indicators that would guide different institutions in developing, implementing, evaluating, and internalizing policies and guidelines that ensure quality assessment. Lastly, it defines the attributes of teaching competencies, insofar as it establishes the requirements for advancement in each career stage (Beginner, Proficient, Highly Proficient, Distinguished) of a STEAM educator

Keywords: model variable, quality assessment, teaching and learning discourse, teaching competencies

4.1. The Model Defined

4.1.1. Why the Assessment Model (Rationalize the Need for the Model)

Key-technologies propel industrial revolutions that result in societal changes. The 4th Industrial Revolution (IR4), characterized by high level of complexity and the incorporation of total network of product and production process (Dombrowski & Wagner, 2014), blurs the barriers between the physical and digital worlds (Kazançoğlu & Özkan Özen, 2018), its vision prompted by technological notions and solutions to attain a blending of the economy of scale with the economy of scope (Dombrowski & Wagner, 2014). These advancements are led by the emergence of modern disciplines like robotics, Artificial Intelligence (AI), Internet of Things (IoT), biotechnology, nanotechnology, autonomous vehicles, 3D printing, quantum computing, material science, and energy storage (Diwan, 2017). The impact of IR4 is felt not only in business, governance and the people, but also affects education, thus the term Education 4.0 was born (Sinlarat, 2016).

Education 4.0 addresses the necessities of IR4 where human capabilities and technological innovations are aligned to permit new opportunities (Hussin, 2018; Harkins, 2008). Interestingly, Fisk (2017) and Goldsberry (2018) noted that the new goals of learning encourages learners to develop both knowledge and skills required, and to recognize the sources of information to become lifelong learners able to acquire knowledge and skills on their own. Education is built around the learners as to where and how to learn and tracking their performance is done through data-based customization. In this connection, peers become very vital in the acquisition of learning. Considerably, they learn together and from each other, while the teachers assume the role of facilitators in their learning.

A countrywide movement to promote the viewpoint of Education 4.0 is stipulated in the Philippine Development Plan 2017-2022 (National Economic and Development Authority (NEDA), 2017), has driven all sectors of the government to innovate for progress. Specifically, significant changes in all levels of education to attain internationalization, globalization, IR4, and the country's economic development through technological advancement, research and innovation, and the acceleration of human capital emphasize developing attributes and qualities of STEAM (Science, Technology, Engineering, Agri-Fisheries, Mathematics)-skilled professionals (National Economic and Development Authority (NEDA), 2017). Since then, government agencies, such as the Commission on Higher Education (CHED), have made concentrated efforts to foster successful STEAM education. For instance, the CHED has clearly articulated the value of STEAM education in the national curriculum to ensure its inclusion in the planning of classroom instruction. Ironically, however, little is known about how STEAM education is actually implemented in school. In particular, we barely know of how teachers, as a key agent of policy implementation, valorize and practice assessment in STEAM education.

Willis and Cowie (2014) view assessment as a 'generative dance' wherein assessment is 're-imagined as a dynamic space where teachers learn about their students, as they learn with their students, and where all students can be empowered to find success and, in turn, develop learner agency' (p. 23). Assessment can provide indicators of learners' progress according to defined standards or through certain norms within a period of learning, as well as performance and achievement at the end of the learning period. Quality assessment takes into consideration both cognitive and affective domains, and must be informed, purposeful, authentic, valid, and reliable (Teachers' guide to assessment, 2016). Studies show that quality assessment may have better impact on student learning than any other intervention (Davies, Herbst, & Reynolds, 2012). Furthermore, data exhibit that all students benefit from quality assessment practice (William, 2011). Thus, a model that can underpin the components involved in the STEAM assessment process is necessary for the STEAM education community. It will provide various STEAM education stakeholders a structured conceptual blueprint involved in the practices of STEAM educators in executing assessment along with the details of the different factors that influence its implementation.

4.1.2. The Assessment Model is…

The STEAM assessment model provides a holistic picture of the major considerations of STEAM educators in delivering quality assessment. It makes use of three key domains: (1) variables of the assessment model, (2) dimensions of the assessment model, and (3) quality indicators of the assessment model; in which we find the blending of core practices, the cyclical and dynamic process, and the crosscutting dimensions central to the assessment process. The model that comes in two forms, validated and emerging, serves as a framework wherein the implications are clear for what STEAM stakeholders, most especially what the teachers must do to deliver a quality assessment. It also equips them with assessment literacy that could advance their career stages.

4.1.3. The Assessment Model is NOT…

The model far from reflecting the ideal assessment practices, but rather mirrors the most dominant and best practices of Philippine STEAM teachers as documented in the gathered data. It does not either aim to be a prescriptive model of what should be done, though mirrors the actual situation and reflects the insights of STEAM stakeholders. Furthermore, the model echoes the assessment process and practices from an investigation that takes STEAM as an all-inclusive discipline; thus, it may not necessarily indicate features specific to individual STEAM areas.

4.1. 4. What is new about the Assessment Model?

The development of the STEAM assessment model followed five consecutive steps: (1) development of the first version from the codes and memos derived from the gathered data; (2) validation of the first version with STEAM experts, coordinators, and administrators; (3) adjustment of the model on the basis of the first validation; (4) validation of the adjusted model through a capability building program with practitioners (2nd validation); and (5) adjustment of the model based on the 2nd validation.

The final output features a Validated Assessment Model, which captures the confirmed assessment practices of Higher Education STEAM teachers, as derived from the data; plus an Emerging Assessment Model that reflects additional facets and inputs that expert validators shared. Both the Validated and Emerging models embody the assessment process and the best practices unique to the Philippine STEAM education. Moreover, it is aligned to the dimensions of the Philippine Professional Standards for Teachers (PPST), the Policies, Standards and Goals (PSG) of CHED, and the components of the Technological, Pedagogical, and Content Knowledge (TPACK). Lastly, the model defines the attributes of teaching competencies, as well as establishes the requirements for advancement in each career stage (Beginner, Proficient, Highly Proficient, Distinguished) of a STEAM educator.

4.1.5. Salient Features of the Assessment Model

The model developed clearly represents the collective idea of the Philippine STEAM assessment process. Specifically, the assessment model:

1. Identifies the support system that enables quality assessment
2. Documents the drivers of assessment in STEAM education
3. Ensures unified assessment process
4. Captures the best STEAM assessment practices in the Philippines
5. Highlights the target STEAM outcomes
6. Incorporates the dimensions of PPST, PSG, and TPACK

4.1.6. What is the Assessment Model?

The Validated STEAM Assessment Model (Figure 4.1) makes four prominent variables, represented by the four layers in the figure, that comprise thirteen dimensions influencing the overall framework of assessment in the Philippine STEAM Education. The first three variables from the outermost layer going inwards are represented as concentric circles encapsulating the fourth (the innermost layer).

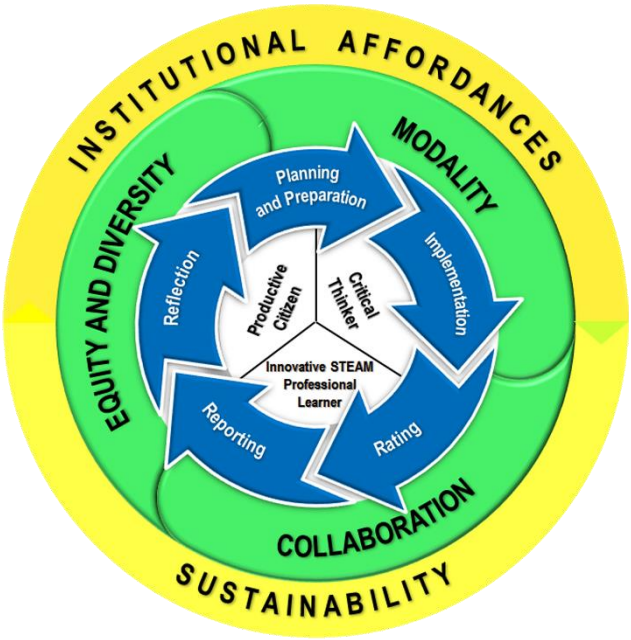

Figure 4.1. The Validated STEAM Assessment Model

The first variable includes the (A) **"Enablers"** of STEAM Assessment which occupies the outermost layer of the model. This variable has two dimensions, (1) ***Institutional Affordances*** and (2) ***Sustainability***, and considered crucial as it highlights the capabilities, forces, and resources that contribute to the success of the assessment process. The first dimension refers to the properties, facilities and policies of educational institutions or an aspect of its environment that describes and aids their STEAM assessment process. The second dimension values the efforts and practices exerted to secure, maintain, and improve the quality of the STEAM assessment process; involving the various research initiatives that aim to oversee and enhance assessment. The connection between the two dimensions indicates the significant linkage between the two and how one influences the other.

The second variable–the (B) **"Drivers"** of STEAM Assessment–is displayed as the next layer of the model. It enumerates the key factors and main considerations in the STEAM assessment process and direction. These factors are categorized into three dimensions: (3) ***Equity and Diversity***, (4) ***Collaboration***, and (5) ***Modality***. By and large, these three dimensions ensure the inclusion of all types of learners, accommodate the context and locale of the students, and make certain that each has a fair and equal opportunity during the assessment process, maintain the dynamic and engaging interactions that exist between various key players in the assessment process, and bestow the use of varied and appropriate tools and methods for various purposes of assessment in the STEAM learning-teaching discourse.

The third variable enumerates the (C) **"Processes"** of STEAM Assessment, located in the third inner layer of the model. This variable identifies five stages which depict the last five dimensions of the model: (6) ***Planning and Preparation***, (7) ***Implementation***, (8) ***Rating***, (9)

Reporting, and (10) ***Reflection***. They represent the different phases of reflective instruction where assessment principles are observed and practiced. The arrows pointing from one stage to the other symbolize that the STEAM assessment follows a specific order and the cyclical nature of the process. Furthermore, the Process of STEAM Assessment, with its corresponding indicators (correlated with the Drivers of STEAM Assessment) commands the assortment of STEAM assessment practices. It also defines the attributes of teaching competencies, if not, establishes the requirements for advancement in each career stage (Beginner, Proficient, Highly Proficient, Distinguished) of a STEAM educator.

The last variable, appearing at the kernel of the model, specifies the desired (D) ***"Outcomes"*** of STEAM Education. It sets forth the intended trait and characteristics of STEAM learners and graduates, categorized into three dimensions: to be (11) ***Innovative STEAM Professional Learner***, (12) ***Critical Thinker***, and (13) ***Productive Citizen*** (members of the society); that also serves as a metric of a successful delivery of STEAM education.

Figure 4.2. The Emerging STEAM Assessment Model

The Emerging STEAM Assessment Model (Figure 4.2) resembles the Validated STEAM Assessment Model, with minor extension in some areas, one of which incorporates ***Innovation*** as a driver of STEAM assessment. This additional dimension (a total of 14 in the Emerging Model) seeks to apply creativity and problem-solving skills in utilizing and maximizing resources in the STEAM learning-teaching discourse. Another difference between the validated and emerging model lies in expanding the outcome "Critical Thinking" into "21st Century Skills", that requires a gamut of abilities that a STEAM graduate should possess. Aside from critical thinking, *21st Century Skills* also foster problem solving capacity and higher order thinking skills, as **sine qua non** in this information technology era.

4.2. Alignment of the Assessment Model to TPACK and Other Theories (PPST and PSG)

One of the major considerations in developing the STEAM assessment model lies on its alignment to the dimensions of TPACK, the domains and strands of PPST, and the indicators of the CHED's PSG. The evaluation process with experts and stakeholders was also observed to ensure the validity of the assessment model and its adherence to the aforecited constructs; results indicate that they were incorporated in the developed model.

Setting forth three components such as Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) and its combinations, the TPACK framework addresses the demands of Education 4.0 (Nurhadi, Purwaningsih, Masjkur, & Nyan-Myau, 2019). All these components are reflected in the assessment model (specifically in the processes variable of STEAM assessment) since the latter pinpoints the role of technology in STEAM assessment as well as focuses on how the content is integrated in the process. The alignment of the model to the TPACK ensures that teachers are able to properly assess the current set of students, expected to have acquired skills for collaborating, problem solving, innovative thinking, and the ability to utilize information and communication technology to the fullest (Valtonen, et al., 2017).

On a similar note, significant changes are about to happen in light of the new PPST that was recently institutionalized in the Department of Education (DepEd, 2017) and eventually by the Commission on Higher Education to bring about greater attention to assessment of learning and even the appraisal of programs in the of STEAM education. The alignment to the PPST and to the PSG of CHED of the STEAM assessment model is then deemed to facilitate the process, especially that we are still in the nascent stages of implementation. Rather than be very positivist – the purpose is to engender deeper rationalizations on how the agency could still be upheld and developed, given the different contexts of each institution. The assessment model appears far being thought of to align assessment forms with the drivers identified and thus recalibrate learning among students, as it is considered to influence the teaching cultures in the educational institutions.

Besides, the PPST specifies standards for teaching, as they align with the subject/course contents. Therefore, the alignment feature of the model represents a rigorous initiative to ensure that the PPST are met, while at the same time, challenges Philippine education – such as quality, equity, and relevance in the light of STEAM – are addressed in such a way that assessment practices are influenced. However, in being able to do so, support must be in place to adopt and implement the STEAM aligned with TPACK, PPST, and PSG to be achieved/done. Considering that institutional affordances and support have been a very important element of the model, the implication is that there ought to be valid, reliable, fair, equitable, and relevant system for assessments.

4.3. Purposes of the Assessment Model

A practicing STEAM educator at any level or discipline does not need to reinvent new ways and processes when looking for effective and efficient ways to ensure quality assessment implementation. After all, numerous educational models could serve as their compass towards meeting goals set for students' learning. Simply put, models offer ways in which instructional experiences and learning environments can be created, organized, or delivered (Wilson, n.d.). They offer instructional or theoretical scaffolds, patterns, visualizations or illustrations for various educational components.

The developed model is an instrument that can be used by teachers, administrators, and other stakeholders concerning assessment practices, as observed in the instructional planning and delivery, because it can help:

A) Teachers:
   1. follow a logical and systematic assessment process;
   2. conceptualize either a more uniform or varied assessment strategies, guided by targeted content or subjects;
   3. become reflective practitioners who continuously improve assessment tools and delivery;
   4. gain insights about various assessment methods, purposes, tools and techniques in relation to students' learning;
   5. understand the many factors that drive assessment practices and processes; and
   6. radically adjust and reconfigure existing assessment practices and instructional delivery to better meet the needs of the target STEAM outcomes.

B) Administrators and educational authorities:
   1. provide technologies and facilities that aid the delivery of quality assessment;
   2. develop and implement policies and programs that secure the successful delivery and sustainability of the assessment process;
   3. furnish appropriate and updated assessment trainings and tools to STEAM teachers; and
   4. promote, encourage, and assist research initiatives that oversee and enhance assessment.

Also, the developed STEAM assessment model projects a coherent image of the components and factors that guarantee quality assessment implementation, to assist teachers and other stakeholders in further developing assessment literacy. From a sociocultural perspective, Willis and colleagues (2013) define assessment literacy as follows:

> "*… a dynamic context dependent social practice that involves teachers articulating and negotiating classroom and cultural knowledge with one another and with learners, in*

the initiation, development and practice of assessment to achieve the learning goals of students." (p. 242)

The assessment model can serve as a shared language that may enable teachers to engage in critical inquiry of their assessment practices, enough to lead them to re-evaluate and adjust their principles and understandings of the assessment process. Through a roadmap that directs towards assessment literacy, teachers can be supported in developing the required skills to attain proficiency in assessment and equip them with the appropriate environment and technology to successfully deliver assessment, vital in quality STEAM education. The technology integration model may yet address the teacher quality and the students' learning, particularly cognitive and affective components. The model intends to provide opportunities for the STEAM educators to update or adapt to new technology used in the classroom and to provide opportunities to capacitate STEAM educators. Furthermore, their effort might probably lead to integrate technology in innovative teaching strategy and thus further improves the teaching. More pointedly, the model outlines the cogency of technology integration to produce quality STEAM learners.

4.4. The Model Explained

This section discusses the domains and the corresponding components of the Assessment Model.

4.4.1. Domain Overview

The developed model comprises three major domains: (1) Variables of the assessment model; (2) Dimensions of the assessment model; and (3) Quality indicators of the assessment model, presented in detail below.

4.4.1.a. Variables of the Assessment Model

A variable is a characteristic or quality, magnitude or quantity that can undertake transformations and that is subject to analysis, measurement, assessment, or control during a research endeavor (Arias, 2012). In terms of STEAM Assessment, the study adapted the definition of a variable as a characteristic that expresses the feature of the practices of STEAM teachers in terms of assessment. Four variables are reflected in the integrative model developed for Assessment in STEAM education. The first variable is the Enablers of STEAM Assessment, so crucial that it embraces the capabilities, forces, and resources that contribute to the success of the assessment process. The second variable refers to the Drivers of the STEAM Assessment, which enumerate the key factors and main considerations in the STEAM assessment process and direction. The third variable, Process of STEAM Assessment, describes the procedure and progression of STEAM teachers' practices in conducting

assessment. Lastly, the fourth variable, labeled as Outcomes of STEAM education, reflects traits and characteristics of STEAM learners and graduates. The last variable is considered as one of the metrics of success in STEAM education that contributes greatly in pedagogical planning, instructional implementation, and assessment considerations of teachers and other stakeholders.

4.4.1.b. Dimensions of the Assessment Model

The dimensions specify the route of the actions and cover the distinctive feature of the whole, as an integrated piece (Butter, Aguilera, Quintana, Pérez, & Valenzuela, 2017), each of which catches a single aspect of STEAM assessment, but when fused together offers a holistic picture of the entire assessment process. The validated model proposed in this study contains 13 dimensions, while the emerging model has 14. The first two dimensions of both the validated and the emerging identify the components that enable STEAM Assessment, as the next three dimensions in the validated and the next four in the emerging make it possible to recognize the considerations of STEAM teachers in conducting assessment. Whereas the last five dimensions in both itemize the stages of the STEAM assessment process. The dimensions and working definition for each is presented in Table 4.1.

Table 4.1. STEAM model dimensions and corresponding working definition

Variables	Dimensions	Working Definition
A. Enablers of STEAM Assessment	Dimension A1: **Institutional Affordances**	Refers to the properties or facilities of educational institutions or an aspect of its environment and policies that aids the STEAM assessment process.
	Dimension A1.1 **Curriculum Development**	The various approaches followed by institutions in continuously updating their curriculum for improvement.
	Dimension A1.2 **Institutional Identities**	The unique characteristics and features that define an institution.
	Dimension A1.3 **Agency and Empowerment**	Purposeful initiatives and actions of institutions that empower those involved in the assessment process.
	Dimension A2: **Sustainability**	Efforts exerted to secure, maintain, and improve the quality of the STEAM assessment process.
	Dimension A2.1: **Quality Assurance**	The verification procedures implemented whether internally or externally that ensure that the desired level of quality in the assessment process is met.
	Dimension A2.2: **Research Undertakings**	The different research initiatives that aim to oversee and improve the assessment process.
	Dimension A2.3: **Policies and Programs**	The system of principles implemented by the institution as a procedure or protocol that guides the STEAM assessment process.

B. Drivers of STEAM Assessment	Dimension B1: **Ensuring Equity**	Ensuring inclusion of all learners and making certain that each student has a fair and equal opportunity during assessment process.
	Dimension B1.1 **Gender Sensitivity**	Understanding and taking into account gender equality in the assessment process.
	Dimension B1.2 **Monitoring and Feedback**	Practices in checking the result, progress, and quality of the assessment and providing constructive information for improvement.
	Dimension B1.3 **Student Interests and Expressions**	Considerations in observing the behavior, expressions, and response of students that might affect the assessment process.
	Dimension B1.4 **Contextualization and Localization**	Factors undertaken in placing and adjusting the assessment process to accommodate the context and locale of the students.
	Dimension B1.5 **Ethics**	Moral principles that govern the assessment process.
	Dimension B2: **Pursuing Collaboration**	Dynamics that exist between the various key players in the assessment process.
	Dimension B2.1 **Student-to-Student**	Interaction among students during the assessment process.
	Dimension B2.2 **Teacher-to-Teacher**	Interaction among teachers during the assessment process.
	Dimension B2.3 **Teacher-to-Student**	Interaction between teachers and students during the assessment process.
	Dimension B2.4 **Community Involvement**	Community participation in the assessment process.
	Dimension B2.5 **Involvement of other Stakeholders**	Participation of other stakeholders in the assessment process.
	Dimension B3: **Utilizing Modality**	Varied tools used and methods applied in the assessment process.
	Dimension B3.1 **Tools and Technology**	Various technological tools used in each dimension of the assessment process
	Dimension B3.2 **Types of Assessment**	Different assessment tools or methods used in STEAM for various purposes
	Dimension B4 (Emerging Model): **Innovation**	Application of creativity and problem-solving skills in utilizing and maximizing resources in the STEAM learning-teaching discourse
C. Process of STEAM Assessment	Dimension C1: **Planning and Preparation**	Practices and guidelines observed during the preparation for the assessment process.
	Dimension C2: **Implementation**	Practices during the actual execution of the assessment process.
	Dimension C3: **Grading**	Processes of marking students' performance, outputs and tests, as well as manner of analyzing the results.
	Dimension C4: **Reporting**	Communicating the results of the assessment process to target clientele.
	Dimension C5: **Reflection**	Impressions and actions considered after the analysis of the results of the assessment process.

D. STEAM Outcomes	Dimension D1: **Critical Thinker (Validated) / 21st Century Skills (Emerging)**	Graduates ability to execute logical, reasoned, and well-thought-out judgments. / Graduates that possess skills, abilities, and attitude necessary to succeed in the 21st century workplaces.
	Dimension D2: **Productive Citizen**	Graduates that are able and have the proper disposition to contribute greatly to the growth and development of the nation.
	Dimension D3: **Innovative STEAM Professional**	Well-trained professionals adapted to today's market needs and societal demands.

4.4.1.c. Quality Indicators for STEAM Assessment

Indicators are a set of features or characteristics that allow or establish the description and evaluation of certain dimensions of a variable. They are usually presented in varied ways like a checklist that measures the achieved degree of quality or as guiding questions.

The study generated a total of 53 quality indicators distributed to the first three variables, useful in verifying the extent of STEAM assessment in the Philippines. These indicators are divided into two groups, presented in Table 4.2 and Table 4.3. The first nine (9) indicators describe distinctive features of the enablers that greatly contribute to a quality assessment in STEAM. The rest of the indicators enumerate teachers' practices that ensure successful assessment and correspond to both the process and the drivers of assessment in the validated STEAM assessment model.

Table 4.2. Dimensions and indicators of variable 1: enablers of steam assessment

Dimensions	Indicators
Dimension A1: **Institutional Affordances**	
Dimension A1.1 **Curriculum Development**	(1) Observation of practices and programs to continuously improve and attain the curriculum
Dimension A1.2 **Institutional Identities**	(2) Presence and utilization of appropriate technology that aids the assessment process
	(3) Appropriations of financial support for improving the assessment process
Dimension A1.3 **Agency and Empowerment**	(4) Existence of continuing faculty development programs and activities related to assessment
	(5) Presence of guidelines for hiring new faculty members
Dimension A2: **Sustainability**	
Dimension A2.1: **Quality Assurance**	(6) Existence and implementation of internal quality assurance practices
	(7) Existence and implementation of external quality assurance practices
Dimension A2.2: **Research Undertakings**	(8) Conduct of research projects/programs in improving the assessment practices
Dimension A2.3: **Policies and Programs**	(9) Existence and implementation of policies and programs ensuring quality of the assessment process

Additionally, the TPACK dimensions (TPCK: Technological Pedagogical Content Knowledge, TCK: Technological Content Knowledge, PCK: Pedagogical Content Knowledge, TPK: Technological Pedagogical Knowledge, TK: Technological Knowledge, PK: Pedagogical Knowledge, CK: Content Knowledge) are emulated in the *Process* of STEAM assessment. The indicators of the aforecited variable were associated with the corresponding TPACK dimension, as shown in Table 4.3.

Table 4.3. Indicators of variable 2: drivers of STEAM assessment and variable 3: process of STEAM of assessment and corresponding TPACK dimension

Variable 3: Process of STEAM of Assessment	**Variable 2: Drivers of STEAM Assessment (Dimensions)**	**Indicators**	**TPACK Dimension**
Dimension C1: **Planning and Preparation**	B1.4; B3.2	(10) Ensures balanced distribution of items in terms of content	PCK
	B1.4; B3.2	(11) Includes real life application problems (since the application is usually disciplined specific)	PCK
	B1.2	(12) Remediates students' difficulties and misconceptions	PCK
	B2.2; B2.4; B2.5	(13) Involves other experts and stakeholders in the assessment process	PCK
	B1.4; B3.1; B3.2	(14) Uses various reliable references (including online sources) to create assessment tools	CK
	B1.1; B1.3; B1.4; B3.1; B3.2	(15) Considers the different background of students in terms of language, circumstances (some are returnees), learning styles, pacing, etc. and contextualizes the assessment	PK
	B1.4; B3.2	(16) Ensures balanced distribution of items on tests in terms of difficulty and assessment tools	PK
	B1.3; B1.4; B3.2	(17) Includes questions that provoke HOTS (high order thinking skills) and critical thinking	PK
	B1.4; B3.2	(18) Involves repetition of items/activities for mastery of skills	PK
	B1.2	(19) Interprets the result of previous assessment and uses it to design the next	PK
	B1.4; B3.2	(20) Selects appropriate assessment based on the competencies and expected outcome	PK
	B1.3; B1.5; B2.3	(21) Orients learners about expectations for the assessment and how they will be graded	PK
	B1.2	(22) Ensures the quality of assessment	PK
	B1.2; B1.5	(23) Plans rules that students must adhere to	PK
	B1.2; B2.1; B2.3; B3.1; B3.2	(24) Identifies the appropriate type of grouping	PK
Dimension C2: **Implementation**	B1.3; B1.4; B3. 2	(25) Encourages students to create (and improve their output)	TPCK
	B1.3; B1.4; B3.1; B3.2	(26) Utilizes both traditional and authentic tasks	TPCK

	B1.4; B3.1; B3.2	(27) Integrates technology to innovate assessment implementation	TPCK
	B2.4; B2.5	(28) Coordinates with other stakeholders in the assessment process	PCK
	B1.2; B1.3; B1.4; B3.2	(29) Exercises the art of questioning (rephrase questions that students cannot understand)	PCK
	B1.3; B1.4	(30) Observes students' expressions	PK
	B1.4; B3.1; B3.2	(31) Uses assessment for/of/as learning	PK
	B1.2; B1.5	(32) Provides clear definite instructions	PK
	B1.2; B1.5	(33) Ensures proper monitoring of the assessment implementation	PK
	B1.1; B2.1; B2.3	(34) Assigns roles to students (leaders, monitors, recorders, participants, etc.)	PK
Dimension C3: **Rating**	B1.5; B3.1	(35) Integrates technology to innovate rating of submission	TPCK
	B3.1; B3.2	(36) Uses rubrics	PCK
	B1.2; B1.3; B1.4; B3.1; B3.2	(37) Identifies students' difficulties	PCK
	B1.2; B1.5; B2.3; B3.2	(38) Rates outputs and performances according to standards (set and agreed)	PCK
	B1.2; B3.1	(39) Conducts item analysis (difficulty and discrimination)	PK
	B1.2; B1.3; B1.5; B2.3; B3.1; B3.2	(40) Ensures the quality of student submission	PK
	B1.2; B1.5; B2.2	(41) Deliberates the grade to be given to the student (some schools do team-teaching)	PK
Dimension C4: **Reporting**	B1.2; B3.1; B3.2	(42) Integrates technology in reporting the assessment results	TPCK
	B1.2; B1.5	(43) Monitors the number of students who reached the standards and progress of each student	PCK
	B1.2; B1.5; B2.3	(44) Informs students about the results of the assessment for/of/as learning	PK
	B1.1; B1.2; B1.5	(45) Practices academic integrity and fairness	PK
	B1.2; B1.5	(46) Maintains confidentiality of results	PK
	B1.2; B2.3	(47) Provides recommendations	PK
Dimension C5: **Reflection**	B1.2; B3.1	(48) Evaluates the effectiveness of integrating technology in innovating the assessment	TPCK
	B1.2; B1.3; B1.4; B2.3;	(49) Analyses reasons/factors for students' difficulties and misconceptions	PCK
	B1.2; B1.5; B3.1	(50) Encourages students to reflect on the result of their assessment	PCK
	B1.2; B1.3; B2.3	(51) Evaluates the need to re-teach the lesson or move-on to the next	PCK
	B1.1; B1.2; B2.2; B2.3; B3.1	(52) Uses item analysis to improve assessment	PCK
	B1.2	(53) Improves classroom practices based on the results of the assessment	PCK

4.4.2. Continuum of Practice

This section presents the traits and characteristics that STEAM educators must possess in each career stage. Each continuum level of teacher proficiency assumes proficiency at the previous level.

4.4.2.a. Beginner

They possess knowledge in using assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement.

4.4.2.b. Proficient

They exhibit effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement; they manifest capability of using assessment data to address challenges in implementing effective teaching and learning practices

4.4.2.c. Highly Proficient

They participate and cooperate in a collective, complete, and sensible planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based programs and plan of actions for better progress in student learning.

4.4.2.d. Distinguished

They model, exemplify, and mentor in planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and in designing of assessment-based programs and plan of actions for better progress in student learning.

4.4.3. Suggested Resources

Information culled and analyzed from the transcripts of the interview and competencies demonstrated during the classroom observations described the resources of the assessment model into three levels – (1) individual, (2) peer/ faculty, and (3) institutional. These levels of resources are anchored on the assessment methods, tools, guidelines and processes, practiced and aspired by STEAM faculty members and administrators. These resources of the assessment model covers from the regulation and principles, as prescribed by CHED and implemented by the institution, to the actual assessment requirements and practices, as observed by individual and among faculty members.

More specifically, the institutional level of resources highlights the facilities, properties and policies, as described by the "enablers" of the assessment model. It further describes the mechanisms on how the institution responds to the assessment needs, provides physical facilities and creates clear processes and policies in translating the assessment specifications and standards for the delivery and enhancement of STEAM courses. These resources include the institution's assessment-related programs for quality assurance, curriculum improvement, personnel empowerment, research undertakings and branding. More specifically, it also stresses the intuitional procedures and parameters in maintaining and improving quality of the assessment context in all "processes" of the model. Expectedly, institutions have identified directions and rules concerning assessment from the planning-preparation process up to the reporting and reflection process, as highly reflected on the institutional actions in adhering with PSGs, constructing physical and online learning environments, enhancing course programs and aligning syllabi with standards like the PPST.

Conversely, the peer-faculty level of resources accentuates on the practice of ensuring equity and diversity, promoting collaboration and utilizing modalities for assessment. These resources are manifested in the "drivers" of the model, where the faculty or unit of the institution established assessment mechanisms and practices related to students' interest and expression, gender- and cultural-sensitivity, ethical considerations and matters on contextualization and localization. This level of resources also describes the varied purposes of assessment (as, of, for learning) being observed in the delivery of STEAM courses all shown on the assessment guidelines, tools and technology set and used by the faculty, together with their aspirations on improving and innovating the assessment understanding and practices of their unit.

The last level of resources reflects the assessment practices of the individual STEAM educator as demonstrated on his or her daily learning-teaching discourses. Moreover, these resources are the instructor's unique and contextualized pedagogical assessment strategies and tools in demonstrating the "drivers" in the different "processes" of the model to achieve the "outcomes" of STEAM education. More particularly, these assessment resources are highly utilized by the individual educators in the whole learning-teaching cycle. They cover the insights gained by the educators and translate them to the planning of instruction, enacting of STEAM courses, rating and reporting of STEAM learners' academic performances, reflecting on the strength and weaknesses of the instructional practice based on students' feedbacks, then return to the drawing board of planning based on certain insights gained. Besides, such level of resources provides information if these very resources from the institutional level are properly cascaded and translated in the sheer experiences of both STEAM educators and learners. It also captures both the strength and limitations of the resources provided by the institution and the faculty, together with the innovative responses of the individual STEAM educators in the context of assessment.

4.4.4. Illustration of Practice

This section provides representations and evidences of the different variables defined in the assessment model. They cover actual practices, aspirations and limitations on the context of assessment derived from the competencies demonstrated during the classroom observations and from the key features culled on the transcript of the interviews with the STEAM educators and administrators.

In the context of the enabler variables of the assessment model, the "institutional affordances" are emphasized through the capacity of the institution in providing a conducive learning environment, adequate physical facilities and properties, substantial financial and appropriations, and training programs that support the underpinnings and processes of assessment so as to realize the standards in delivering STEAM education. It also includes assessment practices integrated in the institutional programs to attain STEAM courses, faculty development activities and guidelines, and to utilize technology. Comparably, "sustainability" is represented in terms of the initiated programs and policies concerning assessment practices of the institution, as aligned with the regulations prescribed by CHED and other educational reforms. It also defines the assessment programs of the institution concerning internal and external quality assurances, research endeavors and action plans for improvement. To illustrate, both enablers are markedly pronounced on the program descriptions, methodologies and sets of technology related to assessment, as stipulated on the course syllabi of STEAM disciplines. They are also presented in the context of classroom functionality, facility availability and restrictions, and practices of technology integration in relation to assessment specifications for local quality assurances and for describing intuitional performances.

The practices of ensuring "equity and diversity" were demonstrated via the aspirations and positive attitudes by STEAM educators toward their learners with varied cultural backgrounds and academic profiles. It was also presented by practicing ethical considerations and confidentiality along with establishing clear academic expectations and protocols. In addition, it observed using student feedbacks, situational cases, rubrics and real life applications in assessing their understanding and learning, as well as by humanizing the procedure of technology for assessment practices. Conversely, "collaboration" variable was highlighted by the actual practices and yearnings of promoting teamwork and establishing academic relationship among STEAM educators and learners. Equally, it captured the assessment practices, as observed in the community and other stakeholder partnerships made possible through extension programs and service learning projects. The "modality" variable was established with the use of varied conventional and authentic assessment strategies and tools by STEAM educators in evaluating learners' understanding and related-skills. Lastly, it presented the practice of the use of technology for assessment and research undertakings.

These practices under the "driver" variable are commonly observed in all aspects of the "process" variable of the assessment model. For example, during the planning and preparation process, STEAM educators observe appropriate distribution of the content on a particular instruction, identify students' misconceptions and difficulties, list questions that promote

critical thinking skills, develop competency-based instruction and organize mechanisms for students' grouping. The appropriate use of traditional and authentic assessment tools, provision of clear assessment instruction and expectations, practice of students' appraisal and mechanisms for monitoring formative and summative tests were resorted to as assessment practices of STEAM educators during the implementation of instruction process. For the rating and reporting processes, STEAM educators showed good understanding of the use of criteria and rubrics, practices item-analysis, observed academic integrity and confidentiality, provided recommendation and feedback, and measured technology effectiveness related to assessment practices. Moreover, assessment practices observed in the reflection process helped identify students' difficulties and misconceptions in learning STEAM courses, enhance test construction, and raise the level instructional delivery and learning environment.

STEAM educators established these assessment practices at different levels and manifestations of observing equity and diversity, stimulating collaboration, employing modalities and introducing novelties to realize the functions of assessment in the actual learning-teaching cycle. They demonstrated these practices, as anchored on the goal of their course discipline to produce STEAM learners with attributes of being innovative professionals, critical thinkers and productive citizens, despite the constraints and other academic and administrative-related challenges encountered.

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CHAPTER 5

ABSTRACT

CHAPTER 5
The Philippine STEAM Education Model

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Science, Technology, Engineering, Agri/Fisheries, Mathematics (STEAM) Education dominates the factors that contribute to national growth and development. This study developed the Philippine STEAM Education (PSE) Model to visualize the Philippine Higher STEAM Education and to check how far we are from the global standards. Grounded on theories (Commission on Higher Education Policies, Standards, and Guidelines [PSG's], Philippine Professional Standards for Teachers [PPST], and Technological Pedagogical Content Knowledge [TPACK]), the study sourced its data from online survey (extracted from 1900 STEAM educator respondents [national survey]), classroom observations and interviews of 106 participants determined through stratified and random sampling of a number of state universities and privately-managed colleges and universities. Coding (manual and software aided) directed the model (Pedagogical, Assessment, Technological Integration) generation.

These models guided the decoding of all indicators of STEAM proficiency attributes and traits to the different TPACK dimensions (T, P, C, PC, TC, TP, TPC) from where the dimensions of the emerging TPACK framework for Philippine Higher STEAM Education surfaced. Analyses of the generated individual domain models (Pedagogical, Assessment, Technological Integration) unified and developed the PSE Model that underwent three-tier validation by experts in the different STEAM disciplines and country-wide identified STEAM educators. The results of the development and validation processes generated the final validated PSE Model that presents a visual of the current Philippine STEAM Education. However, the model development and design process identified several constructs foreseen to forecast the ideal Philippine STEAM Education, which the country hopes for, thus, led to crafting the emerging PSE Model, as envisioned to represent the Philippine STEAM Education in the 21st century. From these crafted models, the higher education agency of the country may initiate carving policies for STEAM education in the nation. R & D (Research and Development) may consider extending this initial endeavor to spawn tools (in assessment), and processes (in pedagogy and technology integration) to capitalize on the benefits of the generated models of Philippine STEAM Education.

Keywords: assessment, pedagogy, technology integration, Science, Technology, Engineering, Agri-Fisheries, Mathematics (STEAM) Education

5.1. Introduction

The Philippine Development Plan (PDP 2017-2022) underscores specific strategic goals and development processes of the Philippine government to realize the envisioned future of every Filipino to enjoy *"Matatag* (stable), *Maginhawa* (comfortable), *and Panatag na buhay* (assured quality of life)*."* The country held that the 2040 goals (spelt out as *AmbisyonNatin* 2040) might be concretized through the three priority areas of the development plan, valorizing: 1) *malasakit* (enhancing the social fabric of concern); 2) *pagbabago* (reducing inequality); and 3) *patuloy na pag-unlad* (increasing growth potential). These three priority areas emphasize among other areas, promotion and awareness of Philippine culture, acceleration of human capital development, promotion of technology, and stimulation of innovation. Apparently, the make-up of the PDP framework puts STEAM as among the cores to achieving the 2040 goals. Thus, necessitates cross-cutting strategies, which may be derived from quality STEAM education for the Filipinos.

As part of the strong foundation, the government needs to accelerate the Human Resource for both highly-trusted and resilient society and globally-competitive knowledge economy. This segment of the development plan features strategies to achieve quality in all levels of education, from achieving a broad stroke quality, accessible, relevant, and liberating basic education program for all, to featuring teacher quality, and quality higher education and technical education accentuating Science, Technology and Innovation field. Thus, a cogent role is entrusted to the Philippine education, teacher quality and Philippine STEAM education for the government to realize the full potential of its workforce, contributory to the achievement of its intended visions.

5.2. Purposes

The attempt is to model the Philippine Higher STEAM Education and check how far we are from the global standards. Specifically, the study sought concrete retorts to the following objectives:

- Develop the Philippine Higher STEAM Education Pedagogical Model and the Philippine Higher STEAM Education Assessment Model
- Set forth the Philippine Higher STEAM Education Technology Integration Model
- Design and come up with the TPACK Model for Philippine Higher STEAM Education
- Devise the Philippine STEAM Education Model

5.3 Theories

In developing the varied frameworks to model the Philippine Higher STEAM education, significant contributions of the different theories, policies, and standards (e.g., Philippine Policies, Standards and Guidelines [PSGs], Philippine Professional Standards for Teachers

[PPST], and Technological, Pedagogical Content Knowledge [TPACK]), contextualized the aforementioned Philippine Higher Education STEAM education model.

5.3.1. Policies, Standards, and Guidelines (PSGs)

Agencies, whether government-owned or privately-managed, adhere to instituting documentary requirements such as policies, standards, and guidelines to ensure security of information within the organization while specifying operating and control details (Policies, Standards and Guidelines, 2009). Organizations typically have four types of documents in place:

- ***Policies***
    - Agencies consider this document as high-level signed by a person of significant authority (such as a corporate officer, president, or vice president, commissioner). This document generally states that a particular high-level control objective is important to the agency's success, which requires mandatory compliance.

- ***Standards***
    - These mid-level documents ensure uniform application and implementation of a policy. Generally, compliance is mandatory, after securing approval. All standards are used as reference points to ensure organizational compliance and are regarded as norms to technical systems that support and help the policy.

- ***Guidelines***
    - The documents intend to determine the course of action containing non-mandatory controls defined to support the standards. These are meant to provide advice pertaining to how organizational objectives might be obtained in the absence of a standard. Guidelines commonly are strongly recommended best practices, and may contain additional recommendations that support and improve controls defined in a standard.

Accordingly, the Philippine Commission on Higher Education (CHED) adopted the Outcomes-based education (Biglete, 2018) to address the call for quality assurance in Philippine Higher Education (Commission on Higher Education Memorandum Order [CMO], No. 46, 2012). This effort consequently updated the Commission's policies, standards, and guidelines. Inclusive of such revisions are: 1) combination of minimum required general education subjects, core subjects, professional or major subjects cum electives, 2) work or experiential learning as part of the curriculum, and 3) ranges of the minimum required total number of credit units for undergraduate programs. Interestingly, almost all programs of the Commission required revision of their respective PSGs, to cover the following key elements:

A. Program Specifications

a. Program Description
    1. degree name
    2. nature of the field of study
    3. program goals
    4. specific professions/ careers/ occupations for graduates

b. Program Outcomes/Set of Learning
    1. Common to all programs in all types of schools
    2. Common to the discipline
    3. Specific to sub-discipline and a major
    4. Based on HEI's mission and vision

c. Sample Performance Indicators

B. Curriculum

a. Curriculum description
b. Sample curriculum
c. Sample curriculum map
d. Sample means of curriculum delivery
e. Sample syllabi for selected core courses

C. Minimum Required Resources

a. Administration
b. Faculty and staff
c. Library, Laboratory & Physical Facilities

5.3.2. Philippine Professional Standards for Teachers (PPST)

The Philippine Quality Framework (PQF, 2012) is a competency-based and labor-market driven national policy, that assures quality of development, recognition and award of qualifications based on standards of knowledge, skills and values acquired in different ways and methods by learners and workers of the country. The framework influences actions and strategies (spelt in PDP 2017-2022) to achieve globalization, internationalization, Industrial Revolution 4.0 (IR 4.0), and the country's economic growth through technological innovations, research and innovation, and the acceleration of human capital. These two national policies (PDP & PQF) illustrate qualities of the Philippine human capital, specifically extracting elaborations of these policies in teacher quality, which the Philippine Professional Standards of Teachers defines (PPST, 2017).

PPST (2017) outlines the needed competencies and skills of quality teachers to enable them to manage and handle emerging global frameworks. Specifically, PPST's aims for: "1) setting clear expectations of teachers along well-defined career stages of professional development from beginning to distinguished practice; 2) engaging teachers to actively embrace a continuing effort in attaining proficiency; and 3) applying a uniform measure to assess teacher

performance, identify needs, and provide support for professional development" (DepEd adopts PPST, 2018).

This Philippine standard includes seven (7) domains, which collectively comprise 37 strands that refer to more specific dimensions of teacher practices:

Domain 1, Content Knowledge and Pedagogy (with 7 strands):

- Content knowledge and its application within and across curriculum areas
- Research-based knowledge and principles of teaching and learning
- Positive use of ICT
- Strategies for promoting literacy and numeracy
- Strategies for developing critical and creative thinking, as well as other higher-order thinking skills
- Mother Tongue, Filipino and English in teaching and learning
- Classroom communication strategies

Domain 2, Learning Environment (with 6 strands):

- Learner safety and security
- Fair learning environment
- Management of classroom structure and activities
- Support for learner participation
- Promotion of purposive learning
- Management of learner behavior

Domain 3, Diversity of Learners (with 5 strands):

- Learners' gender, needs, flaws, strengths, interests and experiences
- Learners' linguistic, cultural, socio-economic and religious backgrounds
- Learners with disabilities, giftedness and talents
- Learners in difficult circumstances
- Learners from indigenous groups

Domain 4, Curriculum and Planning (with 5 strands):

- Planning and management of teaching and learning processes
- Learning outcomes aligned with learning competencies
- Relevance and responsiveness of learning programs
- Professional collaboration to enrich teaching practice
- Teaching and learning resources including ICT

Domain 5, Assessment and Reporting (with 5 strands):

- Design, selection, organization and utilization of assessment strategies
- Monitoring and evaluation of learner progress and achievement
- Feedback to improve learning

- Communication of learner needs, progress and achievement to key stakeholders
- Use of assessment data to enhance teaching and learning practices and programs

Domain 6, Community Linkages and Professional Engagement (with 4 strands):

- Establishment of learning environments that are responsive to community contexts
- Engagement of parents and the wider school community in the educative process
- Professional ethics
- School policies and procedures

Domain 7, Personal Growth and Professional Development (with 5 strands):

- Philosophy of teaching
- Dignity of teaching as a profession
- Professional links with colleagues
- Professional reflection and learning to improve practice
- Professional development goals

5.3.3. Technological, Pedagogical, Content, Knowledge (TPACK)

This framework is heavily influenced by Shulman who acknowledged that merely understanding the subject matter is insufficient to teach a subject. It is the teacher's PCK that makes quality and effective teaching (Karaman, 2012; Park & Oliver, 2007; Shulman, 1987). Researchers identified several factors that may influence teacher's PCK: 1) attendance to workshops and trainings (Clermont, Borko & Krajcick, 1994); 2) content knowledge (Aydin et al., 2009; Kaya, 2009; Usak, 2005; Villaluz, 2005); 3) knowledge of student conception and learning difficulties (Geddis, 1998; Van Driel et al., 1998); and 4) curriculum knowledge and knowledge of instructional strategies and assessment (Magnusson et al., 1999; Usak, 2005).

Guided by the dramatic technology revolution in the 21st century, Clark (2010) held that integrating technology in the curriculum and instruction will bring about significant student achievement leading to deep understanding of concepts. As defined by Clark (2010) "meaningful integration" of technology refers to the process of matching the most effective tool with the most appropriate pedagogy to achieve the learning goals of a particular lesson. A match on this desire are the goals of Mishra and Koehler (2006) of injecting technology on Shulman's (1986) concept of pedagogical content knowledge (PCK) to address the growing prominence of digital technologies in instructional settings. Geared towards tapping the transformative benefits and potentials of introducing technologies in instructional setting, Mishra and Koehler (2006) described the integration of technology into the teaching and learning system as Technological Pedagogical Content Knowledge (TPCK). Adhering to the belief that TPCK formed an integrated whole, the framework was later renamed as TPACK for Total PACKage (Thompson & Mishra, 2008). As a framework, TPACK focuses on the

complex interactions between teacher's knowledge of the content (CK), pedagogy (PK), and technology (TK). Mishra and Koehler (2006) further postulated that a teacher who can navigate between these interrelations acts as an expert much far different than a lone subject matter, pedagogy, or technology expert. With this framework, technology education has become an integral part of teacher education. In fact, assessing the effectiveness of technology education in the development of teachers' TPACK has been the trend in TPACK researches (Angeli & Valanides, 2009; Niess, 2008; Schmidt et al., 2009). Park, Jang, Chen and Jung (2011) even assessed teachers' level of TPACK using a rubric based on observations of teaching practices and pre/post observation interviews. PCK rubric was also developed by Gardner and GessNewsome (2011) using video tapes of teachers' classroom instructions, interviews and written reflections. Additionally, probable categories and profiling of STEAM educators through their TPACK competencies may provide better capacity building strategies as well.

This project envisions to design Quality Tertiary Education consequently aligned to the Philippine and Asian quality standards for quality assurance; and jibes with the themes of *"AMBISYONNATIN 2040:" "Matatag, Maginhawa, at Panatag na Buhay* (Philippine Development Plan [PDP], 2017)." The country suggested that the 2040 goals might be concretized through the three priority areas of the crafted Philippine Development Plan: 1) *malasakit* (enhancing social fabric); 2) *pagbabago* (reducing inequality); and 3) *patuloy na pag-unlad* (increasing growth potential). These three priority areas emphasize among others promotion and awareness of Philippine culture, acceleration of human capital development, promotion of technology, and stimulation of innovation. Apparently, the make-up of the PDP framework puts STEAM as among the cores to achieving the 2040 goals. Thus, necessitates cross-cutting strategies, that may be derived from quality STEAM education for Filipino learners.

This desire for quality STEAM Education is grounded on providing concrete, multi-faceted and interdisciplinary solutions to complex issues and problems that the country usually faces, as brought about by man-made and natural-caused factors. A well-thought of STEAM Education should include all facets of learning defined by the TPACK Framework which includes: Technology integration, innovative pedagogical approaches, appropriate assessment tools, and content standards and competencies. These existing frameworks must have reached the realms of the Philippine Higher Education, yet, concrete implementation of schemes to translate such a framework to concrete outputs may be nil. Thus, this study focuses on developing an emerging TPACK Model for Philippine STEAM Education anchored on the TPACK Framework, PPST, and 46 PSGs, but customized to Philippine STEAM Education to identify the TPACK competencies of STEAM educators; determine the most innovative and appropriate pedagogical approaches for Filipino learners; specify the useful assessment tools to formative development and assessment of learning; model technology integration and identify content standards and competencies of STEAM Education unique to Filipino STEAM learners, but consider global significance to bring them to better competitive stance. This study, thus, provides directions, pathways, and rubric in the field of STEAM education for better management of learning, development of quality STEAM human resources, STEAM literacy

to enhance life management, resources management, risk reduction, and work for sustainability of knowledge and resources for quality living.

5.4. Procedure

The generation of the different models and the emerging TPACK model for Philippine Higher STEAM Education highly depended on sourced data from online survey (extracted from 1900 STEAM educator respondents [national survey]), classroom observations and interviews of 106 participants determined through stratified and random sampling of state universities and privately-managed colleges and universities.

Coding (manual and software aided) directed the model (Pedagogical, Assessment, Technological Integration) generation. These models guided the decoding of all indicators of STEAM proficiency attributes and traits to the different TPACK dimensions (T, P, C, PC, TC, TP, TPC) from where the variables, dimensions, and indicators of the emerging TPACK model for Philippine Higher STEAM Education termed as "The Philippine STEAM Education Model" surfaced. Crafting of the different attributes per dimensions ended the model generation process.

5.5. The Philippine STEAM Education Model (Validated)

The validated model for Philippine STEAM Education is anchored on the TPACK framework, but customized to the Philippine STEAM Education. This model exemplifies innovative, appropriate, and contextualized **pedagogy, assessment,** and **technology integration** in educating the Filipino learners. Sourced from practicing STEAM teachers in the sampled HEIs (SUC levels 1 and 2, LUCs and non-autonomous private schools) in the entire archipelago with two stages of validation process, the model represents the current condition of STEAM teachers in the identified HEI clusters. It is envisioned that the model captures the exact conditions of the STEAM teachers in the identified clusters of HEIs and provides and enhances the teaching competencies of STEAM Educators for them to fluidly traverse the career stages (Beginner, Proficient, Highly Proficient, Distinguished) looking forward to attaining quality in Philippine STEAM Education to develop and craft Generation Z learners with specialized skills (e.g., design thinking, technical know how, and time management) in preparing these citizens to be part of Workforce 4.0. As visualized in Figure 5.1, the model affords directions, pathways, and way forward in the field of STEAM education in these HEI clusters for better management of learning to develop quality STEAM human resources as outcomes, and enhances STEAM literacy to improve life management, resources management, risk reduction and sustainability of knowledge and resources to develop lifelong learning skills for quality living.

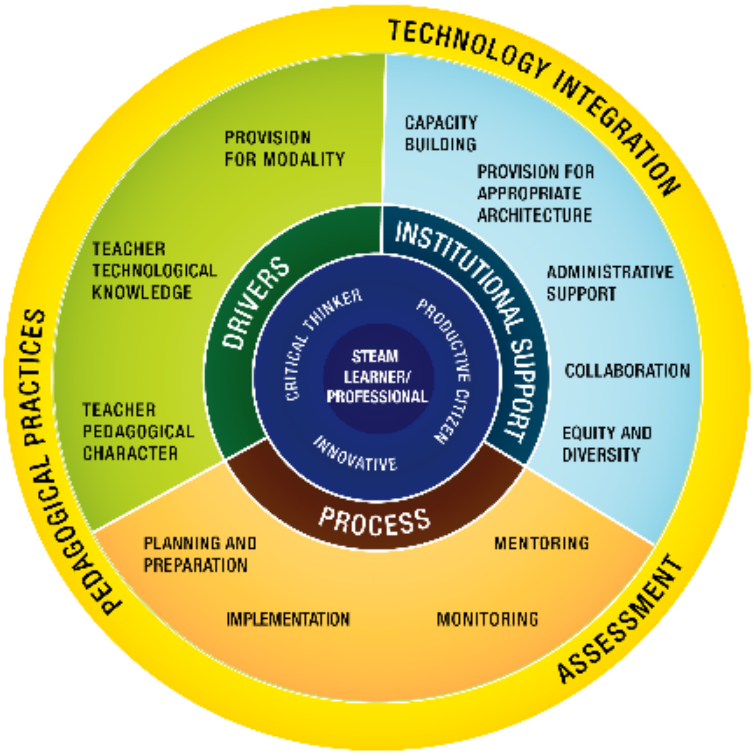

Figure 5.1. The Philippine STEAM Education Model (Validated)

The model in Figure 5.1 shows a wheel-like image emphasizing the three teaching and learning domains (pedagogy, assessment, and technology integration) situated in the outermost part of the wheel, which stress the convolution (entanglement) of the three domains to influence STEAM education.

As a visual fruition of the weaving nature of the three teaching and learning domains, four major variables surfaced as common to the domains: *outcomes* (represented as innovative STEAM learner or professional, critical thinker, productive citizen), *drivers, institutional support*, and *processes*. The circular nature of the model emphasizes balance and equality between and among the variables. The color scheme accentuates the lead institution's and the funding agency's branding underscoring blue (darker shade of the innermost image) to mean intellect and freshness, to represent the outcomes (as innovative STEAM learner or professional, critical thinker, productive citizen), as one of the major variables of the model. Radiating outward are the three other variables with their corresponding dimensions colored in dark blue (for the institutional support) to stress knowledge, power and integrity; green (for drivers) to display harmony of dimensions and variables as well; and brown (for processes) that signifies being down to earth, sustained for stability, and being supported with good structure. Dimensions in the process variable are represented by yellow that exhibits intellect, energy, warming effect, stability, and spontaneity. This chosen color (yellow) seeks to represent the process variable, that exemplifies the TPACK framework generating the seven dimensions that stand for the seven-knowledge system a STEAM educator should develop to marvel upon, as much as disentangle the intricacies and uniqueness of STEAM teaching and

learning. The color signifies the childlike nature of the variable (as yellow is often used as the color of toys) modelling a playroom-like environment that focuses on the learning and the learners (Color Theory in Action, 2015). The uneven number of variables fitting in the stable stance of the three variables, symbolize equity in the teaching and learning domains. Since all data were sourced from less performing HEIs (SUCs levels 1 and 2, LUCs, non-autonomous private institutions) in the country offering STEAM programs, inescapably, though, people tend to insist on quality, the concept of equity issues in the three variables: that institutional support, drivers and processes can hardly be glossed over.

5.5.1. Variables of the Model

The Philippine STEAM Education model adopts the definition of variable as a characteristic or quality, magnitude or quantity, that can undertake transformations and that stands subject to analysis, measurement, assessment, or control during a research endeavor (Arias, 2012; Wright & Lake, n.d.). In STEAM Education, a variable is defined as a characteristic that expresses the feature or parameter (that is, a parameter is an element of a system that is useful, or critical, when identifying the system, or when evaluating its performance, status, condition, etc.) of the practices of STEAM educators in terms of the three domains of teaching and learning: Pedagogy, Assessment, and Technology Integration. Four variables were reflected in the integrative model developed for Philippine STEAM education: outcomes, drivers/enablers, institutional support and the processes. Each variable covers several dimensions that enumerate the scope of the variable in terms of Philippine STEAM education. The dimensions, as described in this model, frame the route of the actions and cover the distinctive feature of the whole, as an integrated piece (Butter, Aguilera, Quintana, Perez, & Valenzuela, 2017). Specifically, a dimension of a variable seizes a single aspect of STEAM model. Sourced from the three education domains, the study identified common dimensions from the domains to match the intentions and roles for each of the aforesaid variables.

5.5.1.a. Outcomes

This variable appears as the core of the Philippine STEAM Education model. Generally, ***outcomes*** are the expected result of a program or a project. These are very specific statements or phrases that describe exactly what a learner will be able to do in a measurable way (Gosselin, n.d.). In the context of the philosophy of Outcomes-based Education (OBE) that the country advocates, higher and advanced learning in all disciplines refers to outcomes expected of the schools to achieve.

Drawn from the model analysis of the three domains and from the three-tier validation, outcomes of the Philippine STEAM Education sourced from the major STEAM pedagogical processes that includes STEAM human resource who: a) shows critical thinking skills, b) is an innovative STEAM professional/learner, and c) exhibits being a productive citizen (member of the society).

5.5.1.b. Drivers

The second variable refers to the Drivers of Philippine STEAM Education *(teacher technological knowledge, teacher pedagogical character, provision for modality)*, detailing the key factors and main considerations of STEAM education in the country. They include knowledge, conditions, or set of characteristics of people that initiate and support the activities for which the Philippine STEAM education is designed.

5.5.1.c. Institutional Support

This vital variable refers to the capabilities, forces, and resources that contribute to the success of the Philippine STEAM Education processes. The variable traces the support of the institution to STEAM Education processes, covering *capacity building, provision for appropriate architecture, administrative support, collaboration and equity and diversity*. Particularly, administrative support dwells on infrastructure, program and manpower management, finance and other administrative concerns. Collaboration captures the range of institution-initiated and supported collaborations, strengthened by research collaboration between and among institutions, and instructional and research collaboration among faculty and staff within and among institutions.

5.5.1.d. Processes

The last variable refers to the mechanisms and progressions of STEAM teachers' STEAM education practices covering the three education domains: pedagogy, assessment and technology integration. The process variable *(planning and preparation, implementation, monitoring, mentoring*) involves a wide spectrum that features plan of action, course and line of action, drills, practices and strategies with reflective means to sustainable operation of processes of educating STEAM learners.

Dimensions of the Models

Coded responses from Philippine STEAM educators supplied the major indicators sourced from the three domains and clustered in the different dimensions of the model, and then labeled as per TPACK framework. In this model, the term *"Indicators"* is taken as a set of features or characteristics that allow or establish the description and evaluation of certain dimensions of a variable. They usually come in varied ways like a checklist that enables the measurement of the achieved degree of quality or as guiding questions. Figure 3 shows the detailed map of the variables, and the dimensions in each variable with the different corresponding indicators labeled according to TPACK framework knowledge constructs. Mind mapping is a technique used to represent all enumerated specifics and connections of variables and construct relations

of the model's variables, dimensions, and indicators. To code the indicators in the corresponding knowledge in TPACK framework, colors were used.

5.6. The Philippine STEAM Education Model (Emerging)

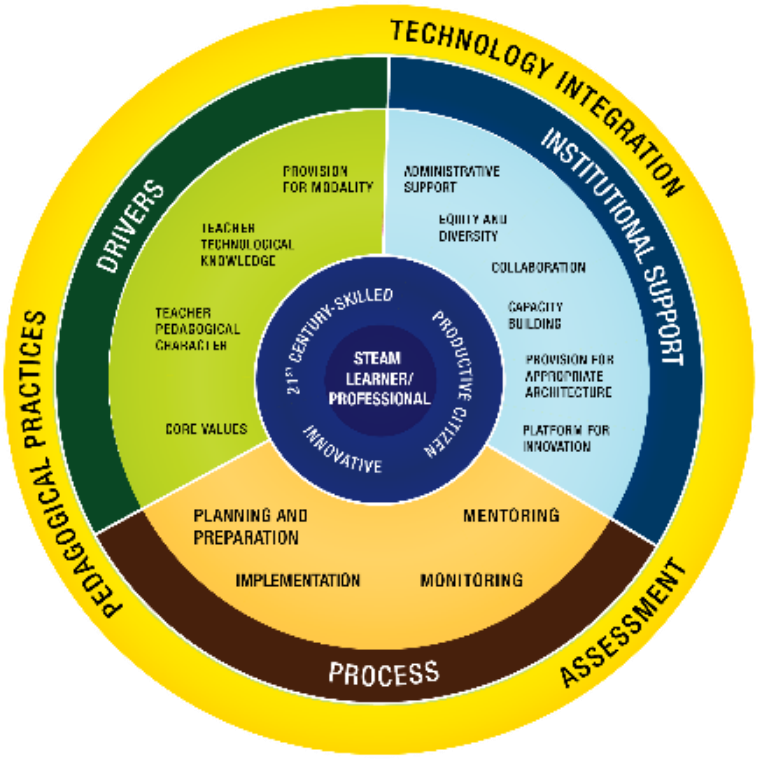

Figure 5.2. The Philippine STEAM Education (Emerging)

The emerging model for Philippine STEAM Education is anchored on the TPACK framework but customized to the Philippine STEAM Education. This model exemplifies innovative, appropriate, and contextualized **pedagogy, assessment,** and **technology integration** in educating the Filipino learners to become productive citizens, innovative STEAM professionals, and 21st century-skilled human resource. Sourced from practicing STEAM teachers in the sampled HEIs (SUC levels 1 and 2, LUCs and non-autonomous private schools) in the entire archipelago, and from the inputs of exemplar STEAM educators from Philippine HEIs tagged as Centers of Excellence (COE) and Centers of Development (COD), the emerging model visualizes the Philippine STEAM Education goal to produce outcomes (*productive citizens, innovative STEAM professionals, and 21st century-skilled human resource*) to improve the country's STEAM condition and enhance its global and international metrics as well. It is envisioned that the model captures the exact conditions of the STEAM teachers in HEIs, and at the same time provides and enhances the teaching competencies of

STEAM Educators for them to fluidly traverse the career stages (Beginner, Proficient, Highly Proficient, Distinguished) looking forward to attaining quality in Philippine STEAM Education to develop and craft Generation Z learners with specialized skills (e.g., design thinking, technical know-how, and time management) to prepare these citizens to be part of Workforce 4.0. Additionally, the model (as visualized in Figure 1) affords directions, pathways, and way forward in the field of STEAM education for better management of learning to develop quality STEAM human resources as outcomes, and enhances STEAM literacy to improve life management, resources management, risk reduction and help sustain of knowledge and resources to develop lifelong learning skills for quality living.

The model in Figure 5.2 shows a wheel-like image emphasizing the three teaching and learning domains (*pedagogy, assessment, and technology integration*) situated in the outermost part of the wheel, stressing the convolution (entanglement) of the three domains to influence STEAM education.

As a visual output of the weaving nature of the three teaching and learning domains, four major variables surfaced as common to the domains: outcomes (*represented as innovative STEAM learner or professional, 21st century-skilled human resource, productive citizen*), drivers, institutional support, and processes. The circular nature of the model upholds balance and equality between and among the variables. The color scheme accentuates the lead institution's and the funding agency's branding underscoring blue (dark shade of the innermost image) to mean intellect and freshness, representing the outcomes (*indicated as innovative STEAM learner or professional, 21st century-skilled human resource, productive citizen*), as one of the major variables of the model. The inward orientation of the model depicts the concerted efforts of the variables (*drivers, pedagogical practices, and institutional support*) and the dimensions in each variable in attaining the envisioned outcomes, as nuances of colors accentuate the meanings. The three other variables with their corresponding dimensions are shown in dark blue (for the institutional support) to account for knowledge, power and integrity; green (for drivers) to display harmony of dimensions and variables as well; and brown (for processes) to signify being down to earth, sustained for stability, and being supported with good structure. Dimensions in the process variable are represented by yellows that imply intellect, energy, warming effect, stability, and spontaneity. This preferred color represents the process variable, supposedly exemplifying the TPACK framework generating the seven dimensions that stand for the seven-knowledge system a STEAM educator should develop to marvel upon the intricacies and uniqueness of STEAM teaching and learning. Moreover, the color (yellow) signifies the childlike nature of the variable (as yellow is often used to colors toys) modelling a playroom-like environment that focuses on the learning and the learners (Color Theory in Action, 2015).

The uneven number of variables fitting in the stable stance of the three variables, represent equity in the teaching and learning domains. Since all data were sourced from less performing HEIs (SUCs levels 1 and 2, LUCs, non-autonomous private institutions), and from the inputs of exemplar STEAM educators from Philippine HEIs tagged as Centers of Excellence (COE)

and Centers of Development (COD) in the country offering STEAM programs, it is noted that though people always prefer quality, the study considered and accented on the concept of equity issues in the three variables: ***institutional support, drivers and processes.***

5.6.1. Variables of the Model

The Philippine STEAM Education model adopts the definition of variable as a characteristic or quality, magnitude or quantity, that can undertake transformations and stands as subject to analysis, measurement, assessment, or control during a research endeavor (Arias, 2012; Wright & Lake, n.d.). In STEAM Education, a variable is defined as a characteristic that expresses the feature or parameter (that is, a parameter is an element of a system that is useful, or critical, when identifying the system, or when evaluating its performance, status, condition, etc.) of the practices of STEAM educators in terms of the three domains of teaching and learning (Pedagogy, Assessment, and Technology Integration).

Four variables were reflected in the ***"emerging"*** integrative model developed for Philippine STEAM education: (***outcomes, drivers, institutional support, and processes)***. Each variable covers several dimensions that enumerate the scope of the variable in terms of Philippine STEAM education. The dimensions, as described in this model, frame the route of the actions, and cover the distinctive feature of the whole, as an integrated piece (Butter, Aguilera, Quintana, Pérez, & Valenzuela, 2017). Specifically, a dimension of a variable seizes a single aspect of STEAM model. Sourced from the three education domains, common dimensions from the domains were identified to match the intentions and roles of each of the aforementioned variables.

5.6.1.a. Outcomes

This variable appears as the core of the Philippine STEAM Education model. Generally, ***outcomes*** are the expected result of a program or a project. These are very specific statements or phrases that exactly describe what a learner will be able to do in a measurable way (Gosselin, n.d.). In the context of the philosophy of Outcomes-based Education (OBE) that the country advocates, higher and advanced learning in all disciplines refer to outcomes as expected of schools to achieve.

Drawn from the model analysis of the three domains and from the inputs of experts, the outcomes of the Philippine STEAM Education is defined and sourced from the major STEAM pedagogical processes that cover STEAM human resource equipped with: *a) 21st century-skills, b) innovative STEAM professional/learner, and c) productive citizens (members of the society).*

5.6.1.b. Drivers

The second variable refers to the *Drivers of Philippine STEAM Education (teacher technological knowledge, teacher pedagogical character, provision for modality, and core values),* detailing the key factors and main considerations of STEAM education in the country. They include knowledge, conditions, or set of characteristics of people that initiate and support the activities for which Philippine STEAM education is designed. Specifically, the teacher technological knowledge refers to how STEAM educators understand technology. Their knowledge of technology goes from familiarity with various technology through understanding how to make and use specific technology to identified lessons, and assessing when technology assists or impedes lesson delivery. Teacher pedagogical character features the STEAM educators' epistemological beliefs and pedagogical practices. Provision for modality as one of the drivers, views STEAM education as flexible in delivering all STEAM disciplines. Finally, core values highlight institution-based or directed individual value systems deemed necessary for institutions to determine if they are on the right track in fulfilling their vision, mission and goals, as anchored on the desired STEAM outcomes.

5.6.1.c. Institutional Support

This animated variable refers to the capabilities, forces, and resources that contribute to the success of the Philippine STEAM Education processes. The variable traces the institutional support to STEAM Education processes, involving *administrative assistance, equity and diversity, collaboration, capacity building, provision for appropriate architecture, and platform for innovation*. Specifically, administrative support dwells on infrastructure, program and manpower management, finance and other administrative concerns. Collaboration captures the entirety of institution-initiated and supported collaborations, such as research collaboration between and among institutions and instructional and research collaboration among faculty and staff within and among institutions. Finally, platform for innovation covers all aspects of STEAM education (i.e., products, processes, services, technologies).

5.6.1.d. Processes

The last variable refers to the mechanisms and progressions of STEAM teachers' STEAM education practices covering the three education domains: pedagogy, assessment and technology integration. The process variable *(planning and preparation, implementation, monitoring, mentoring)* involves a wide spectrum that covers plan of action, course and line of action, drills, practices and strategies with reflective means to sustainable operation of processes of educating STEAM learners.

Variables and Dimensions of the Models

Coded responses from Philippine STEAM educators supplied the major indicators sourced from the three domains and clustered in the different dimensions of the model, and then labeled as per TPACK framework. In this model, the term *"Indicators*" is taken as a set of features or characteristics that allow or establish the description and evaluation of certain dimensions of a variable. They usually come in varied ways like a checklist that enables the measurement of the achieved degree of quality or as guiding questions. Figure 5.3 shows the detailed map of the variables, and the dimensions in each variable with the different corresponding indicators labeled according to the TPACK framework knowledge constructs. Mind mapping shows a technique to represent all enumerated specifics and linkages of variables and construct relations of the model's variables, dimensions, and indicators. Colors were used to code the indicators in the corresponding knowledge in TPACK framework.

5.7. TPACK Framework Indicators for Philippine STEAM Education

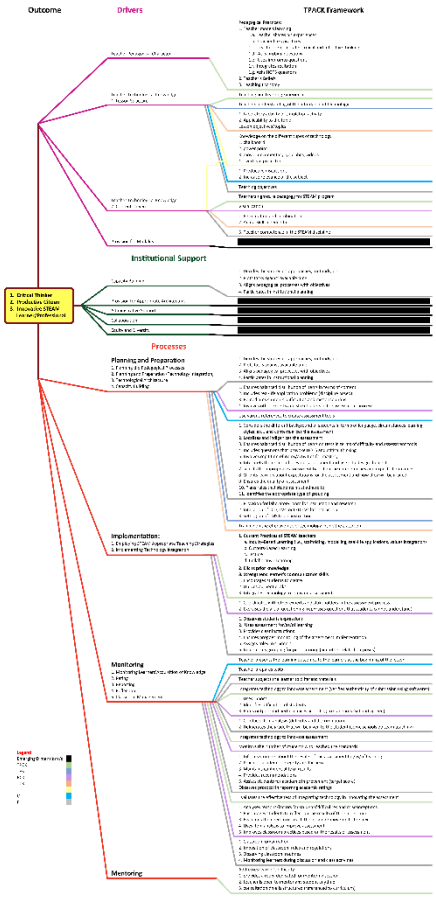

Figure 5.3. TPACK-influenced mapped Indicators and Dimensions of the Philippine STEAM Education Model (Validated)

Outcomes list the least number of dimensions that spell out the products of Philippine STEAM Education: critical thinker/21st-century-skilled (for emerging model), productive citizen, and innovative STEAM learner/professional. As the Model (Figure 5.2) shows, these are the outcomes of the integrated efforts of the remaining variables. Drivers comprise four dimensions with indicators coded following the knowledge developed in the TPACK framework. Among the four knowledge constructs, 1) TPCK (Technological Pedagogical Content Knowledge), 2) and TCK (Technological Content Knowledge, register the most number of indicators of the "Drivers." Similarly, the "Institutional Support" variable only covers five dimensions, but most indicators point to PK (Pedagogical Knowledge). Interestingly, the most represented "Process" variable registers the greatest number of dimensions and indicators per dimension. However, the map (Figure 5.3) reveals that though this variable comprises a handful of indicators (as sourced from STEAM educators in the field), TPCK (5) and PCK (4) come only next to "Pedagogical Knowledge," PK (8) that dominates the entire "Process" variable.

Apparently, the model (with the map in Figure 5.3) exemplifies the current STEAM education in the Philippines and the educators' STEAM education proficiency (quantifiable by using the developed tool: Proficiency Indicators for Philippine STEAM Education with the Scoring Framework [*Appendix I*]), as described, using the TPACK framework. The tagged TPACK dimension shown by the indicators in each of the variables and dimensions of the variables present a linear progression of STEAM education proficiency of educators. As reinforced by sourced data through intensive classroom observations and interviews, the STEAM educators try to singly develop one knowledge construct of the TPACK framework at a time. More often than not, we observe the sequence of development as content, pedagogy, and technology. This might be the case since, STEAM educators are profiled as discipline-specific, higher and advanced learning educators who focus on singular knowledge of the TPACK framework before being able to take a step further to blending the knowledge in the TPACK framework until they eventually attain a status in which they possess an understanding of how: 1) technology applies to represent the concepts of the discipline; 2) to effectively use technology in pedagogical techniques; and 3) technologies can address the difficulties students face when learning the concepts. All attributes mark the success of TPACK in STEAM education, admittedly, a blurred situation current in Philippine STEAM education. Efforts may be emphasized in upgrading the skills and capacity building to help our STEAM educators blend and weave TPACK knowledge for them to easily traverse the Philippine STEAM Educator career stages until they reach the apex or highest identified career stage with attributes provided in Table 1 and the required documents for verification per career stages in the succeeding Tables.

Table 5.1. Attributes of career stages

	Career Stage 1 Beginner/ Novice (They have acquired the skill)	Career Stage 2 Proficient/ Developing (They are applying the skills)	Career Stage 3 Highly Proficient/ Competent (They collaborate to improve their application of skills)	Career Stage 4 Distinguished/Expert (They try to mentor and establish policies)
General Attributes of STEAM Educator	Beginning/Novice STEAM Educators have gained the basic qualifications recognized for entry into the Philippine Higher STEAM Education.	Proficient STEAM Educators professionally rely on the applications of skills vital for them to employ knowledge of STEAM disciplines, language and communication within and across curriculum to support student learning, understanding, engagement and achievement in different STEAM learning contexts.	Highly Proficient STEAM Educators collaborate, share or disseminate knowledge and transfer technology to unfailingly exhibit a high level of competence in their STEAM education practice grounded on local and national perspectives, and research-based undertakings, anchored on globally-acclaimed best and finest suitable practices and principles.	Distinguished STEAM Educators mentor colleagues and initiate policy inputs to exemplify the highest standard for STEAM education grounded on local and national perspectives, and research-based undertakings, anchored on globally-acclaimed best and finest suitable practices and principles.
Knowledge of STEAM Discipline	They have a strong understanding of the STEAM discipline in which they are trained in terms of content knowledge, pedagogy, and integration of technology.	They provide and apply focused STEAM teaching programs that meet curriculum and assessment requirements.	They collaborate to share and disseminate effective application of STEAM discipline, research, language, and communication, within and across curricula to promote STEAM literacy and to develop Filipino learners' critical and creative thinking, and higher-order thinking skills responsive to	Their exceptional capacity to acquire knowledge and exemplar practice to improve knowledge on STEAM disciplines and in the fields of research, languages and communication utilizing STEAM meta-discipline to develop Filipino learners' STEAM skills (e.g., design thinking skills, time management, technical know-how, and cognitive and emotional intelligences) responsive to national and global goals, as

			national and global goals.	shown in their ability to train others in acquiring a strong grasp of the discipline.
Research-based knowledge of STEAM disciplines	They demonstrate possession of research-based knowledge of STEAM discipline, its related fields (research, language and communication and STEAM-related laboratory/clinical skills), and principles of teaching and learning to enhance their professional practice.	They utilize research-based knowledge of STEAM disciplines, its related fields (research, language and communication and STEAM-related laboratory/clinical skills), and principles of teaching and learning to enhance their professional practice.	They manifest an in-depth and sophisticated understanding of STEAM research and are able to collaborate for the conduct and application of STEAM research to promote the welfare of STEAM profession in schools and the community as well.	They exemplify knowledge generation, dissemination, and knowledge sustainability for professional practice, community service to promote the welfare of STEAM profession both schools and the community.
Knowledge, Skills and Values for STEAM teaching and learning processes	They possess the requisite knowledge, skills and values that support the STEAM teaching and learning process. They show possession of knowledge of teaching strategies and they manifest capacity to manage learning programs that promote learning based on the students learning needs.	They demonstrate skills in planning, implementing and managing learning programs and curricula within the STEAM classroom. They manifest a gamut of teaching strategies that promote STEAM literacy and other skills by actively engaging in collaborative learning with the professional community and other stakeholders for mutual growth and advancement.	They support STEAM education by contributing to the STEAM profession as collaborators and participants in projects and programs aimed at forging productive and innovative products, programs and curricula through local and international partnerships. They work together with colleagues in applying research-based pedagogy that promotes inquiry, problem- and product-based learning, curriculum planning, management of	They are recognized as trail blazers in STEAM education, contributors to the STEAM profession and initiators of collaborations that can forge productive and innovative products, programs and curricula through local and international partnerships. They champion modelling and mentoring of research-based pedagogy that promotes inquiry, problem- and product-based learning, curriculum planning, management of learning, and valuable use of technology to create lifelong impact in the lives of other STEAM professionals, colleagues, diverse learners/students and the community.

			learning, and valuable use of technology to create lifelong impact in the lives of other STEAM professionals, colleagues, diverse learners/students and the community.	
Assessment, Monitoring Learning and Feedback System	They have knowledge of the use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement.	They exhibit effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement. They manifest capability in using assessment data to address challenges in implementing effective teaching and learning practices.	They participate and cooperate in a collective, complete, and sensible planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based programs and plan of actions for better progress in student learning.	They model, exemplify, and mentor planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based programs and plan of actions for better progress in student learning.
Professional Development and Personal Growth	They seek professional growth through attendance to conferences, fora, seminars, and workshop to gain knowledge on content and teaching the STEAM discipline from STEAM professionals, and experienced colleagues to constantly improve their practice.	They seek professional growth by presenting research outputs in conferences, fora, seminars, and workshop to disseminate knowledge, and gain knowledge as well on STEAM discipline and on content and teaching the STEAM discipline from STEAM professionals, and experienced colleagues to improve their practice.	They continually aspire to improve their professional and personal growth through knowledge creation, and dissemination, and collaboration with experienced colleagues and STEAM experts and professionals on discipline and on content, and teaching the STEAM discipline.	They sustainably advance and pursue excellence in STEAM quality teaching and research, and commits themselves to inspire the education community and stakeholders to improve education in the Philippines.

Table 5. 2. Required documents for verification (Beginner)

	Career Stage 1 Beginner/Novice	Required Documents for Verification
General Attributes of STEAM Educator	Beginning/Novice STEAM Educators have gained the basic qualifications recognized for entry into the Philippine Higher STEAM Education.	• Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (Undergraduate degree program) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (for Graduate degree-Masters) • Program or Discipline-based required standard (e.g., licensing, certification) • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Others (please specify and provide annotations)
Knowledge of STEAM Discipline	They have a strong understanding of the STEAM discipline in which they are trained in terms of content knowledge, pedagogy, and integration of technology.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus highlighting strong understanding of the STEAM discipline through knowledge of the discipline, pedagogy, and technology integration. • Instructional materials and teaching tools used in the demonstration teaching highlighting possession of strong understanding of the discipline • Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester. • Results of the assessment and performance highlighting understanding of the lesson by the STEAM learners. • Copy of student evaluation • Others (please specify and provide annotations)

Research-based knowledge of STEAM disciplines	They demonstrate possession of research-based knowledge of STEAM discipline, its related fields (research, language and communication and STEAM-related laboratory/clinical skills), and principles of teaching and learning to enhance their professional practice.	• Program or Discipline-based required standard (e.g., licensing, certification) related to research. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Certificates of Participation or Attendance to Seminars, fora, trainings, workshops, conferences. • Others (please specify and provide annotations)
Knowledge, Skills and Values for STEAM teaching and learning processes	They possess the pre-requisite of knowledge, skills and values that support the STEAM teaching and learning process. They have acquired knowledge of teaching strategies, and they manifest capacity to manage learning programs that promote learning based on the students learning needs.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus highlighting strong understanding of the STEAM discipline through knowledge of the discipline, pedagogy, and technology integration. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of attendance/participation to seminars and trainings on teaching strategies i STEAM fields, assessment, technology integration. • Others (please specify and provide annotations)
Assessment, Monitoring Learning and Feedback System	They possess knowledge on using assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement. They manifest capability of using assessment data to address challenges in implementing effective teaching and learning practices	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus highlighting strong understanding of the STEAM discipline through knowledge of the discipline, pedagogy, and technology integration. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of attendance/participation to seminars and trainings on teaching strategies in STEAM fields, assessment

		• Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester • Results of the assessment and performance highlighting understanding of the lesson by the STEAM learners. • Others (please specify and provide annotations)
Professional Development and Personal Growth	They seek professional growth through attendance to conferences, fora, seminars, and workshop to gain knowledge on content and teaching the STEAM discipline from STEAM professionals experienced colleagues to improve their practice.	• Certificates of Participation or Attendance to Seminars, fora, trainings, workshops, conferences. • Copy of their session guide and syllabus highlighting strong understanding of the STEAM discipline through knowledge of the discipline, pedagogy, and technology integration. • Others (please specify and provide annotations)

Table 5.3. Required documents for verification (Proficient)

	Career Stage 2 Proficient/Developing	Required Documents for Verification
General Attributes of STEAM Educator	Proficient STEAM Educators professionally rely on the applications of skills vital for them to employ knowledge of STEAM disciplines, language and communication within and across curriculum to support student learning, understanding, participation, engagement and achievement in different STEAM learning contexts.	• Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (Undergraduate degree program) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (for Graduate degree-Masters) • Transcript of Record or certification of Units taken in a STEAM doctoral program • School-based merit system or promotion system (for private HEIs and LUCs) document of proficiency as a tertiary educator or Rating **(for Assistant Professor level) based on Faculty Ranking and Promotion of NBC 461 (for SUCs)** • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators

		• Membership to Professional Organizations • Student Evaluation • Others (please specify and provide annotations)
Knowledge of STEAM Discipline	They provide focused STEAM teaching programs that meet curriculum and assessment requirements.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the faculty's ability to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Instructional materials, specific discipline-based technology, and teaching tools used in the demonstration teaching highlighting command of his/her STEAM discipline in the teaching and learning process of STEAM learners. • Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester. • Results of the assessment and performance highlighting an **in-depth** understanding of the lesson by the STEAM learners. • Copy of student evaluation • Others (please specify and provide annotations)
Research-based knowledge of STEAM disciplines	They utilize research-based knowledge of STEAM disciplines, their related fields (research, language and communication and STEAM-related laboratory/clinical skills), and principles of teaching and learning to enhance their professional practice.	• Program or Discipline-based required standard related to research (copy of research proposal, completed research, publication). • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Certificates for Presentation of Research in national, regional or international research fora • Membership to research organizations.

		• Certificate of attendance and participation in Research and Publication Capability Building Programs • Copy of published book or instructional materials • Others (please specify and provide annotations)
Knowledge, Skills and Values for STEAM teaching and learning processes	They display skills in planning, implementing and managing learning programs and curricula within the STEAM classroom. They manifest the use of wide range of teaching strategies that promote STEAM literacy and other skills by actively engaging in collaborative learning with the professional community and other stakeholders for mutual growth and advancement.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the faculty's ability to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Minutes of Meeting stipulating attendance and participation in Department-level and/or College-level, curricular workshops. • Memorandum stipulating that STEAM educator is a member of curricular or curriculum committee. • Certification by the head of the department or college dean for collaborative team teaching. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of attendance/participation in seminars and trainings on teaching strategies in STEAM fields, assessment, technology integration. • Others (please specify and provide annotations)
Assessment, Monitoring Learning and Feedback System	They exhibit effective use of assessment strategies, monitoring and evaluation, and feedback system consistent with the curriculum requirement. They manifest capability of using assessment data to address challenges in implementing effective teaching and learning practices	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the faculty's ability to organize the teaching-learning process to enable students to learn

		the required concepts in the STEAM discipline. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of attendance/participation in seminars and trainings on teaching strategies in STEAM fields, assessment, monitoring and evaluation of student learning. • Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester • Results of the assessment and performance highlighting understanding of the lesson by the STEAM learners. • Minutes of Meeting stipulating attendance and participation in Department-level, College-level, Institution-level discussion on assessment results for instructional planning • Others (please specify and provide annotations)
Professional Development and Personal Growth	They seek professional growth by presenting research outputs to conferences, fora, seminars, and workshop to disseminate knowledge and gain knowledge as well on STEAM discipline and on content and teaching the STEAM discipline from STEAM professionals experienced colleagues to improve their practice.	• Certificates of Participation or Attendance to Seminars, fora, trainings, workshops. • Certificates for Presentation of Research in national, regional or international research fora • Membership to research organizations. • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the faculty's ability to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Others (please specify and provide annotations)

Table 5.4. Required documents for verification (Highly Proficient)

	Career Stage 2 Highly Proficient/Competent	Required Documents for Verification
General Attributes of STEAM Educator	Highly Proficient STEAM Educators collaborate, share or disseminate knowledge and transfer technology to unfailingly exhibit a high level of competence in their STEAM education practice grounded on local and national perspectives, and research-based undertakings, anchored on globally-acclaimed best and finest suitable practices and principles.	• Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (Undergraduate degree program) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (for Graduate degree-Masters) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (for Graduate/ Doctorate) • School-based merit system or promotion system (for private HEIs and LUCs) document of proficiency as a tertiary educator or Rating **(for Associate Professor level) based on Faculty Ranking and Promotion of NBC 461 (for SUCs)** • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Active Membership (e.g., joins committee, holds a position in the board) to Professional Organizations • Invited as resource speaker in teaching the STEAM discipline or in the discipline • Author of textbooks or published instructional materials, and research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • With a number of research citations (h-index[google scholar] of at least 3 • Certificate of significant contribution to the community • Student Evaluation • Others (please specify and provide annotations)

Knowledge of STEAM Discipline	They collaborate to share and disseminate effective application of STEAM discipline, research, language, and communication, within and across curricula to promote STEAM literacy and to develop Filipino learners' critical and creative thinking, and higher-order thinking skills responsive to national and global goals.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the use of STEAM as a meta-discipline and the faculty's ability to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Certificate or minutes of meeting or workshop stipulating facilitation and participation in collaborative development of instructional materials, specific discipline-based technology, and teaching tools in teaching and learning of the STEAM discipline of STEAM learners. • Certificate or minutes of meeting or workshop stipulating facilitation and participation in the collaborative development of assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester. • Results of the assessment and performance highlighting an **in-depth** understanding of the lesson by the STEAM learners and **acquisition of 21st century skills** such as design thinking, critical thinking, and innovativeness. • Certificate of Appreciation or Recognition as resource speaker in teaching the STEAM discipline or in the STEAM discipline • Author of textbooks or published instructional materials, and/or research publications • Copy of student evaluation • Others (please specify and provide annotations)

Research-based knowledge of STEAM disciplines	They manifest an in-depth and sophisticated understanding STEAM research and collaborate for the conduct and application of STEAM research to promote the welfare of STEAM profession in schools and the community.	• Program or Discipline-based required standard related to research (*copy of research proposal of a locally-funded research, completed research, publication in CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals*). • Collaborative work on developing utility models for STEAM • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Certificates for Presentation of Research in national, regional or international research fora (Scopus-indexed and ISI-indexed fora) • Active Membership (e.g., joins committee, holds a position in the board) to Professional Organizations • Certificate of Appreciation or Recognition as resource speaker in teaching the STEAM discipline or in the STEAM discipline • Certificate of Appreciation or Recognition as resource speaker in Research and Publication Capability Building Programs • Certificate of mentorship of undergraduate graduate students (masters program) • Copy of published book or instructional materials • Certificate of significant contribution to the community • Others (please specify and provide annotations)
Knowledge, Skills and Values for STEAM teaching and learning processes	They exhibit support to STEAM education by contributing to the STEAM profession as collaborators and participants in projects and programs aimed to forge productive and innovative products, programs and curricula through local and international partnerships. They work together with colleagues in applying research-based pedagogy that promote inquiry, problem- and product-based	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that emphasizes the use of STEAM as a meta-discipline, and the faculty's ability to use the findings and products of STEAM research to organize the

	learning, curriculum planning, management of learning, and valuable use of technology to create lifelong impact in the lives of other STEAM professionals, colleagues, diverse learners/students and the community.	• teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Minutes of Meeting stipulating facilitation of curricular workshops in College or Department level and/or attendance and participation in Institution-level curricular workshops. • Memorandum stipulating that STEAM educator is a member of curricular or curriculum committee (institutional-level). • Certification by the head of the department or college dean that the STEAM faculty **facilitated** collaborative team teaching. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Certificate of Appreciation or Recognition as resource speaker in teaching the STEAM discipline or in the STEAM discipline • Others (please specify and provide annotations)
Assessment, Monitoring Learning and Feedback System	They participate and cooperate in a collective, complete, and sensible planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based programs and plan of actions for better progress in student learning.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the use of STEAM as a meta-discipline, and the faculty's ability to use the findings and products of STEAM research to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of attendance/participation in seminars and trainings on teaching strategies in STEAM fields, assessment, monitoring and evaluation of student learning. • Certification by the head of the department or college dean that

		the STEAM faculty **facilitated** collaborative planning, selecting, implementing, and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based program and plan of action. • Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester • Results of the assessment and performance highlighting understanding of the lesson by the STEAM learners. • Minutes of Meeting stipulating facilitation of Department-level, College-level, and attendance and participation in Institution-level discussion on assessment results for instructional planning • Others (please specify and provide annotations)
Professional Development and Personal Growth	They continually aspire to improve their professional and personal growth through knowledge creation, and dissemination, and collaboration with experienced colleagues and STEAM experts and professionals on discipline and on content and teaching the STEAM discipline.	• Certificate of Appreciation or Recognition as resource speaker in teaching the STEAM discipline or in the STEAM discipline • Certificate of Appreciation or Recognition as resource speaker in Research and Publication Capability Building Programs • Certificates for Presentation of Research in national, regional or international research (Scopus- and ISI-indexed) fora • Active Membership (e.g., joins committee, holds a position in the board) to Professional Organizations • Invited as resource speaker in teaching the STEAM discipline or in the discipline • Wrote textbooks or published instructional materials, and research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • With a number of research citations (h-index [google scholar] of at least 3 • Certificate of significant contribution to the community • Student Evaluation • Others (please specify and provide annotations)

Table 5.5. Required documents for verification (Distinguished)

	Career Stage 2 Distinguished/Expert	Required Documents for Verification
General Attributes of STEAM Educator	Distinguished STEAM Educators mentor colleagues and initiate policy inputs to exemplify the highest standard for STEAM education grounded on local and national perspectives, and research-based undertakings, anchored on globally-acclaimed best and finest suitable practices and principles.	• Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (Undergraduate degree program) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (for Graduate degree-Masters) • Transcript of Record or Diploma in any of the STEAM Disciplines stipulating completion of any of the STEAM Program (**for Master's degree-Doctorate**) • School-based merit system or promotion system (for private HEIs and LUCs) document of proficiency as a tertiary educator or Rating **(for Full Professor level) based on Faculty Ranking and Promotion of NBC 461 (for SUCs)** • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Active Membership (e.g., chair of committee, holds a position in the board) to Professional Organizations • Invited as resource speaker in teaching the STEAM discipline or in the discipline • Certificates for Appreciation or Recognition as Plenary Speaker in Research Conferences and Fora in national, regional or international research fora (Scopus-indexed and ISI-indexed fora) • Certificate of mentorship of graduate students (master's program and doctorate programs) • Wrote tertiary textbooks, edited books which are internationally-published or published instructional materials, and research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • With a number of research citations (h-index[google scholar] of at least 5

		• Patent/inventions/discoveries or utility model certifications • Certificate of Project/Program Leadership of funded research (national and/or international) • Recipient of National and/or International Awards • Certificate of significant contribution to the community • Student Evaluation • Others (please specify and provide annotations)
Knowledge of STEAM Discipline	Their exceptional capacity to acquire knowledge and exemplar practice to improve knowledge on STEAM disciplines and in the fields of research, languages and communication utilizing STEAM meta-discipline to develop Filipino learners' STEAM skills (e.g., design thinking skills, time management, technical know-how, and cognitive and emotional intelligences) responsive to national and global goals as shown in their ability to train others in acquiring a strong understanding of the discipline.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the use of STEAM as a meta-discipline, to **facilitate research-based teaching**, and the faculty's ability to use the findings and products of STEAM research to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Certificate or minutes of meeting or workshop stipulating initiating programs for mentoring colleagues and collaborative development of instructional materials, specific discipline-based technology, and teaching tools in teaching and learning of the STEAM discipline of STEAM learners. • Certificate or minutes of meeting or workshop stipulating initiating programs for mentoring colleagues and collaborative development of assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester. • Results of the assessment and performance highlighting an **in-depth** understanding of the lesson by the STEAM learners and **acquisition of 21st century skills** such as design thinking, critical thinking, innovativeness, technical know-how, and cognitive and emotional intelligences.

		• Certificate of Appreciation or Recognition as Lead Speaker or Plenary Speaker in workshops, seminars and training on teaching the STEAM discipline or in the STEAM discipline. • Wrote textbooks or published instructional materials, and research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • Copy of student evaluation • Others (please specify and provide annotations)
Research-based knowledge of STEAM disciplines	They exemplify knowledge generation, dissemination, and knowledge sustainability for professional practice, community service to promote the welfare of STEAM profession in schools and the community as well.	• Program or Discipline-based required standard related to research (*copy of research proposal of a locally-funded research, completed research, publication in CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals*). • Documents (e.g., MOA) stipulating facilitation of or initiation of Institutional research collaborations to develop STEAM products for copyright and patents • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Active Membership (e.g., chair of committee, holds a position in the board) to Professional Organizations • Invited as resource speaker in teaching the STEAM discipline or in the discipline • Certificates for Appreciation or Recognition as Plenary Speaker in Research Conferences and Fora in national, regional or international research fora (Scopus-indexed and ISI-indexed fora) • Certificate of mentorship of graduate students (masters program and doctorate programs) • Wrote tertiary textbooks, edited books which are internationally-published or published instructional materials, and

		research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • With a number of research citations (h-index[google scholar] of at least 5 • Patent/inventions/discoveries or utility model certifications • Certificate of Project/Program Leadership of funded research (national and/or international) • Copy of published book or instructional materials • Certificate of significant contribution to the community • Others (please specify and provide annotations)
Knowledge, Skills and Values for STEAM teaching and learning processes	They trail-blazed STEAM education, contributed to the STEAM profession and initiated collaborations that can forge productive and innovative products, programs and curricula through local and international partnerships. They champion modelling and mentoring of research-based pedagogy that promotes inquiry, problem- and product-based learning, curriculum planning, management of learning, and valuable use of technology that impact on the lives of other STEAM professionals, colleagues, diverse learners/students and the community.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that emphasizes the use of STEAM as a meta-discipline, to **facilitate research-based teaching**, and the faculty's ability to use the findings and products of STEAM research to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Certificate or minutes of meeting or workshop stipulating initiating programs for mentoring colleagues and collaborative development of instructional materials, specific discipline-based technology, and teaching tools in teaching and learning of the STEAM discipline of STEAM learners. • Certificate or minutes of meeting or workshop stipulating initiating programs for mentoring colleagues and collaborative development of assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester.

		• Minutes of Meeting stipulating initiating programs for mentoring colleagues on Institution-level curricular workshops. • Memorandum stipulating that STEAM educator Chairs or co-chairs the curricular or curriculum committee (institutional-level). • Document stipulating participation of the STEAM faculty in national curricular reforms (CHED or DepEd) • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Certificate of Appreciation or Recognition as resource speaker in teaching the STEAM discipline or in the STEAM discipline • Others (please specify and provide annotations)
Assessment, Monitoring Learning and Feedback System	They model, exemplify, and mentor planning, selecting, implementing and monitoring assessment and evaluation of student learning, feedback system and designing of assessment-based programs and plan of actions for better progress in student learning.	• Classroom Observation Rating Tool (Rating Scale, Notes, Technology Integration Checklist, Assessment Checklist) • Copy of their session guide and syllabus focused on teaching program (embedding knowledge of the discipline, pedagogy, assessment, and technology integration) that stresses the use of STEAM as a meta-discipline, to **facilitate research-based teaching**, and the faculty's ability to use the findings and products of STEAM research to organize the teaching-learning process to enable students to learn the required concepts in the STEAM discipline. • Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Copy of student evaluation • Copy of Certificate of Recognition or Appreciation as Resource Speaker or Plenary Speaker in seminars and trainings on teaching strategies in STEAM fields, assessment, monitoring and evaluation of student learning. • Certification by the head of the department or college dean that the STEAM faculty **initiated** collaborative planning, selecting, implementing, and monitoring

		assessment and evaluation of student learning, feedback system and designing of assessment-based program and plan of action (Institution-wide). • Copy of the assessment (with TOS) and performance tasks (with Rubrics) used in the course within the term or semester • Results of the assessment and performance highlighting understanding of the lesson by the STEAM learners. • Minutes of Meeting stipulating initiating of College-level, and/or Institution-level discussion on assessment results for instructional planning • Others (please specify and provide annotations)
Professional Development and Personal Growth	They sustainably advance and pursue excellence in STEAM quality teaching and research and commit themselves to inspire the education community and stakeholders for improving the education provision in the Philippines.	• Proficiency Rating using the Proficiency Indicators for Philippine STEAM Educators • Active Membership (e.g., chair of committee, holds a position in the board) to Professional Organizations • Invited as resource speaker in teaching the STEAM discipline or in the discipline • Certificates for Appreciation or Recognition as Plenary Speaker in Research Conferences and Fora in national, regional or international research fora (Scopus-indexed and ISI-indexed fora) • Certificate of mentorship of graduate students (masters and doctorate programs) • Authorship of tertiary textbooks, edited books which are internationally-published or published instructional materials, and research publications (*CHED-accredited journals, Scopus-indexed journals and Clarivate Analytics-indexed journals)* • With a number of research citations (h-index[google scholar] of at least 5 • Patent/inventions/discoveries or utility model certifications • Certificate of Project/Program Leadership of funded research (national and/or international)

- Recipient of National and/or International Awards
- Certificate of significant contribution to the community
- Student Evaluation
- Others (please specify and provide annotations)

5.8. Descriptions of Models

5.8.1. Pedagogical Model (Validated)

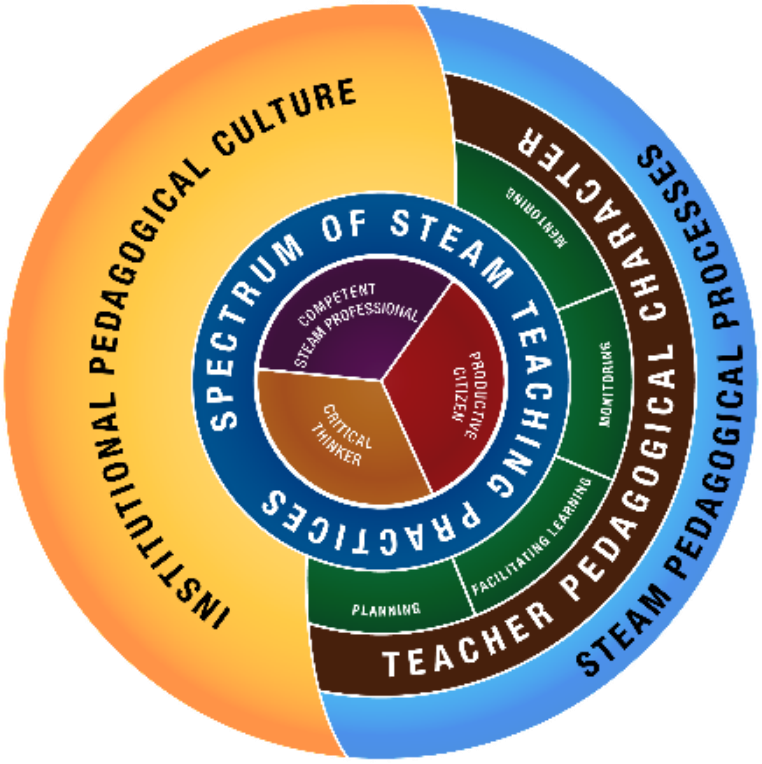

Figure 5.4. The Pedagogical Model (Validated)

The STEAM Pedagogical Model in Philippine Higher Education Institutions (HEIs) demonstrates an interdependence between Institutional Pedagogical Culture and STEAM Pedagogical Processes. The pedagogical culture of an HEI pertains to its framework and

mechanism for planning, disseminating, and evaluating the pedagogical processes and the extent by which research and teaching nexus is advanced in all these processes. Planning the pedagogical processes specifically ensures alignment of learning objectives and activities, parallel positioning of faculty specialization and content taught, partnership between school and industry, and stress on the relevance of STEAM to the community. An institutional pedagogical culture comparably demands disseminating institutional pedagogical policies and curricular reforms, programs, and innovations. Evaluation of pedagogical processes imposes periodic institutional review of curriculum and evaluation of teachers' pedagogical processes and consequently drawing implications for ranking, promotion, and continuing professional development. Pedagogical culture further promotes mentoring among faculty members, and tenders continuing professional development opportunities for teachers.

The pedagogical culture of an HEI drives its STEAM pedagogical processes, specifically the teaching practices, and shapes the pedagogical character of its teachers. As illustrated by the "yin yang" pattern, the institutional pedagogical processes and teachers' pedagogical character exemplify the institution's pedagogical culture. This suggests that pedagogical processes also entail planning, facilitating, and monitoring learning, as well as establish a mentoring mechanism for learners. The Philippine STEAM pedagogical model emphasizes inquiry-based and output/product-based learning and teaching, and a spectrum of related teaching practices. Furthermore, it promotes ethical conduct of STEAM pedagogical processes and research for continuous improvement of STEAM pedagogy.

A teacher's epistemological beliefs and teaching practices comprise his/her pedagogical character. STEAM teachers acknowledge that there is no perfect teaching strategy to suggest that appropriateness of teaching approach must be given attention in planning the pedagogical processes. Hence, STEAM teachers are skilled in various teaching strategies, if not adept in switching across strategies whenever fit and necessary. STEAM teachers also model learning by linking practice and teaching, and by demonstrating critical and reflective thinking.

The Pedagogical model of Philippine STEAM Education explicates that the nexus between an institution's pedagogical culture and its pedagogical processes is gauged by the quality of its learners and teachers. Specifically, the Philippine STEAM education aims at nurturing critical thinkers, productive citizens, and competent STEAM professionals. The circular frame of the model depicts sustainability of every relationship demonstrated, as by its variables and dimensions.

5.8.2. Pedagogical Model (Emerging)

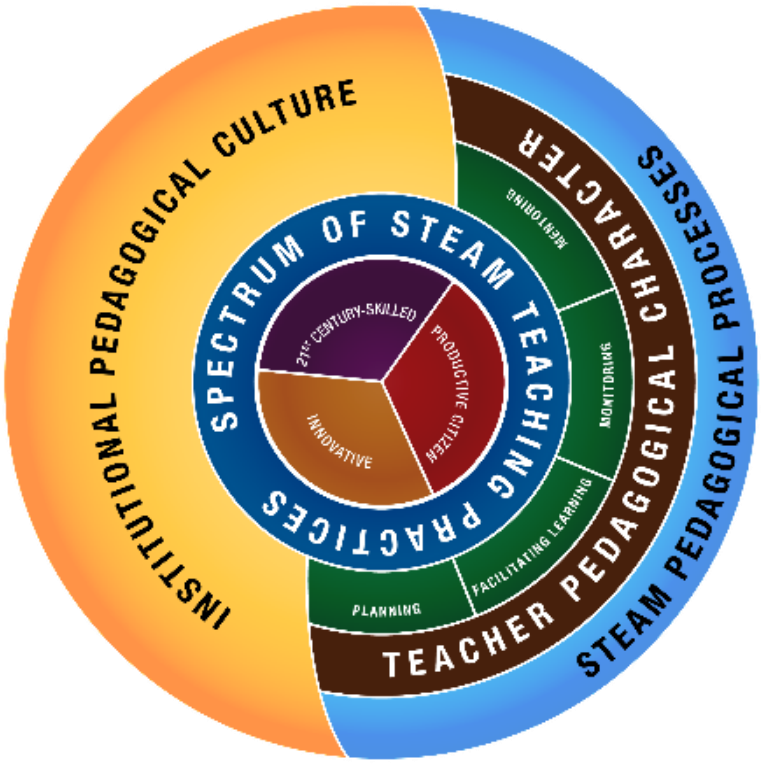

Figure 5.5. The Pedagogical Model (Emerging)

The STEAM Pedagogical Model in Philippine Higher Education Institutions (HEIs) demonstrates an interdependence between Institutional Pedagogical Culture and STEAM Pedagogical Processes. The pedagogical culture of an HEI refers to its framework and mechanism for planning, disseminating, and evaluating the pedagogical processes and the extent by which research and teaching nexus are advanced in all these processes. In particular, planning the pedagogical processes ensures alignment of learning objectives, activities, as well as faculty specialization and content taught, partnership between school and industry, and stress on the relevance of STEAM to the community. An institutional pedagogical culture likewise requires disseminating institutional pedagogical policies and curricular reforms, programs, and innovations. Evaluation of pedagogical processes demands periodic institutional review of curriculum and evaluation of teachers' pedagogical processes and consequently drawing implications for ranking, promotion, and continuing professional development. Pedagogical culture further promotes mentoring among faculty members, and tenders their continuing professional development opportunities.

The pedagogical culture of an HEI stems from STEAM pedagogical processes, more so on the teaching practices, if not shapes the pedagogical character of its teachers. As illustrated by the **yin yang** construct, the institutional pedagogical processes and teachers' pedagogical character exemplify the institution's pedagogical culture. This notion suggests that pedagogical processes

equally demand careful planning, facilitating, and monitoring learning, as well as establishing a mentoring mechanism for learners. The Philippine STEAM pedagogical model emphasizes inquiry-based and output/product-based learning and teaching, and a spectrum of related teaching practices. Moreover, it promotes ethical conduct of STEAM pedagogical processes and research for continuous improvement of STEAM pedagogy.

A teacher's epistemological beliefs and teaching practices bespeak his/her pedagogical character. STEAM teachers acknowledge that there is no perfect teaching strategy to suggest that appropriate teaching approach must be given attention in planning the pedagogical processes. Hence, STEAM teachers are skilled in various teaching strategies and are adept in switching across strategies whenever proper and necessary. Similarly, STEAM teachers model learning by linking practice and teaching, better yet, by demonstrating critical and reflective thinking.

The Pedagogical model of Philippine STEAM Education unfolds the nexus existing between an institution's pedagogical culture and its pedagogical processes, as gauged by the quality of its learners and teachers. Specifically, Philippine STEAM education aims at nurturing 21st century-skilled human resource, productive citizens, and competent STEAM professionals. The circular frame of the model depicts sustainability of every relationship demonstrated by its variables and dimensions.

5.8.3. Assessment Model (Validated)

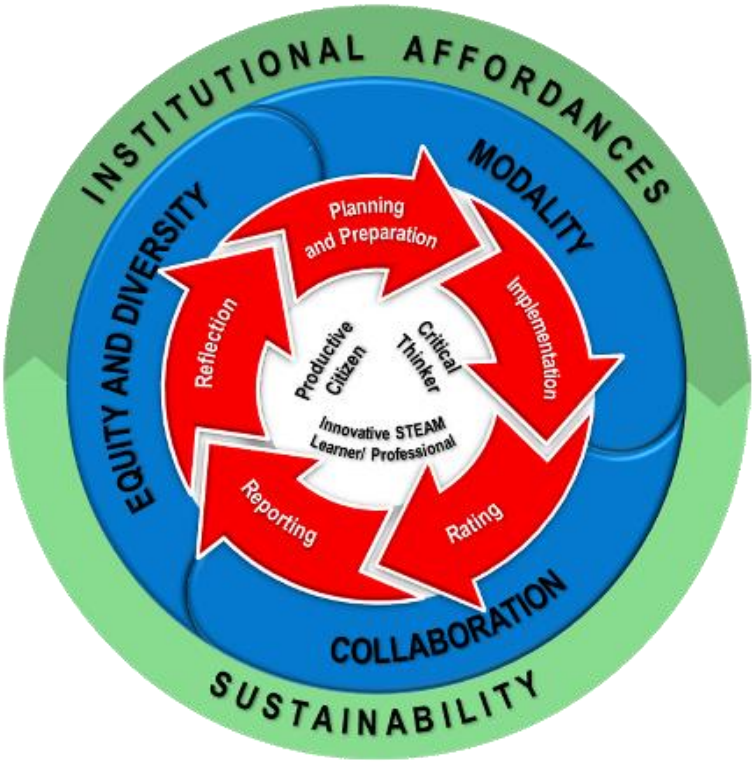

Figure 5.6. The Assessment Model (Validated)

The STEAM Assessment Model (Figure 5.6) highlights the four variables and thirteen dimensions that influence the overall framework of the Philippine STEAM Education. The first three variables are represented as concentric circles that encapsulate the fourth.

The first variable includes the (A) **"Enablers"** of STEAM Assessment which occupies the outermost layer of the model. This variable has two dimensions, (1) ***Institutional Affordances*** and (2) ***Sustainability***, and considered crucial, as this variable highlights the capabilities, forces, and resources that contribute to the success of the assessment process. The first dimension refers to the properties, facilities and policies of educational institutions or an aspect of its environment that describes and aids their STEAM assessment process. The second dimension pertains to the efforts and practices exerted to secure, maintain, and improve the quality of the STEAM assessment process; involving the various research initiatives that seek to oversee and enhance assessment. The connection between the two dimensions indicates the sheer, utmost linkage between the two, and how one influences the other.

The second variable are the (B) **"Drivers"** of STEAM Assessment displayed as the next layer of the model that enumerates the key factors and main considerations in the STEAM assessment process and direction. These factors are categorized into three dimensions: 3) ***Equity and Diversity***, (4) ***Collaboration***, and (5) ***Modality***. By and large, these three dimensions ensure the inclusion of all types of learners, accommodate the context and locale of the students, and make certain that each has a fair and equal opportunity during the assessment process; maintain the dynamic and engaging interactions that exist between various key players in the assessment process; and bestow the use of varied and appropriate tools and methods to address various purposes of assessment in the STEAM teaching-learning discourse.

The third variable enumerates the (C) **"Processes"** of STEAM Assessment, located in the third inner layer of the model. This variable identified five stages which depict the last five dimensions of the model: (6) ***Planning and Preparation***, (7) ***Implementation***, (8) ***Rating***, (9) ***Reporting***, and (10) ***Reflection***, all representing the different phases of reflective instruction where assessment principles are observed and practiced. The arrows pointing from one stage to the other symbolize that the STEAM assessment follows a specific order, if not the cyclical nature of the process. Furthermore, the Process of STEAM Assessment, with its corresponding indicators (correlated with the Drivers of STEAM Assessment) demands the assortment of STEAM assessment practices. It also defines the attributes of teaching competencies, as well as establishes the requirements for advancement in each career stage (Beginner, Proficient, Highly Proficient, Distinguished) of a STEAM educator.

The last variable, appearing at the kernel of the model, specifies the desired (D) "**Outcomes**" of STEAM Education. It sets forth the intended trait and characteristics of STEAM learners and graduates, categorized into three dimensions: (11) ***Innovative STEAM Professional Learner***, (12) ***Critical Thinker***, and (13) ***Productive Citizen*** (members of the society), serving as a metric in delivering STEAM education successfully.

5.8.4 Assessment Model (Emerging)

Figure 5.7. The Assessment Model (Emerging)

The STEAM Assessment Model (Figure 5.7) accentuates on the four variables and fourteen dimensions that influence the overall framework of the Philippine STEAM Education. The first three variables are represented as concentric circles that encapsulate the fourth.

The first variable includes the (A) **"Enablers"** of STEAM Assessment, occupying the outermost layer of the model. This variable has two dimensions: (1) ***Institutional Affordances*** and (2) ***Sustainability***, and considered crucial as this variable focuses on the capabilities, forces, and resources that contribute to the success of the assessment process. The first dimension refers to the properties, facilities and policies of educational institutions or an aspect of its environment that describes and aids their STEAM assessment process. The second dimension pertains to the efforts and practices exerted to secure, maintain, and improve the quality of the STEAM assessment process; involving the various research initiatives that aim to oversee and enhance assessment. The connection between the two dimensions indicates the significant linkage between the two, and how one influences the other.

The second variable points to (B) **"Drivers"** of STEAM Assessment displayed as the next layer of the model that enumerates the key factors and main considerations in the STEAM assessment process and direction. These factors are categorized into four dimensions: (3) ***Equity and Diversity***, (4) ***Collaboration***, (5) ***Modality*** and (6) ***Innovation***. By and large, these three dimensions ensure that all types of learners are included, that the context and locale of the students are accommodated, and that each has a fair and equal opportunity ascertained

during the assessment process. Equally, the triadic dimensions maintain the dynamic and engaging interactions that exist between various key players in the assessment process, bestow the use of varied and appropriate tools and methods for various purposes of assessment, and incorporate creativity and problem solving skills in utilizing and maximizing resources in the STEAM learning-teaching discourse.

The third variable enumerates the (C) **"Processes"** of STEAM Assessment, found in the third inner layer of the model. This variable identified five stages, depicting the last five dimensions of the model. These are (7) ***Planning and Preparation***, (8) ***Implementation***, (9) ***Rating***, (10) ***Reporting***, and (11) ***Reflection***. They represent the different phases of reflective instruction where assessment principles are observed and practiced. The arrows pointing from one stage to the other symbolize that the STEAM assessment orderly follows the cyclical nature of the process. Furthermore, the Process of STEAM Assessment, with its corresponding indicators (correlated with the Drivers of STEAM Assessment) commands the assortment of STEAM assessment practices. It also defines the attributes of teaching competencies, as well as establishes the requirements for advancement in each career stage (Beginner, Proficient, Highly Proficient, Distinguished) of a STEAM educator.

The last variable, appearing at the kernel of the model, specifies the desired (D) "**Outcomes**" of STEAM Education. It sets forth the intended trait and characteristics of STEAM learners and graduates, categorized into three dimensions: (12) ***Innovative STEAM Professional Learner***, (13) ***Critical Thinker***, and (14) ***Productive Citizen*** (members of the society); which also serve as a metric for delivering STEAM education successfully.

5.8.5. Technology Integration Model (Validated)

Technology integration refers to the use of technology resources (e.g., computers, mobile devices like smartphones and tablets, digital cameras, social media platforms and networks, software applications, the Internet, etc.) in learning, in daily classroom practices, in teachers' major and other duties, and in managing a school (Edutopia, 2007; Education4site, 2011). The technology integration model for STEAM education shows three variables: *teacher technological knowledge (TTK), institutional support (IS)* and *outcomes*. **Teacher technological knowledge (TTK)** refers to the understanding of teachers about technology. This model requires of the teacher familiarity with various technology, understanding how to make and use specific technology to identified lessons, and assessing when technology assists or impedes lesson delivery. Teacher technology knowledge has two dimensions, lesson structure and content-driven. While *Lesson structure* aims to integrate technology in specific parts of the lesson, at most, for faster lesson delivery and better presentation, *Content-driven* makes use of technology in instruction specifically applicable to courses on which the content of the course is bound to technology use.

Institutional Support (IS) has two dimensions: capacity building and quality of technology, architecture, system and design. *Capacity building* purports to enhance technological literacy

of teachers in the appropriate use of technology for a specific purpose. To achieve this goal, institutions need to conduct trainings and workshops for teachers in the proper use of technology. *Quality of technology, architecture, design and system* refers to various software, applications, devices and other instruments that the teachers need to carry out in the teaching-learning process, a dimension approximated by the affordability, availability and appropriateness of the technology used in instruction and/or assessment. Current and modern designs to ensure the comfortable use of technology in teaching and learning are essential to produce *critical thinkers, productive citizens and innovative STEAM professionals* in promoting quality STEAM education.

The model theorizes on using the TPACK, SAMR and Triple E framework with emphasis on Triple E: *engagement, enhancement and extension*. While the model shows no barriers that divide the dimensions of the variables, it signifies the interrelationship/interconnections of dimensions. Similarly, the Triple E Framework components observed in the outermost circle denote that technology integration can be a way to evaluate the choice of tools to meet and address the learning goals, as well as design learning episodes using tools that impact on tudents to deduce the desired learning outcome.

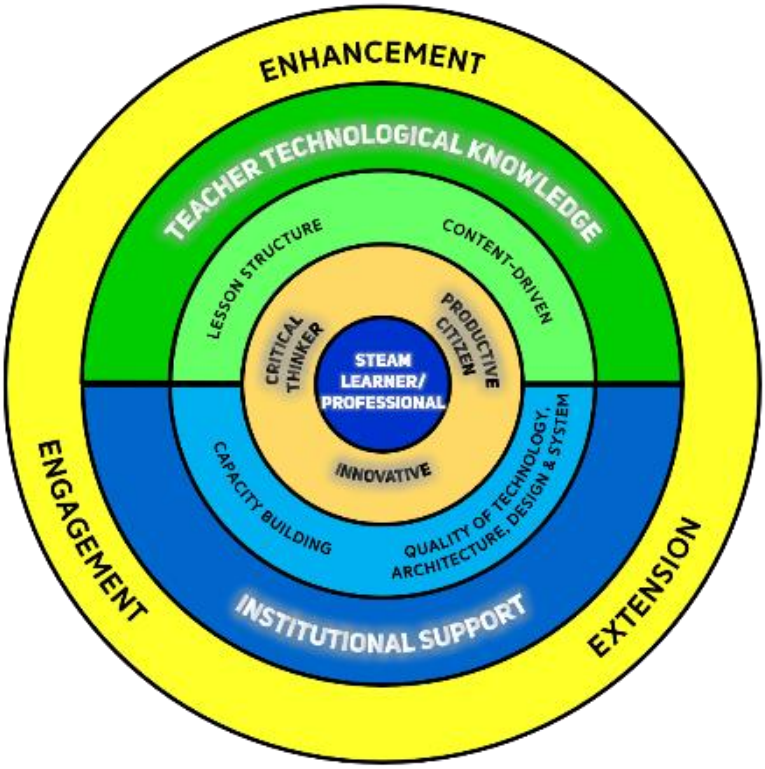

Figure 5.8. The Technology Integration Model (Validated)

5.8.6. Technology Integration Model (Emerging)

The emerging technology integration model was a direct off-shoot of the three-tier validation. The same variables are present in the model: *teacher technological knowledge, institutional support and outcomes.* The emerging model has an additional dimension each under teacher technological knowledge, and institutional support. *Context-based* under the teacher technological knowledge refers to the conditions, physical, economic or cultural, of the school, teachers including the students. Additionally, under institutional support added one dimension: research in technology development. *Research in technology development* refers to the dimension of institutional support that creates opportunities to innovate and develop technology related to STEAM disciplines. Indeed, one of the outcomes of being a STEAM learner/profession is to possess 21st century skills to survive in a highly technological, competitive world.

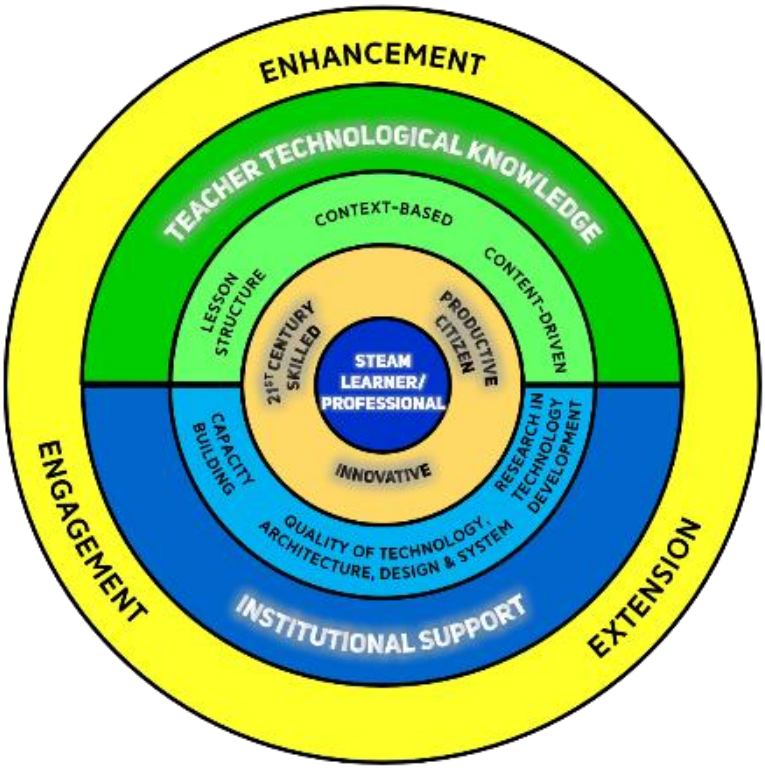

Figure 5.9. The Technology Integration Model (Emerging)

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CHAPTER 6

ABSTRACT

CHAPTER 6
STEAM Educators Professional Development

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If educators wish to continuously excel in the art and science of teaching, they need to undergo professional development to constantly upgrade their professional knowledge, skills, competence and effectiveness. As defined, professional development refers to many types of educational experiences or specialized activity designed for educators to improve and update knowledge, skills, and competence related to the practice of teaching. In this component of the entire STEAM program, sampled Philippine Higher STEAM educators experienced being capacitated in a variety of ways. Training orientation and workshop brought them concomitant, practical experiences of working with other STEAM educators to craft their Lesson Exemplars in their respective disciplines anchored on the details of the Philippine STEAM Education Model.

This activity simulates knowledge generation, where each STEAM educator crafted a specialized flow of enacting a particular STEAM discipline. Knowledge sharing began in the National Forum on STEAM education, where all STEAM educators (core researchers and participants) shared their generated knowledge on these topics: Philippine STEAM education models, Proficiency Indicators and scoring system, designing lesson exemplars, Philippine STEAM educators proficiency, and documentations of the conduct of lesson exemplars.

Keywords: capacity building, forum, Lesson Exemplar, STEAM education

6.1. Capacity Building Program

In contributing to a strong human capital, the Capability Building Program (CBP) of the CHED-funded project/program titled, Technological Pedagogical Content Knowledge (TPACK) in Philippine STEAM (Science, Technology, Engineering, Agri/Fisheries and Mathematics) Education generally aimed to enhance Philippine Higher Education STEAM Educators skill on the teaching and learning domains (pedagogy, assessment and technology integration). Specifically, the CBP is designed to: 1) inform PHE STEAM teachers of general level of STEAM teaching proficiency of the PHE STEAM educators, 2) acquaint PHE STEAM Educators with Philippine TPACK model generated from the CHED-funded research titled, TPACK in Philippine STEAM Education, 3) appraise PHE STEAM Educators with emerging models for Philippine STEAM Education such as Pedagogical Model, Assessment Framework, and Technology Integration Model, 4) enable PHE STEAM Educators to overcome areas of weaknesses, as informed by the general STEAM teaching proficiency level of tertiary teachers, 5) facilitate the development of Lesson Exemplars to exemplify utilization of the models and TPACK framework in Philippine STEAM Education, and 6) provide venue for PHE STEAM teachers and professionals to work together and share their knowledge in teaching approaches and researches that could contribute to quality STEAM education in the country.

The three-day training and workshops highlighted three major events. Day one of the entire training program focused on knowledge sharing of the validated and emerging STEAM Education Models (Pedagogical Model, Assessment Model, Technology Integration Model, and Philippine STEAM Education Model). The second tier validation was also conducted on this day to further polish the presented models. Queries and discussions were featured activities for the first day, just as consolidated comments and suggestions on the validated models informed revisions done soon after. Furthermore, the presentation of the models stressed the research process of the development. This section of the training informed the participants of the general proficiency of STEAM educators, which also identified areas of weaknesses in terms of the TPACK framework. Day 2 of the training program started with a recap of the first day, and oriented participants in discussing the Lesson Exemplar. The organizing team clustered the participants according to their respective STEAM disciplines. Each cluster (Physical Science, Biological Science with Agri/Fisheries, Technology and Engineering, Mathematics), facilitated by the members of the TPACK team, formed groups of five wherein each group developed a Lesson Exemplar on one topic in their respective disciplines. Peer review succeeded the development of the Lesson Exemplar. After two rounds of peer review, the groups revised their lessons, based on the comments and suggestions in the two rounds of peer review. Day 2 ended with decisions and consensus from each cluster, as to which among their Lesson Exemplars would be presented on the third day of the training. Day 3 recapped the second day, presented and critiqued the Lesson Exemplars per cluster. Cluster representatives presented their respective Lesson Exemplars, subjected to panel interview for comments and suggestions on how to further improve their lesson in line with the PHS STEAM model.

Finally, the research team (TPACK) acknowledged the efforts of all the participants in the closing program. It was graced by no less than the Vice President for Research and Quality Assurance of the Lead Institution. Participants shared their impressions on the CPB expressing positive and inspiring comments on their considerable satisfaction for updates in the teaching and learning of STEAM disciplines to help them "become Teachers 4.0 to train the Generation z learners and help craft 21st century-skilled learners, innovative STEAM professionals, and productive Filipino citizens."

6.1.1. Training Design and Implementation

The Capacity Building Program (CBP) featured plenary presentations of the frameworks and models generated for the CHED-funded research titled, *TPACK in Philippine STEAM Education*. Primarily, the CBP acquainted the pre-selected tertiary STEAM teachers on the four major frameworks and models (Philippine TPACK framework, Pedagogical Model for Philippine Higher Education (PHE) STEAM, Assessment Framework for PHE STEAM, and Technology Integration Model for PHE STEAM) crafted as their paradigm and guide in the design of STEAM lessons. Design of lesson exemplars were the focus product of the training program.

6.1.1.a. Objectives of the Capability Building Program

The Capacity Building Program (CBP) is designed to:

1. Inform PHE STEAM teachers of the general level of STEAM teaching proficiency of the PHE STEAM educators.
2. Acquaint PHE STEAM Educators with the Philippine TPACK models generated from the CHED-funded research, *TPACK in Philippine STEAM Educatio*n.
3. Appraise PHE STEAM Educators with the emerging models for Philippine STEAM Education such as Pedagogical Model, Assessment Framework, Technology Integration Model, and Philippine STEAM Education Model.
4. Help PHE STEAM Educators overcome flawed areas, as informed by the general STEAM teaching proficiency level of tertiary teachers.
5. Facilitate the development of Lesson Exemplars to exemplify the utilization of the models, TPACK framework, and the Philippine STEAM Education Model in Philippine STEAM Education.
6. Serve as a venue for PHE STEAM teachers and professionals to work together and share their knowledge in teaching approaches and researches that could contribute to quality STEAM education in the Philippines.

6.1.1.b. The Program of Activities

The activities of the CBP program followed a sequence of providing the participants with the general principles and concepts in Philippine STEAM Education through the presentation of

all the generated models. In succeeding parts, Lesson Exemplars concretized the Philippine STEAM Education Model. Consequently, the participants developed their Lesson Exemplars in their respective clusters following the guideline set by the core team adhering to all the principles of the presented models. These crafted Lesson Exemplars underwent two rounds of peer review and revisions before panel presentation and critiquing.

Table 6.1. Day 1 Program of the Activities for the Capability Building Program

Time	Activities (March 19, 2019)
08:00 – 09:00 AM	Registration
09:00 – 10:00 AM	**Opening Program** Opening Remarks **Dr. Rosemarievic V. Diaz**, Vice President for Research, Planning and Quality Assurance Message **Dr. Maria Antoinette C. Montealegre**, PNU-OIC-President Orientation **Dr. Marie Paz E. Morales**, Principal Investigator
10:00-11:00 AM	**Technology Integration** **Prof. Ruel A Avilla**, Co-investigator Facilitator: **Roselle A. Laureano**
11:00-12:00 AM	**Assessment** **Dr. Celina P. Sarmiento**, Lead Researcher Facilitator: **Jonathan Diokno**
12:00-01:30 PM	**LUNCH BREAK**
01:30-02:30 PM	**Pedagogical Model** **Prof. Jovito C. Anito**, Lead Researcher Facilitator: **Milano O. Torres**
02:30-03:30 PM	**The Philippine STEAM Education Model** **Prof. Jovito C. Anito**, JRU Researcher Collaborator Facilitator: **Maribel D. Ganeb**

Table 6.2. Day 2 Program of the Activities for the Capability Building Program

Time	Activities (March 20, 2019)
08:00 – 10:00 AM	**Recap of the First Day** **Milano O. Torres**

	Features of the Lesson Exemplar **Dr. Ranzivelle Marianne L. Roxas-Villanueva**, UPLB Research Collaborator Facilitators: **Raquel A. Gonzales & Kristent Leo D. Tuscano**
10:00 – 12:00 AM	**Workshop on Lesson Exemplar** **Dr. Caesar P. Palisoc**, Lead Researcher ***GROUPS FOR BREAKOUT SESSIONS:*** **SCIENCE** **Dr. Caesar P. Palisoc**, Lead Researcher **Prof. Benilda R. Butron**, Lead Researcher Facilitator: **Maribel D. Ganeb** **TECHNOLOG AND ENGINEERING** **Prof. Kriztine R. Viray**, PUP Research Collaborator **Prof. Randy D. Sagun**, PUP Research Collaborator Facilitator: **Roselle A. Laureano** **AGRI-FISHERIES** **Dr Ranzivelle Marianne L. Roxas-Villaneuva**, UPLB Research Collaborator **Dr. Felixberto M. Mercado**, MSEUF Research Collaborator Facilitator: **Dennis B. Masangcay** **MATHEMATICS** **Dr. Celina P. Sarmiento**, Lead Researcher **Dr. Levi E. Elipane**, Lead Researcher Facilitator: **Jonathan P. Diokno**
12:00-01:00 PM	**LUNCH BREAK**
01:00-02:30	**Peer Review of Lesson Exemplar** **Dr. Celina P. Sarmiento**, Lead Researcher **Prof. Jovito C. Anito, Jr.,** JRU Research Collaborator Facilitator: **Milano O. Torres**
02:30-05:00 PM	**Workshop on Revision of Lesson Exemplar based on Peer Review** **Dr. Maricar S. Prudente**, DLSU Research Collaborator **Prof. Brando C. Palomar,** Lead Researcher Facilitator: **Raquel A. Gonzales**

Table 6.3. Day 3 Program of the Activities for Capability Building Program

Time	Activities (March 21, 2019)
08:00–11:00 AM	**Recap of the Second Day** **Raquel A. Gonzales** **Presentation & Critiquing** **Dr. Marie Paz E. Morales**, Principal Investigator

	Prof. Thaddeus Owen D. Ayuste, Lead Researcher **Dr. Felixberto M. Mercado**, MSEUF Research Collaborator **Dennis B. Masangcay**, PhD Graduate Student Facilitator: **Raquel A. Gonzales**
11:00–12:00 AM	**Closing Program** **Closing Remarks** **Dr. Rosemarievic V. Diaz**, Vice President for Research, Planning & Quality Assurance (VPRPQA) **Impression** **Distribution of Certificates**
12:00-01:00 PM	**LUNCH BREAK**
01:00-Onwards	**Business Meeting** **Core Research Team and Research Collaborators only**

6.1.2. Lesson Exemplars

6.1.2.a. Orientation to Lesson Exemplars

On March 19 to 21, 2019, the Philippine Normal University (PNU) core team organized and held the Capability Building Program for STEAM Education, projected to develop and produce Lesson Exemplars. The 132 invited participants included the a) field researchers/representatives, b) STEAM teachers that were observed and interviewed, and c) STEAM educator self-survey participants from the 26 visited higher education institutions. On March 20, 2019, the team's University of the Philippines Los Baños (UPLB) research collaborator introduced the features of the team's first draft of the lesson exemplar template and the corresponding rubric and peer review form (Appendix III and IV).

6.1.2.b. Development of Exemplars

The organizing team clustered the participants according to their STEAM disciplines. Each cluster (Physical Science, Biological Science with Agri/Fisheries, Technology and Engineering, Mathematics), facilitated by the members of the TPACK team, formed groups of five wherein each group developed a Lesson Exemplar, using the features of the first draft of lesson plan, on one topic in their respective discipline.

6.1.2.c. Validation of Lesson Exemplars

The validation of the Lesson Exemplar comes in two-tier: Peer Review and Panel Presentation.

Peer Review

Peer review followed the development of the Lesson Exemplar using the Peer-review form presented during the orientation session. After two rounds of peer review within the cluster, groups started their revisions based on the comments and suggestions in the two rounds of peer review, with each cluster deciding and agreeing which among their Lesson Exemplars would be presented in plenary.

Panel Presentation and Critiquing

Critiquing followed the plenary presentation of the Lesson Exemplars per cluster. After presenting their respective Lesson Exemplar, they were subjected to panel interview for comments and suggestions on how to further improve their lesson exemplars following the Philippine STEAM education model. The groups per cluster consolidated all comments based on peer reviews and panel critiquing for the revisions.

On the basis of the peer review, panel presentation and critiquing, an enhanced TPACK lesson plan template was produced and proposed to be used for the final version of the best Lesson Exemplars in each cluster.

Pilot Testing

The core team asked each of the chosen best Lesson Exemplar to test the plan in their respective classes and document, through video and audio recording, the delivery of the lesson and learner's response for presentation in the National Forum for STEAM in Higher Education held on April 25 and 26, 2019, at the Heritage Hotel, Manila.

6.1.3. Training Evaluation

Based on the evaluation of the participants of the Capability Building Program (Appendix V), the organizers received good to excellent equivalent numerical ratings in all aspects of the program (educational content, relevance to practice, questions and discussions, selection of topics). Plenary sessions, workshops, oral presentations, overall event, venue, registration process, administration before the program and organization during the program). The majority of the participants pointed out good assessment of the program. Also, they found the program to have helped achieve the intended purpose of informing them of the trends in STEAM

education and of enabling them to develop their own Lesson Exemplars. However, certain constraints such as ventilation, venue, and the limited time to craft the Lesson Exemplars had to be considered.

6.2. Knowledge Sharing: The National Forum for STEAM in Higher Education

A little knowledge that acts is worth infinitely more than much knowledge that is idle (Kahlil Gibran, 1931). The Lebanese poet's stance supports the need to utilize and apply in real life situations all knowledge created and generated through research to sustain research culture and tradition in the academe. In our knowledge-based society, higher education institutions have eventually evolved to serve as partners of industry, government, and the community in translating the rapid growth of data and technologies produced by research. In fact, a significant role of higher learning institutions in a knowledge-based society (where the growth of data and technologies are rapidly occurring) is the inevitable transition of knowledge generated by and created through research. Thus, the need to manage, collaborate, and disseminate the existing knowledge. Knowledge-sharing covers the range of activities to capture internal knowledge and promote its transfer to and its reuse by others (Trudell, 2006, p.27).

The two-day forum featured three major events. Day one of the entire Forum focused on knowledge sharing of the validated and emerging STEAM Education Models (Pedagogical Model, Assessment Model, Technology Integration Model, and Philippine STEAM Education Model) after the second-tier validation on March 19-21, 2019. The event was graced by the welcome remarks of the Vice President for Research, Planning and Quality Assurance of the Philippine Normal University and an inspirational and motivational message by the Lead University's Officer-in-Charge. Concretizing the theme: Modelling TPACK in STEAM Education, Cr. Custer Deocaris, the Direction of the Research Division of the Commission on Higher Education highlights Industrial Revolution 4.0 vis-à-vis Education 4.0. The organizers and the invited plenary speakers presented all the models in a research presentation format to disseminate knowledge created from the CHED-funded project on TPACK in Philippine STEAM Education.

Day 2 of the National Forum commenced with a recap of the first day, and the presentation of the Pedagogical Model. We culminated the first session of the day with a panel Q and A with the core research team. This session was followed by the presentation of all articles drawn and written from the entire study covering the first component of the research program, with the collaborating researchers and the core team members doing justice to their task. Day 2 also discussed the Best Lesson Exemplars and how the STEAM teachers implemented these exemplars in their respective STEAM classes in four STEAM clusters: Biology and Agri/Fisheries, Physical Sciences, Engineering and Technology and Mathematics. Finally,

some volunteer graduate students–beneficiaries of the research program–presented the emerging Graduate Mentoring Program to share their experiences in the course of the study.

6.2.1. Conference Design and Implementation

Inductive approach influenced the conference design to present and share all the knowledge generated from the CHED-funded research, *TPACK in Philippine STEAM Education*. The core team initiated all presentations of the generated Philippine STEAM Education in a research format to present the current condition of Philippine STEAM education in terms of overall aspect, technology integration, assessment and pedagogy. All presented visions and products link to the global bandwagon (Industrial Revolution 4.0) that dictates the new learning landscape known as Education 4.0, specifically for STEAM Education. These models include emerging versions to capture how the country envisions the Philippine STEAM Education in the technological era. Consequently, the presentation of Lesson Exemplars marked how STEAM educators concretize the generated Philippine STEAM Education Models in the field. They presented (in a research format presentation as well) the validation of the models through perfectly-designed lesson exemplars in the different STEAM fields. Lastly, the conference ended with the presentation of the emerging program of the project–The Graduate Mentoring Program–that initiated a design where graduate students actively joined a commissioned research for the apprenticeship.

Table 6.4. Day 1 Program of the Activities for the National Forum for STEAM in Higher Education

TIME	April 25, 2019 (Thursday)
08:00 – 09:00 AM	Registration
09:00 – 10:0AM	**Opening Program** • Prayer/Doxology • National Anthem **Welcome Remarks** **Dr. Rosemarievic V. Diaz** Vice President for Research, Planning and Quality Assurance **Message** **Dr. Maria Antoinette C. Montealegre** Officer-in-Charge, Office of the University President

10:00 – 11:00 AM	**Keynote Address:** **Dr. Custer C. Deocaris** Chief, Research Management Division, Commission on Higher Education (CHED) ***Facilitator*** **Dr. Levi E. Elipane** Lead Researcher, Philippine Normal University
11:00 – 12:00 PM	**STEAM Education:** **Dr. Maricar S. Prudente** Research Collaborator, De La Salle University-Manila ***Facilitator*** **Prof. Jovito C. Anito, Jr.** Research Collaborator, Jose Rizal University-Mandaluyong
12:00 – 01:00 PM	LUNCH
01:00 – 02:00 PM	**TPACK Framework (Validated and Emerging):** **Dr. Marie Paz E. Morales** Principal Investigator ***Facilitator*** **Dr. Celina P. Sarmiento** Lead Researcher, Philippine Normal University
02:00 – 03:00 PM	**Technology Integration Model:** **Prof. Ruel A. Avilla** Co-Investigator, Philippine Normal University ***Facilitator*** **Prof. Thaddeus Owen D. Ayuste** Lead Researcher , Philippine Normal University
03:00 – 03:30 PM	BREAK
03:00 – 04:00 PM	CASIO (Workshop)
04:00 – 05:00PM	**Assessment Model:** **Dr. Celina P. Sarmiento** Lead Researcher, Philippine Normal University ***Facilitator*** **Roselle A. Laureano** PhD Graduate Student, Philippine Normal University

Table 6.5. Day 2 Program of the Activities for the National Forum for STEAM in Higher Education

TIME	April 26, 2019 (Friday)

08:00 – 09:00 AM	**Pedagogical Model:** **Prof. Jovito C. Anito, Jr.** Research Collaborator, Jose Rizal University ***Facilitator*** **Milano O. Torres** PhD Graduate Student, Philippine Normal University
09:00 – 10:0 AM	**Proficiency Indicator (Articles 1 and 2):** **Dr. Emil C. Alcantara** Research Collaborator, Batangas State University **Dr. Caesar P. Palisoc** Lead Researcher, Philippine Normal University ***Facilitator*** **Jonathan P. Diokno** PhD Graduate Student, Philippine Normal University
10:00 – 10:30 AM	**STEAM Educators Proficiency (Article 3.a.):** Dr. Felixberto M. Mercado, Research Collaborator, Manuel S. Enverga University Foundation ***Facilitator*** **Kristent Leo D. Tuscano** PhD Graduate Student, Philippine Normal University
10:30 – 11:00 AM	**Overall Generation of Lesson Exemplar:** **Dr. Racidon P. Bernarte** Research Collaborator, Polytechnic University of the Philippines ***Facilitator*** **Prof. Randy D. Sagun** Research Collaborator, Polytechnic University of the Philippines
11:00 – 11:45 AM	**Lesson Exemplar 1: Science (Bio and Agri-Fisheries)** • **Lorelie S. Doblado**, Holy Trinity University • **Princess Janine A. Guillermo**, Holy Trinity University • **Rachel M. Itok**, Holy Trinity University • **Mildred P. Palon**, Holy Trinity University ***Facilitator*** **Prof. Thaddeus Owen D. Ayuste** Lead Researcher, Philippine Normal University
11:45 – 12:30PM	**Lesson Exemplar 2: Technology & Engineering** • **Lynda Christine V. Diaz**, Divine Word College of San Jose • **Ariel M. Lorenzo**, University of Saint Louis Tuguegarao • **Ginalyn B. Panghulan**, Polytechnic University of the Philippines Sto. Tomas • **Sander T. Sedano**, University of Saint Louis Tuguegarao ***Facilitator*** **Prof. Thaddeus Owen D. Ayuste** Lead Researcher, Philippine Normal University
12:30 – 01:30 PM	LUNCH

01:30 – 02:15 PM	**Lesson Exemplar 3: Science (Physics and Chemistry)** • **Jesica M. Marfil**, Iloilo State College of Fisheries • **Maria Krisvie Abigale F. Mendoza**, Bulacan Agricultural State College • **Dolores C. Mirabueno**, De La Salle College of Saint Benilde-Antipolo • **Melody Joy V. Mique**, Cordillera Career Development College • **Andy Nestor Ryan Pazon**, De La Salle College of Saint Benilde • **Marilou A. Yadao**,University of San Jose-Recoletos ***Facilitator*** **Prof. Brando C. Palomar** Lead Researcher, Philippine Normal University
02:15 – 03:00 PM	**Lesson Exemplar 4: Mathematics** • **Jeff J. Abanag**, Cordillera Career Development College • **Erovita Teresita B. Agustin**, University of Saint Louis Tuguegarao • **Jean D. Centina**, Davao del Norte State College • **Winnie Beth E. Clemente**, De La Salle University • **Melvin M. Crisostomo**, City University of Pasay • **Merlita C. Medallon**, Lyceum of the Philippines University Laguna ***Facilitator*** **Prof. Brando C. Palomar** Lead Researcher, Philippine Normal University
03:00 – 04:00 PM	**Graduate Mentoring:** **Raquel A. Gonzales** PhD Graduate Student, Philippine Normal University **Milano O. Torres** PhD Graduate Student, Philippine Normal University **Maribel D. Ganeb** PhD Graduate Student, Philippine Normal University
04:00 – 05:00 PM	**Closing Remarks:** **Prof. Ruel A. Avilla** Co-investigator

6.2.2 Presentation of Final Models

Model presentation followed the research presentation format. Each presenter focused on informing STEAM educators with all the major research protocols in developing each of the models. This phase includes coherence of each model development objectives with the corresponding data collection and analysis, and data presentation. Presenters also stressed the vitality and solid foundations of all data collection and analyses, in generating the models. Succeeding such process is the robust process of tiered validation to ensure a solid outcome for the intended Philippine STEAM Education Model(s). Figure 6.1 shows presentation modes of these generated Models.

Figure 6.1. The Presenters of the Final Models

6.2.3. Presentation of Model Lesson Exemplars

Similarly, the presentation of model Lesson Exemplar by purposively selected groups of STEAM educators followed the format of a research presentation. The model Lesson Exemplar presenters stressed how their group generated the model Lesson Exemplar as informed by the Philippine STEAM Education models. While they dedicated the attempt to concretize the variables, dimensions, and indicators of the Philippine STEAM Education, they also demonstrated a methodical aspect in the presentation where they narrated how they pilot tested or validated the developed exemplar for informed reflection and improvement seeking to share whatever knowledge they generated and to help the core research team to provide evidence of success for the developed and validated Philippine STEAM Education model.

Figure 6.2. The Presentation of the Lesson Exemplars

6.2.4. Forum Evaluation

Based on the evaluation of the participants of the National Forum, it received good to excellent equivalent numerical rating (see attached summary of evaluation results-*Appendix VI*) in all aspects of the program (educational content, relevance to practice, questions and discussions, selection of topics). Participants rated highly all plenary sessions, oral presentations, overall event, venue, registration process, administration before the program and organization during the program. In fact, the majority of the participants agreed and/or strongly agreed on the attainment of the all objectives of the National Forum (please see attached results-*Appendix VI*). A great number excellently assessed the National Forum that they planned attending the same forum in the future. They voiced out however, the need for some workshops to complement all plenary sessions and oral research presentations.

6.2.5. Future Directions

Anchoring from the responses on the evaluation form and feedback of the participants in the National Forum on STEAM Education, the following culled items provided the following themes which set the tones and aspirations for future directions of this project:

(1) Provide follow-up training programs on the implications of the STEAM Model. Most of the participants agreed on the significance of the STEAM Education Model as highlighted on the knowledge sharing they experienced on the two-day forum. However, they also recognized the essence of knowledge transfer of these models in their actual learning-teaching discourse. They suggested that participants with training programs focus on: (a) proper integration of technology in teaching STEAM courses (e.g. agri-fisheries and information technology); (b) design, development and utilization of lesson exemplars on specific STEAM courses; (c) mechanism on how the models address current issues and gaps on STEAM Education in the country; (d) promotion and interaction of STEAM disciplines and the community; and (e) processes and techniques in doing STEAM-related research undertakings. Participants also suggested that future trainings be more collaborative, hands-on and observe workshop format for them to be more participative and interactive with the speakers and with each other.

(2) Create collaboration projects and in-depth research undertakings on the quality of STEAM educators. This theme emerged as part of the participants' aspirations to establish collaboration among SUCs described as CHED's Center for Excellence (COE) and Center of Development (COD) on STEAM courses. These responses suggested learning the best pedagogies, technology integration and assessment practices from the aforesaid institution so as to enhance the quality of their local STEAM context. It also explained their vision of establishing linkages and partnerships with the COE and COD institutions. Besides, some participants aspired to conduct research undertakings focused on describing, measuring and developing the teaching proficiencies among STEAM educators, as well as on the current status of both validated and emerging PSE models with TPACK framework. They recognized the value of improving their teaching practices, more particularly on the use of updated and innovative technology applications in teaching STEAM courses and on the conduct of Participatory Action Research.

These concerns served as their response on the challenge of Education 4.0 and other drivers influencing the practices on STEAM education. And,

(3) Improve policies and guidelines on STEAM Education. The models presented in the Forum provided a better understanding on the different practices, processes and variables influencing the quality of STEAM education in the country. Thus, certain realizations on the need of enhancing the current guidelines of delivering STEAM courses by HEIs rose from the participants. These concerns covered the following items: (a) provision of new methodologies in delivering STEAM courses; (b) discussion the proficiency level of STEAM educators; (c) alignment and improvement of physical facilities together with online and offline technological tools used in realizing the objectives of STEAM disciplines; and (d) development of learning environment and practices that foster 21st century skills and research undertakings. These aspirations were considered incremental steps by the participants, as viewed from the institutional and national levels, gearing towards quality STEAM education.

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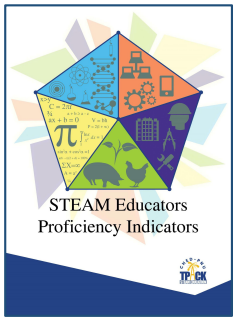
OUR PRODUCTS

Research Resources

STEAM Educators Proficiency Indicators

ISBN: 978-971-568-046-2
URL: http://pnu-onlinecommons.org/omp/index.php/chedpnutpack/catalog/book/495
Suggested Citation: Morales, M.P.E., Abulon, E.R., Anito, J.C., Jr., Avilla, R.A.., Palisoc, C.P., & Casilla, N.A. (2018). *TPACK in Philippine STEAM Education: STEAM Educators Proficiency Indicators*. Manila, Philippines: Philippines Normal University.

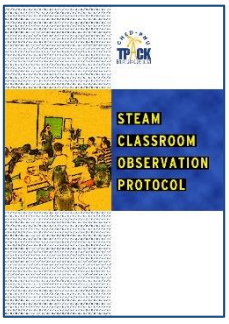


The STEAM (Science, Technology, Engineering, Agri-Fisheries, and Mathematics) Educators Proficiency Indicators is a self-rating tool which informs the level of STEAM Educator Proficiency as *Beginning STEAM Educator*, *Proficient STEAM Educator*, *Highly Proficient STEAM Educator*, and *Distinguished STEAM Educato*r. This tool consists of 60 items or indicators categorized into seven TPCK dimensions and seven PPST domains in no particular order.

STEAM Classroom Observation Protocol (COP)

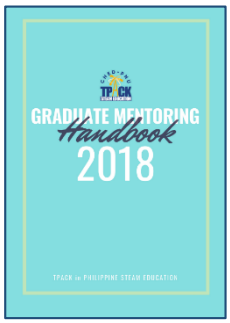
ISBN: 978-971-568-044-8
URL: http://pnu-onlinecommons.org/omp/index.php/chedpnutpack/catalog/book/494
Suggested Citation: Morales, M.P.E., Abulon, E.R., Anito, J.C., Jr., Avilla, R.A.., Palisoc, C.P., Elipane, L.E., & Casilla, N.A. (2018). *TPACK in Philippine STEAM Education: STEAM Classroom Observation Protocol*. Manila, Philippines: Philippines Normal University.

The STEAM Classroom Observation Protocol is a tool designed to help educators and researchers derive or deduce important information from STEAM educators significant to inform practices and policies in Philippine STEAM Education. The protocol contains the following instruments: 1) *STEAM Classroom Observation Rating Scale*; 2) *Classroom Observation Notes*; 3) *TPACK Interview Protocol*; 4) *Technology Integration Checklist*; and 5) *Assessment Checklist*.



Graduate Mentoring Handbook

ISBN: 978-971-568-045-5
URL: http://pnu-onlinecommons.org/omp/index.php/chedpnutpack/catalog/book/493
Suggested Citation: Morales, M.P.E., Abulon, E.R., Anito, J.C., Jr., Avilla, R.A.., Palisoc, C.P., Elipane, L.E., … Casilla, N.A. (2018). *TPACK in Philippine STEAM Education: Graduate Mentoring Handbook 2018*. Manila, Philippines: Philippines Normal University.

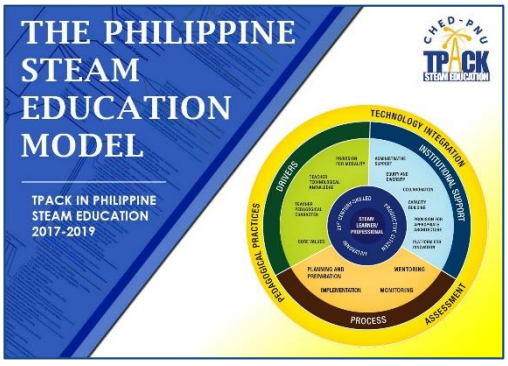


The **Graduate Mentoring Handbook** seeks to provide volunteer graduate students with a glimpse of how the CHED-funded research, Technological Pedagogical Content Knowledge (TPACK) in Philippine STEAM Education initiated research apprenticeship with STEAM graduate students in selected collaborating institutions. It features a brief on the previously mentioned research, another briefer on how the research mentoring program started, pedagogical framework used in the conduct of the mentoring program, materials, protocols, guide and instrument for apprenticeship, and reflections by the recipient graduate students.

The Philippine STEAM Education Model

ISBN: 978-971-568-048-8
URL: http://pnu-onlinecommons.org/omp/index.php/chedpnutpack/catalog/book/586
Suggested Citation: Morales, M.P.E., Anito, J.C., Jr., Avilla, R.A.., Sarmiento, C.P., Palisoc, C.P, Elipane, L.E., Ayuste, T.O.D., Butron, B.R., & Palomar, B.C. (2019). *The Philippine STEAM Education Model*. Manila, Philippines: Philippine Normal University.

The **Philippine STEAM Education (PSE) Model** is meant to visualize the Philippine Higher STEAM Education, to check how far we are from the global standards, and to support and might as well improve higher and advanced learning of STEAM (Science, Technology, Engineering, Agri-Fisheries, and Mathematics) disciplines in the country. Drawing from the current evidence base, it considers the following frameworks and ingenuities: a) Outcomes-Based Education (OBE), b) TPACK Framework, c) Philippine Professional Standards for Teachers (PPST), d) the Pedagogical Model of the Philippine STEAM Education, e) the Technology Integration of the Philippine STEAM Education, and f) the Assessment Model of the Philippine STEAM Education Model.



Proficiency Indicators for Philippine STEAM (Science,Technology, Engineering, Agri/fisheries, Mathematics) Educators

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Abstract

The study sought to develop a self-rating tool to determine the proficiency of Philippine Higher Education (PHE) STEAM (Science, Technology, Engineering, Agri-Fisheries, Mathematics) Educators. More deeply, this design and development research elaborated on the Philippine Professional Standards for Teachers (PPST) in the tertiary STEAM education aligned with the Policies, Standards, and Guidelines (PSGs) of 46 STEAM programs (science – 22, technology – 7, engineering – 10, agriculture – 5, and mathematics – 2). The crafted indicators went through expert and statistical validations and analyses to establish the indicators' content validity, construct validity, and reliability. The experts assessed the indicators' similarity and variance, appropriacy, phraseology, and ambiguity of items and found that most items from the first version (90 items) suit the criteria and the country's context. Principal axis factor (PAF) analysis showed that only 60 items represent the seven factor loadings generated from the analyses. These seven factors also matched the seven TPCK dimensions: Factor 1 (TPACK [Technological Pedagogical Content Knowledge]), Factor 2 (TPK [Technological Pedagogical Knowledge]), Factor 3 (TCK [Technological Content Knowledge]), Factor 4 (PCK [Pedagogical Content Knowledge]), Factor 5 (TK [Technological Knowledge]), Factor 6 (PK [Pedagogical Knowledge]), and Factor 7 (CK [Content Knowledge]). The first four factors with a majority of the generated 60 indicators already explained more than half of the variance as per PAF. Furthermore, all seven factors and the entire set of 60 indicators obtained above standard reliability indices, following Cronbach's alpha analysis, thus incurring valid and reliable 60 indicators of proficiency for PHE STEAM educators that may be utilized for reflective practice and policy inputs to Philippine STEAM Education.

Keywords: proficiency indicators, STEAM education, technological pedagogical content knowledge

Suggested Citation: Morales, M.P.E., Anito, J.C., Jr., Avilla, R.A., Abulon, E.L.R., & Palisoc, C.P. (2019). Proficiency Indicators for Philippines STEAM (Science, Technology, Engineering, Agri/fisheries, Mathematics) Educators. *Philippine Journal of Science, 148* (2), 265-281. http://philjournalsci.dost.gov.ph/87-next-issue/vol-148-no-2-june-2019/972-proficiency-indicators-for-philippine-steam-science-technology-engineering-agri-fisheries-mathematics-educators

Developing STEAM Educators' Proficiency Scoring Framework

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Abstract

The study aimed to develop the scoring framework for the self-rating proficiency indicators for Philippine STEAM educators. The study further sought to design mathematical framework and program for scoring STEAM educators' proficiency and validate the designed scoring program. About 1507 responses from the self-rating STEAM proficiency tool were used to undergo the three tier quantitative and qualitative validation. Mathematical equations were derived to direct the development of the scoring programs using Microsoft Excel and Fortran. Results show an agreement between the proficiency profiles generated from the Microsoft Excel and Fortran program. Using the online survey and the classroom observation rating, proficiencies were compared, as determined through the Fortran program of the pre-determined career stage (distinguished, highly proficient, proficient, beginner). Lastly, qualitative validation was performed by comparing the generated codes in the interview transcripts and observation notes and the attributes in the PPST domains and TPACK dimensions. Qualitative validation indicates that the occurrences of the indicators in the interview and classroom observation matched with the expected attributes per career stage, according to the PPST. This indicates that the validation of the scoring system developed for the online survey generate the STEAM educator proficiency. Further, the scope of the scoring framework developed appears universal and adaptable to suit any local setting. However, increasing the number of interviews and classroom observations to 10% of the sample population of teachers will produce a robust scoring program.

Keywords: STEAM education, TPACK dimension, PPST domain, STEAM educators' proficiency, STEAM proficiency scoring program

Philippine Higher STEAM Educators Proficiency

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Abstract

This study determined the national STEAM Education proficiency level of Philippine Higher Education (PHE) STEAM educators in terms of Technological Pedagogical Content Knowledge (TPACK) dimensions and Philippine Professional Standards of Teachers (PPST) domains. Sampled (Tier 1: stratified random sampling for 156 Philippine Higher Education Institutions [HEIs] distributed in 17 regions, and Tier 2: complete enumeration of STEAM educators in the sampled HEIs) 1940 STEAM educators took the online survey in January to December 2018. Data analysis (i.e., programmed scoring framework, descriptive statistics, percentile rank, and t-test) determined that self-rated proficiency defines their teaching and learning competence. In terms of PPST and TPACK framework, they perceived themselves as falling within the range of "Highly Proficient to Distinguished", leaning on the "Distinguished" self-perception as STEAM educators. Males and females do not register significant differences on how they perceive themselves except in one or two (i.e., learning environment, diversity of learners, pedagogy) domains and dimensions, which by nature favor the female gender. Neither, school type (private and government-owned) indexes significant difference, except on Community Linkages and TPACK as a whole. These findings may inform policy creation to improve and/or sustain these proficiency levels and help build stronger Philippine Workforce 4.0.

Keywords: proficiency level, self-perception, STEAM (Science, Technology, Engineering, Agri/Fisheries, Mathematics) Education

Developing the Lesson Exemplars for STEAM Disciplines in the Philippine Higher Education

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Abstract

The study developed Lesson Exemplars anchored on the feature of the Philippine STEAM Education (PSE) Model. The Lesson Exemplar is a compilation of lesson guides that can be utilized by STEAM (Science, Technology, Engineering, and Mathematics) Educators in teaching STEAM lessons in any STEAM discipline. Sampled 104 total participants (63 females, 41 males; [purposively sourced from a population determined using a two-tier sampling procedure employed in a state-funded research to which this study is anchored]) included: a) the field researchers/representatives, b) STEAM teachers that were observed and interviewed, and c) other STEAM educator self-survey participants from the 26 visited higher education institutions. A Lesson Exemplar (LE) instructional design and template directed the development by the participants (clustered into physical sciences, biological sciences and agri-fisheries, mathematics, technology and engineering). The rubric for LE guided the participants in the development process. The LE peer review form (designed from the PSE model) identified points for revision in the LEs after two rounds of peer review [used as validation process] of the developed LEs. Panel presentation and critiquing (as the second tier validation) provided more inputs for improvement. Developed LEs in all clusters showcased all the features of the PSE model exemplifying embedded principles of TPACK and all learning theories (e.g., inquiry learning, constructivism, collaborative practice) in all aspects of the LEs. Pilot tests of these LEs showed how the STEAM teachers highly engaged the learners in the learning of STEAM disciplines, which may eventually lead to quality STEAM education for the country.

Keywords: Lesson Exemplar, peer review, panel critiquing, PSE model, STEAM teachers

Designing the Graduate Mentoring Program of a State-Funded Research

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Abstract

The study explored how the designed graduate mentoring program of a state-funded research developed collaborative practice and action, and improved the research skills of the graduate student mentees transitioning them to becoming reflective teachers. Participatory Action Research (PAR) designed as a methodical and program framework engaged 10 mentors, 8 volunteer graduate students (senior mentees) and 19 volunteer graduate students (junior mentees [with 8 of them actively joining the field research]). Implementation of the mentoring program highly depended on training-based mentoring [workshops and field work], small group mentoring [within research cells], peer mentoring [field work and software-aided coding analysis]. Observations, narrations by mentors, reflection journals extracted the experiences of the participants on the mentoring program. Reflections and narrations reveal that both mentors and mentees (both levels: senior and junior) learned many skills during the mentoring program. They encountered several challenges and difficulties in the aspect of time management, and field work, which they were able to convert into learning episodes, consequently exhibiting reflection-in-action and reflection-on-action. They emphasized their realization of the importance of theory-practice-reflection scheme in all research endeavors. However, other volunteers showed very little or low engagement in the mentoring sessions especially in field works due to time and schedule aspects, which may be looked into for the next attempt on mentoring using PAR.

Keywords: learning episodes, mentees, mentor, mentoring, participatory action research (PAR)

Technology Integration in Philippine Higher STEAM (Science, Technology, Engineering, Agri/Fisheries, Mathematics) Education

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Abstract

The study profiled the Philippine Higher STEAM educators' technology integration traditions and transitions, and determined their common and best practices as well. Data sourced from 85 responses (to surveys, interviews and classroom observations) of purposively selected higher and advanced learning STEAM teachers from strata (17 regions) sampled Philippine Higher Education Institution undergo qualitative data analysis (two-level coding system) to profile their technology integration practices. Additionally, four technology integration frameworks were used (TIM [Technology Integration Matrix], Triple E [Engage, Enhance, Extend], SAMR [Substitute, Augment, Modify, Redefine], TPACK [Technological Pedagogical Content Knowledge]). Findings reveal that the STEAM teachers favor the use of traditional technology and practice a very low level of engagement to web and learning applications. They advocate integrating improvised tools, equipment and even alternative chemicals and solutions. Their primary considerations in choosing technology for integration favor usability (availability and ease of use), pedagogy and content/discipline, and learners. The majority of the sampled STEAM teachers qualify as Beginners exhibiting a level over the lowest in all the frameworks used for analysis of their integration level. Apparently, Philippine universities and colleges may explore better and holistic professional development programs for STEAM teachers to upgrade their technology integration levels, and industry-university partnership to address affordances and provide better access to complex technology.

Keywords: Education 4.0, Philippine STEAM Education, technology integration, Technology

Assessing Learning in Philippine Higher STEAM Education

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Abstract

The study critically explored the unique practices of the sampled Philippine Higher STEAM Educators (106 STEAM teachers from purposely selected universities or colleges drawn from the 17 regions based on stratified random sampling) to determine their assessment practices, and their common and best practices in assessing STEAM learners in advanced and higher learning. Data sourced from the database of a state-funded research on Philippine STEAM education (using the Classroom Observation Protocol as the measure), and analyzed systematically (using data condensation, data display, and drawing and verifying conclusions) revealed that STEAM teachers effectively use of both appropriate traditional and authentic assessment tools and strategies (inclusive integration of technology-influenced tools and assessment processed). Furthermore, our findings show that STEAM teachers best practices may be categorized as: 1) assessment for career or industry readiness, 2) mounting assessment system to support instruction, and 3) collective and reflective assessment process. However, we only sourced data from a limited number of STEAM educators with an end view of exploring their current assessment practices. It may be better to further probe the extent on how STEAM educators are demonstrating these assessment practices and its influence on their students' learning, which may better provide inputs for policies and standards on STEAM education assessment.

Keywords: STEAM education; assessment; best practices

TPACK in Philippine STEAM Education

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Abstract

The study wove three frameworks (Philippine Policies, Standards, and Guidelines [PSGs], Philippine Professional Standards for Teachers [PPST], and Technological Pedagogical Content Knowledge [TPACK]) to develop the TPACK model for Philippine STEAM Education. It utilized exploratory design, and design and development research (using both qualitative [e.g., interviews, classroom observations, coding, and model analysis] and quantitative approach [e.g., survey, approaches) to 106 (from purposely selected universities or colleges drawn from the 17 regions based on stratified random sampling) in generating the TPACK model for Philippine STEAM Education. The generated model shows that STEAM educators try to singly develop one knowledge construct of the TPACK framework at a time. As per sequence, they often start with a mastery of the content, then move on to pedagogy, before employing or integrating appropriate technology. Apparently, our education system developed STEAM educators (profiled as discipline-specific), who focus on singular knowledge of the TPACK framework, and sequentially building on blended TPACK knowledge until they eventually attain a status in which they possess an understanding of: 1) how technology applies represent the concepts of the discipline, 2) how to effectively use technology in pedagogical techniques, 3) and how technologies can address the difficulties students face when learning concepts. It is envisioned that the model could help track and finally enhance the competencies of Philippine STEAM educators to deliver 21st century-skilled STEAM workforce for the country.

Keywords: STEAM (Science, Technology, Engineering, Agri-Fisheries, Mathematics) Education, TPACK (Technological Pedagogical Content Knowledge), Philippine Higher Education, model

The Pedagogical Model of Philippine STEAM Education

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Abstract

Education must respond appropriately to the changing economic and social landscape. Specifically, the data-driven and algorithm-based operations across all work sectors demand new set of competencies from higher education graduates. Being at the frontier of all technological advancements, the Science, Technology, Engineering, Agri-Fisheries, and Mathematics (STEAM) Education must deliver graduates whose competencies match the current demands of the world of work. This study was conducted to revisit the pedagogical context of STEAM education in the country. A pedagogical model of Philippine STEAM education was developed following a three-tier qualitative data analysis of interview transcripts from in-depth interviews with higher education administrators, STEAM program coordinators, and STEAM teachers from 33 Higher Education Institutions (HEIs) across the country. The developed model demonstrates an interdependence between institutional pedagogical culture and STEAM pedagogical processes. The pedagogical culture of an HEI pertains to its framework and mechanism for planning, disseminating, and evaluating the pedagogical processes and the extent by which research and teaching nexus is advanced in all these processes. The pedagogical culture of an HEI drives its STEAM pedagogical processes, specifically the teaching practices, and shapes the pedagogical character of its teachers. Teachers' epistemological beliefs and teaching practices comprise their pedagogical character. STEAM teachers acknowledge that there is no perfect teaching strategy to imply that appropriateness of teaching approach must be given attention in planning the pedagogical processes. Hence STEAM teachers are skilled in various teaching strategies and are adept in switching across strategies whenever appropriate and necessary. STEAM teachers likewise model learning by linking practice and teaching, and demonstrating critical and reflective thinking. The Pedagogical model of Philippine STEAM Education explicates that the synergy between an institution's pedagogical culture and its pedagogical processes is gauged by the quality of its learners and teachers. Specifically, Philippine STEAM education aims at nurturing critical thinkers, productive citizens, and competent STEAM professionals.

Keywords: STEAM Education, Pedagogical Model, divergent grounded theory, Philippines

Promoting multi-level reflexivity in a model-building qualitative research

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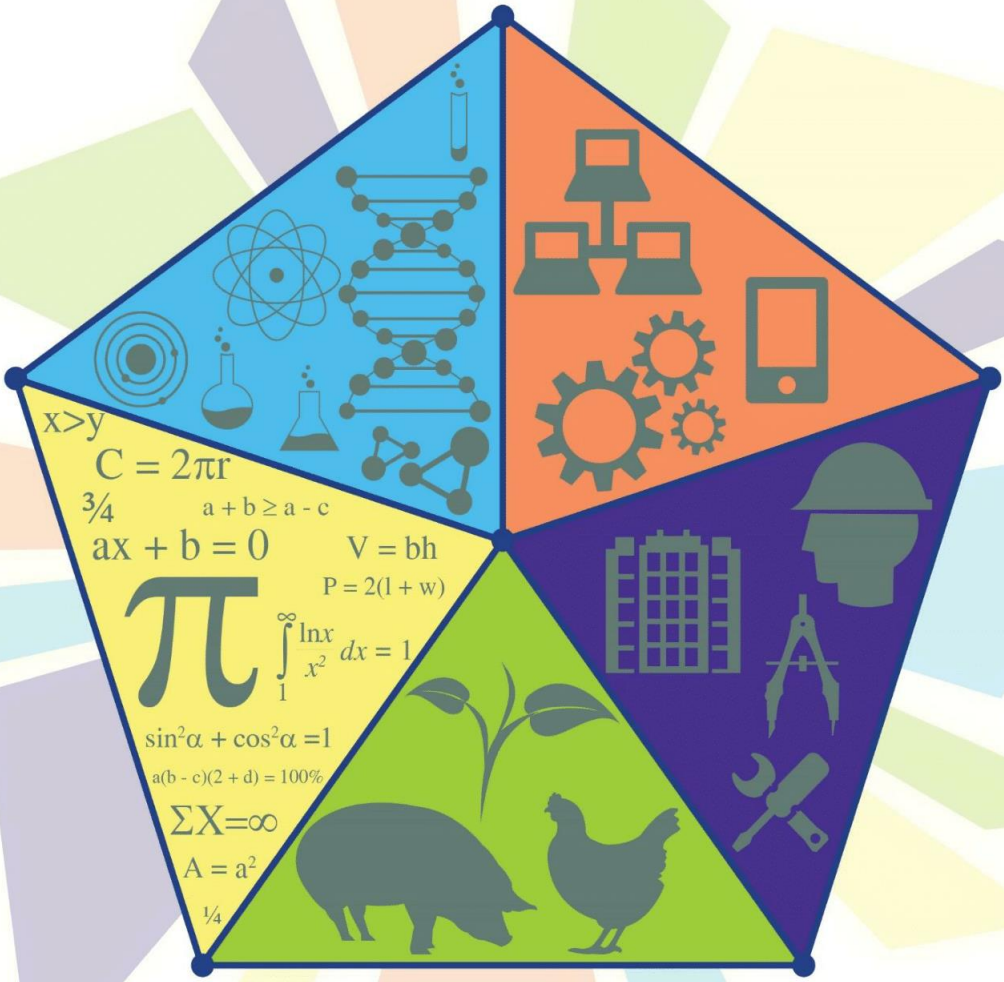
Abstract

Reflexivity is crucial in qualitative research because of the need to address the insider-outsider duality in any qualitative investigation. Establishing quality of qualitative method and results necessitates researchers to critically examine their paradigms relative to those of others in a studied context. This is because the researchers' paradigmatic stance may affect, in any way, the entire qualitative research. Researchers then need to exert conscious effort to observe reflexivity in all stages of a qualitative research process. This article aims to demonstrate how the embedment of reflexivity in data collection, data analysis, and quality audit processes paved way to the development of the Pedagogical Model of Philippine Science, Technology, Engineering, Agri-Fisheries, and Mathematics (STEAM) Education. Working on this statefunded model-building research project entailed administrative and logistics constraints which prompted the researchers to diversify the qualitative method employed. This article further underscores how the multilevel reflexivity mechanism advanced quality in a divergent qualitative method.

Keywords: divergent grounded theory, quality audit, reflexivity, STEAM education, Philippines

APPENDICES

Appendix I. STEAM Educators Proficiency Indicators



STEAM Educators Proficiency Indicators

STEAM Educators Proficiency Indicators

Philippine Normal University
The National Center for Teacher Education
Taft Ave., Manila

This self-rating scale, ***STEAM Educators Proficiency Indicators,*** may inform the level of STEAM Educator Proficiency as Beginning STEAM Educator, Proficient STEAM Educator, Highly Proficient STEAM Educator, and Distinguished STEAM Educator.

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STEAM EDUCATORS PROFICIENCY INDICATORS

Informed Consent Form

Being over the age of 18 years old (legally independent), I hereby consent to participate in the research project titled: "Technological-Pedagogical-Assessment-Content-Knowledge (TPACK) in STEAM Education" by answering the herein STEAM EDUCATORS PROFICIENCY INDICATORS

I am aware that my participation is voluntary in nature;

I understand that I may not directly benefit from taking part in this research;

While the information gained in this study will be published as a research article, I will not be identified, and individual information will remain confidential;

Any information and related data obtained during the pilot testing shall be used solely for research and academic purposes; and

I may provide comment/s and suggestion/s to the items in the research instrument and the process of pilot testing as I deemed necessary.

Dear Respondent,

The Philippine Normal University would like to know your level of proficiency as a STEAM Educator. Please rate yourself in terms of the indicators/attributes listed by highlighting the choice of your answer.

Scale to use (4-point scale):

4 = Always true to myself
3 = Often true to myself
2 = Occasionally true to myself
1 = Rarely true to myself
N/A = Not applicable

This self-rating scale may inform the level of STEAM Educator Proficiency as Beginning STEAM Educator, Proficient STEAM Educator, Highly Proficient STEAM Educator, and Distinguished STEAM Educator.

Thank you for taking time in answering.

PNU Researchers

*E-mail Address: _____

Name (Optional): _____

*Gender: _____

*Age: _____

*School Affiliation: _____

*Address: _____

*No. of Years of STEAM Teaching: _____

*Specific Area/Field (Science, Technology, Engineering, Agriculture, or Mathematics) _____

*Subject being taught _____

*Year Level being taught _____

Item No.	Indicators	4	3	2	1	N/A
1	Possesses content knowledge on STEAM (Science, Technology, Engineering, Agriculture, and Mathematics).	☐	☐	☐	☐	☐
2	Demonstrates content knowledge on core STEAM courses.	☐	☐	☐	☐	☐
3	Demonstrates content knowledge on STEAM-related fields (i.e., research, language and communication).	☐	☐	☐	☐	☐
4	Demonstrates STEAM-related laboratory/clinical skills.	☐	☐	☐	☐	☐
5	Possesses knowledge on related industry/community as service providers.	☐	☐	☐	☐	☐
6	Exhibits knowledge on STEAM fields (content and skills) responsive to national goals and global concerns.	☐	☐	☐	☐	☐
7	Plans, conducts, and disseminates STEAM-related research.	☐	☐	☐	☐	☐
8	Designs, improves, innovates, and supervises basic to advance systems and/or procedures as solutions to local and global problems within realistic constraints.	☐	☐	☐	☐	☐
9	Utilizes research outputs to enhance professional practice and to address national and global concerns.	☐	☐	☐	☐	☐
10	Develops/Improvises new technology (software, laboratory equipment, and teaching materials) using locally available resources to advance effective and efficient practice of the profession.	☐	☐	☐	☐	☐
11	Uses modern statistical and computing techniques and tools in predicting future trends and processes of STEAM.	☐	☐	☐	☐	☐
12	Familiarizes with database relevant to the STEAM profession.	☐	☐	☐	☐	☐
13	Uses advanced and research-based techniques and tools in teaching STEAM content knowledge.	☐	☐	☐	☐	☐
14	Communicates effectively across multiple platforms, both oral and written, especially in the English language.	☐	☐	☐	☐	☐
15	Seeks out information on subject related research, e.g., via journals or by attending conferences.	☐	☐	☐	☐	☐
16	Facilitates development of reflective and critical thinking among students.	☐	☐	☐	☐	☐

17	Promotes inquiry attitude through questioning.	☐	☐	☐	☐	☐
18	Facilitates active classroom discussion using inquiry learning strategies (project-based, problem-based, product-based).	☐	☐	☐	☐	☐
19	Allows flexible channels of communication to get across students of different abilities and comprehension skills and even allows occasional use of mother tongue to help express themselves or their answers better (then translate them to a common language for everyone to appreciate and learn from).	☐	☐	☐	☐	☐
Comment for Item Nos. 1-19						
20	Observes precautionary measures in the laboratory rooms and classrooms (fire extinguishers, fire force) alarm systems, and campus security.	☐	☐	☐	☐	☐
21	Facilitates ethical use of online resources.	☐	☐	☐	☐	☐
22	Promotes working effectively in multidisciplinary and multi-cultural teams.	☐	☐	☐	☐	☐
23	Exhibits capability to facilitate large classes.	☐	☐	☐	☐	☐
24	Promotes proper care and handling of laboratory instruments, tools, equipment, online systems, virtual laboratories, and software.	☐	☐	☐	☐	☐
25	Promotes seamless transition of topics and establishes relevant relationship of concepts.	☐	☐	☐	☐	☐
26	Utilizes teaching strategies suited to diverse learners.	☐	☐	☐	☐	☐
27	Monitors each student by establishing eye contact, walking around the area, being aware of what's happening in the class during sessions, site visits, field trips, tours, and other supervised visits.	☐	☐	☐	☐	☐
28	Models various scientific attitudes and STEAM professional traits.	☐	☐	☐	☐	☐
29	Promotes the concept of voluntary service by making students carry out classroom-related duties (e.g., monitoring cleanliness and orderliness in the classroom).	☐	☐	☐	☐	☐
Comment for Item Nos. 20-29						
30	Facilitates lessons and activities that are suited to the students' interests and individual differences and do not discriminate any cultural groups and are sensitive to students' needs.	☐	☐	☐	☐	☐
31	Arranges opportunities for students to learn by allowing them to form varied group structures (solo, pair, groups, and teams).	☐	☐	☐	☐	☐
32	Develops gender-sensitive instructional materials.	☐	☐	☐	☐	☐
33	Takes into consideration the cultural, social, and emotional differences among students.	☐	☐	☐	☐	☐
34	Prepares materials and lessons appropriate to specific learning capability.	☐	☐	☐	☐	☐
35	Facilitates peer learning to support other students cognitively and affectively.	☐	☐	☐	☐	☐

36	Listens skillfully, reasonably, and patiently to students during consultation.	☐	☐	☐	☐	☐
Comment for Item Nos. 30-36						
37	Possesses knowledge on curricular programs including goals and framework.	☐	☐	☐	☐	☐
38	Engages the students in planning and achieving the learning outcomes.	☐	☐	☐	☐	☐
39	Utilizes various teaching methods.	☐	☐	☐	☐	☐
40	Applies current trends, practices, and innovations in the teaching process.	☐	☐	☐	☐	☐
41	Uses updated syllabi and teaching methods to meet the desired learning outcomes.	☐	☐	☐	☐	☐
42	Ensures that the learning outcomes are attained.	☐	☐	☐	☐	☐
43	Designs, communicates, and implements STEAM-related activities in partnership with the community/industry.	☐	☐	☐	☐	☐
44	Uses multimedia and other learning resources like journals and online materials in the teaching and learning process.	☐	☐	☐	☐	☐
45	Adapts and utilizes STEAM technologies in the teaching and learning process.	☐	☐	☐	☐	☐
Comment for Item Nos. 37-45						
46	Selects standard assessment methods appropriate for instructional decisions.	☐	☐	☐	☐	☐
47	Recognizes unethical, illegal and otherwise inappropriate assessment methods and uses of assessment information.	☐	☐	☐	☐	☐
48	Possesses skills in using assessment results when making decisions about individual students, planning teaching, developing curriculum, and school improvement.	☐	☐	☐	☐	☐
Comment for Item Nos. 46-48						
49	Emphasizes the effects and impacts of the STEAM disciplines to the community and society.	☐	☐	☐	☐	☐
50	Conducts STEAM-related activities involving the learners, parents and the community.	☐	☐	☐	☐	☐
51	Demonstrates dedication and commitment to work with honesty and integrity.	☐	☐	☐	☐	☐
52	Recognizes and understands the professional, social and ethical responsibilities of the STEAM profession.	☐	☐	☐	☐	☐
53	Practices STEAM profession in accordance with the existing laws, legal, ethical and moral standards.	☐	☐	☐	☐	☐
54	Models the existing general policies, rules and regulations to promote the welfare of the STEAM professions.	☐	☐	☐	☐	☐
55	Observes the existing policies to better serve the students, the school, and the community.	☐	☐	☐	☐	☐
Comment for Item Nos. 49-55						

56	Maintains reputation as a pedagogical leader.	☐	☐	☐	☐	☐
57	Participates in seminars and conferences that may provide valuable inputs to make STEAM teaching relevant and responsive to the changing times.	☐	☐	☐	☐	☐
58	Uses appropriate modern techniques and tools necessary for the practice of STEAM profession in order to be globally competitive.	☐	☐	☐	☐	☐
59	Pursues higher learning (ex. graduate studies or short term courses) and accomplishes higher goals to advance in one's career stage.	☐	☐	☐	☐	☐
60	Engages in professional activities other than teaching (publish articles, conduct valuable and impactful research, take part in the curriculum development, re-echo seminars etc.) to further improve teaching competencies as well as leadership qualities and make a distinction in the field of science.	☐	☐	☐	☐	☐
Comment for Item Nos. 56-60						

Appendix II. STEAM Classroom Observation Protocol

STEAM CLASSROOM OBSERVATION PROTOCOL

STEAM Classroom Observation Protocol

Philippine Normal University
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CLASSROOM OBSERVATION PROTOCOL FOR STEAM

Philippine Normal University

In the country's journey to improve the quality of life of Filipinos and to establish high economic growth, aspects of science, technology, engineering, agriculture and mathematics (STEAM) may highlight skills to achieve our goals. In fact, the adherence of the country to STEAM highlights the "AMBISYONNATIN 2040," themed as, "*Matatag, Maginhawa, at Panatag na Buhay* (Philippine Development Plan [PDP], 2017)." The country believed that the 2040 goal may be concretized through the three priority areas of the crafted Philippine Development Plan which includes: 1) *malasakit* (enhancing social fabric); 2) *pagbabago* (reducing inequality); and 3) *patuloy na pag-unlad* (increasing growth potential). These three priority areas emphasize among others promotion and awareness of Philippine culture, acceleration of human capital development, promotion of technology, and stimulation of innovation. Apparently, the make-up of the PDP framework puts STEAM as among the cores to achieving the 2040 goals. Thus, necessitates cross-cutting strategies, which may be derived from quality STEAM education for the Filipinos. Relative thereto, our study aims to craft an Emerging Technological-Pedagogical-Assessment-Content Knowledge (TPACK) Model for Philippine STEAM Education and to provide inputs to policies for Philippine STEAM Education.

The **STEAM Classroom Observation Protocol** is a tool designed to help educators and researchers derive or deduce important information from STEAM educators significant to inform practices and policies in Philippine STEAM Education.

The Protocol contains the following instruments:

STEAM Classroom Observation Rating Scale – This instrument is a 6-point Likert scale sectioned into basic descriptive information and instruction. The rating scale determines the extent of visibility of the identified traits, characteristics, processes and products relative to content, knowledge and pedagogy; the learning pedagogy; and the diversity of learners. It is not recommended that this worksheet be used by teachers to rate classroom practice of their peers or for use by administrators to evaluate teacher performance. The worksheet is intended to be used in conjunction with the other instruments and protocol included in this set.

Classroom Observation Notes – This instrument includes questions clustered into the dimensions of TPACK. The observation notes is designed for use by researchers who would want to collect qualitative data on STEAM Education anchored to the TPACK framework It is not recommended that this worksheet be used by teachers to rate classroom practice of their peers or for use by administrators to evaluate teacher performance.

TPACK Interview Protocol—This instrument includes sets of questions intended to guide the researcher or evaluator in the collection of qualitative observations and extrapolation of meanings and explanations that will be used augment all areas of concern not completely provided by the two other instruments. Themes highlighted in this interview guide include: Teacher's scientific attitude and pedagogical reputation, inquiry-based learning and teaching, inclusive and relevant STEAM education, classroom management, attainment of learning outcomes, knowledge of STEAM and STEAM related fields.

Technology Integration Checklist – This checklist can be used to document the nature of the teacher and the student's use of technology in the classroom.

Assessment Checklist- This instrument includes items on various techniques a STEAM educator utilizes to assess the performance of the student.

Possible Uses

The table below describes several possible uses of this tool. It also identifies which forms are most appropriate for each use:

Possible Use	STEAM Classroom Observation Rating Scale	Classroom Observation Notes	TPACK Interview Protocol	Technology Integration Checklist	Assessment Checklist
In-service Professional Development: In this case the tools are used by teachers or administrators to collect data on the knowledge and practice of in-service teachers regarding STEAM Education. Data collected can serve as baseline for analysis and development of framework leading to In-service trainings to enhance Philippine STEAM Education.	✔	✔	✔	✔	✔
Pre-service Professional Development: Teacher preparation programs would find the tool useful to help pre-service teachers to understand how to enact quality STEAM Education. What different traits and aspects of classroom such as pedagogy, assessment and classroom management are needed to practice quality STEAM Education?	✔	✔	✔	✔	✔
Data Collection for Research of Evaluation: Researchers or evaluators would use the tool to formally collect data. In this case the tool would need to be used under more rigorous standards by observers who have been trained on the use of the tool and who have a deep understanding of STEAM instructional practice.	✔	✔	✔	✔	✔

Some Tips in Classroom Observation

Below are several tips to take into consideration when collecting classroom observation data.

- Stick on to all normal protocol when observing classes that relate to your role. This may include obtaining permission from the administrator and teacher, signing in when you visit the school, obtaining certificate of appearance, if you are from a government school.

- Meet briefly with the teacher of the class you plan to observe before the observation and ask the pre-observation questions (checklist) provided on the instrument pack to gather information about the lesson and the classroom context.

- It is important that the lesson observed be a typical lesson. Therefore, do not indicate to the teacher what it is that you are looking for because then the teacher feels obligated to show you that and adjust the lesson accordingly. Do not share any of the worksheets or protocols with the teacher.

- You must be able to observe at least several classes of the teacher to get a feel of the lesson and the education quality, particularly on pedagogy, assessment, technology integration and content knowledge of the teacher.

- During each observation, take notes on separate paper. Avoid interactions with students and do not become a teaching assistant by helping students with the activity. It may be necessary to quietly ask a few students a question or two to check their understanding. Focus your observation on what the students are doing, saying, and looking and on the teacher.

- After the lesson is finished, ask the teacher the post-observations questions on the worksheet to get a better understanding of the lesson from the teacher's perspective.

- Ask also for some students for the student interview or focus-group-discussion (if necessary).

- In using the ***STEAM Observation Rating Scale*** check the number which you think is the appropriate rating during observation. The "don't know" is usually intended for items which you are not really familiar with regards the teacher concern or have no way of finding out. The "N/A" is chosen for unconnected or unrelated items to the class being observed.

STEAM Classroom Observation Rating Scale

Observation Date: _____ Time Start: _____ Time End: _____

School:_____ Address: _____

Teacher: _____

PART ONE: THE LESSON

SECTION A. BASIC DESCRIPTIVE INFORMATION

1. Teacher Gender: _____:Male _____:Female
2. Subject Observed:_____
3. Level: _____
4. Program:_____
5. Course Title (if applicable): _____
6. Class Period (if applicable): _____
7. Number of Students: _____:Male _____:Female

SECTION B: INSTRUCTION

D1. Content, Knowledge and Pedagogy	N/A	Not at all				To a great extent
	(0)	(1)	(2)	(3)	(4)	(5)
1. Possesses content knowledge on STEAM (Science, Technology, Engineering, Agriculture, and Mathematics).						
2. Demonstrates content knowledge on core STEAM courses.						
3. Demonstrates content knowledge on STEAM-related fields (i.e., research, language and communication).						
4. Demonstrates STEAM-related laboratory/clinical skills.						
5. Possesses knowledge on related industry/community as service providers.						
6. Exhibits knowledge on STEAM fields (content and skills) responsive to national goals and global concerns.						

7. Plans, conducts, and disseminates STEAM-related research.						
8. Designs, improves, innovates, and supervises basic to advance systems and/or procedures as solutions to local and global problems within realistic constraints.						
9. Utilizes research outputs to enhance professional practice and to address national and global concerns.						
10. Develops /Improvises new technology (software, laboratory equipment, and teaching materials) using locally available resources to advance effective and efficient practice of the profession.						
11. Uses modern statistical and computing techniques and tools in predicting future trends and processes of STEAM.						
12. Familiarizes with database relevant to the STEAM profession.						
13. Uses advanced and research-based techniques and tools in teaching STEAM content knowledge.						
14. Develops models of STEAM knowledge and processes.						
15. Communicates effectively across multiple platforms, both oral and written, especially in the English language.						
16. Seeks out information on subject related research, e.g., via journals or by attending conferences.						
17. Facilitates development of reflective and critical thinking among students.						
18. Promotes inquiry attitude through questioning.						
19. Facilitates active classroom discussion using inquiry learning strategies (project-based, problem-based, and product-based).						
20. Allows flexible channels of communication to get across students of different abilities and comprehension skills and even allows occasional use of mother tongue to help express themselves or their answers better (then translate them to a common language for everyone to appreciate and learn from).						
D2. Learning Environment						
21. Ensures a safe STEAM learning environment (free from fire hazards, safe electrical wiring, conforms to building code).						
22. Observes precautionary measures in the laboratory rooms and classrooms (fire extinguishers, fire force) alarm systems, and campus security.						
23. Facilitates ethical use of online resources.						
24. Promotes working effectively in multidisciplinary and multi-cultural teams.						
25. Exhibits capability to facilitate large classes.						
26. Manages proper and fair implementation of Problem/Project-based Learning activities.						
27. Promotes proper care and handling of laboratory instruments, tools, equipment, online systems, virtual laboratories, and software.						

28. Promotes seamless transition of topics and establishes relevant relationship of concepts.						
29. Provides students with activities and classroom situations where they can implement independent individual or collaborative group work when suitable.						
30. Promotes student engagement and quality performance in class activities such as during group work, projects, and other activities.						
31. Utilizes teaching strategies suited to diverse learners.						
32. Monitors each student by establishing eye contact, walking around the area, being aware of what's happening in the class during sessions, site visits, field trips, tours, and other supervised visits.						
33. Models various scientific attitudes and STEAM professional traits.						
34. Promotes the concept of voluntary service by making students carry out classroom-related duties (e.g., monitoring cleanliness and orderliness in the classroom).						
35. Promotes proactive classroom management and exhibits capability of handling untoward behavior with fairness and prudence.						
D3. Diversity of Learners						
36. Develops instructional plan appropriate to the identified learners.						
37. Facilitates lessons and activities suited to the students' interests and individual differences, do not discriminate against any cultural groups, and are sensitive to students' needs.						
38. Arranges opportunities for students to learn by allowing them to form varied group structures (solo, pair, groups, and teams).						
39. Develops gender-sensitive instructional materials.						
40. Takes into consideration the cultural, social, and emotional differences among students.						
41. Prepares materials and lessons appropriate to specific learning capability.						
42. Offers additional classroom-based sessions (within official hours) to improve learning.						
43. Designs, plans, and implements working and support groups to provide help to learners in difficult circumstances.						
44. Facilitates peer learning to support other students cognitively and affectively.						
45. Is open to invitations for team teaching to provide supplemental learning from each member of the team for more holistic student learning.						
46. Listens skillfully, reasonably, and patiently to his or her students during consultation.						
47. Develops different learning paths to respond to the student differences brought about by culture and ethnicity.						
48. Being aware of norms, cultures, and traditions so as not to cause discrimination in the delivery of lessons.						

TPACK Classroom Observation Notes

This instrument includes questions clustered into the dimensions of TPACK. The observation notes is designed for use by researchers who would want to collect qualitative data on STEAM Education anchored to the TPACK framework It is not recommended that this worksheet be used by teachers to rate classroom practice of their peers or for use by administrators to evaluate teacher performance.

Dimensions	Items	Observer's Field Notes
CK	What content/topic does the teacher intend to teach?	Does the teacher possess sufficient understanding of the topic being discussed? **1. enumerate indicators of mastery of subject matter (see examples below)** ☐ Uses Department's Scope and Sequence documents as appropriate ☐ Uses relevant curriculum documents specific to year/subject level ☐ Keeps abreast of new ideas and techniques through professional reading ☐ Integrates knowledge and skills in content area **(Observer may enumerate as many indicators as possible)** **2. provide details of observed teacher's misconceptions (if any)** **3. take note of the provided real-life examples (if there are any) inappropriate to the concept being advanced**
PK	**Intended Strategy (Based on the Session Plan)**	**Is the teacher skillful in implementing the teaching strategy/ies used?** 1. describe the teaching strategy/ies used 2. provide indicators of effective (or ineffective) use of specific strategy (e.g. student engagement, student participation, productive work of students, smooth flow of laboratory work)
TK	**Intended tools for teaching and**	**Is the teacher adept in using learning tools?**

	learning (based on session plan)	1. enumerate/describe the teaching materials/tools used (e.g. specific softwares, equipment, gadgets, improvised material, laboratory materials) ☐ CB (Chalkboard/whiteboard/SMART board) ☐ OP (Overhead Projector/Opaque Projector) ☐ PP (PowerPoint or other digital slides) ☐ CL (Clicker Response System) ☐ D (Demonstration Equipment, e.g. could include Chemistry demonstrations of reactions, physics demonstrations of motion or any other material being used for the demonstration of a process or phenomenon) ☐ DT (Digital Tablet or any technology where the instructor can actively write on a document cameras as well as software on a laptop that allows for writing on PDF files) ☐ M (Movie, documentary, video clips, or YouTube videos) ☐ Si (Simulations that can be digital applets or web-based simulations and animations) ☐ WEB (Website which includes instructor interaction with course website or other online resource other than YouTube videos. This can also include using website for student responses to questions in lieu of clickers) ☐ LDEM (Use of equipment (e.g. lab equipment, computer simulation to convey course content) ☐ IAE (Improvised apparatus or equipment) ☐ LA (Learning applications, e.g. Kahoot) 2. provide indicators of effective (or ineffective) use of learning tools
PCK	1. Did the teacher implement the lesson using the intended pedagogy? 2. Does the teacher manifest deep understanding of both the content and the strategy during the session? 3. Did the teacher fluently and fluidly conduct	**Is the strategy used appropriate to the topic being discussed?** 1. List down indicators where the teaching strategy used promotes students' understanding of the subject matter ☐ Introductory part of the lesson ☐ Activity proper ☐ Lecture proper ☐ Discussion Proper **(Provide additional list if necessary)**

	the lesson using the intended strategy? 4. Did the teacher resort to "on the spot" changes in the intended strategy to accommodate students' needs? 5. Did the teacher extract high student engagement during the session?	
TCK	**Did the teacher use digital tools in class?**	**Are the teaching tools used appropriate to the topic being discussed?** 1. List down indicators where the teaching tools used promote students' understanding of the subject matter
TPK	**How did the teacher use the intended technology to extract the desired learning outcomes and experiences?**	**Are the teaching tools used appropriate to the teaching strategy/ies** employed? 1. List down indicators where the teaching tools used enhance the effectiveness of the teaching strategy
TPACK	**Assessment of TPACK Integration**	
	Session Plan	Actual Session

Interview Questions

Theme: Teacher's Scientific Attitude and Pedagogical Reputation		
Main Question	***(For STEAM Teachers)*** *What scientific characteristics do you possess that you want to model to your learners?* ***(For STEAM Teacher Education only)*** *What scientific and pedagogical characteristics do you possess that you want to model to your learners?*	***(For School Heads, College Deans, and Other Officials)*** *How would you assess the scientific and pedagogical characteristics that your STEAM faculty model to STEAM learners?*
Probing Points	***(Please customize the questions to the discipline of the interviewee)*** 1. How do you emphasize in your learning and teaching processes that STEAM should benefit the society (e.g. school, community)? 2. How do you exhibit dedication and commitment to realize the goals of the STEAM discipline? 3. How do you promote academic integrity in teaching STEAM? a. ethical conduct as a professional such as, but not limited to the ethical treatment of shared information and knowledge (e.g. online resources) b. ethical use of assessment results and student data 4. How do you establish (or maintain) a reputation as a "good STEAM teacher"? 5. Describe your research activities in the past five years (in terms of): a. efforts to familiarize with sources of information regarding STEAM b. researches conducted c. research results utilized for policies and decisions and predicting trends in STEAM and STEAM education d. technologies developed from one's research results	1. What indicators that your STEAM faculty emphasize in their teaching processes that STEAM should benefit the society from (e.g. school, community)? 2. How do you assess the dedication and commitment of your STEM Faculty realizing the goals of the STEAM discipline? 3. How do you guide your STEAM faculty in maintaining a reputation as a "good" STEAM teacher and promoting academic integrity in teaching STEAM? c. ethical conduct as a professional such as but not limited to the ethical treatment of shared information and knowledge (e.g. online resources) d. ethical use of assessment results and student data 4. As an administrator, how do you manage negative feedback of students to your STEAM teachers? 5. Describe the research activities you facilitate in the past five years (in terms of): a. efforts to familiarize yourself with sources of information regarding STEAM b. researches conducted c. research results utilized for policies and decisions and in predicting trends in STEAM and STEAM education technologies developed from one's research results
Theme: Inquiry-Based Learning and Teaching		
Main Question	***(For STEAM Teachers)***	***(For School Heads, College Deans, and Other Officials)***

	Do you believe that inquiry-based learning and teaching approach is appropriate in the teaching of STEAM? ***(Please customize the questions to the discipline of the interviewee)***	*Do you believe and encourage your faculty to advocate inquiry-based learning and teaching approach is appropriate in the teaching of STEAM?*
Probing Points	1. How do you promote critical and reflective thinking in class? 2. How do you structure your questions during class discussion to maximize learning? 3. How do you promote active and collaborative learning? 4. How do you promote seamless transition of lessons and establish connection of concepts?	1. What are your ways and means to help your STEAM faculty promote critical and reflective thinking in class? 2. Do you encourage your faculty to attend trainings on assessment of learning, active and collaborative learning and contextual learning? In what way do you extend support? Do you allow all request for trainings, seminars and attendance to conferences? Why or Why not? 3. If your school sponsored the STEAM faculty in conferences and seminars, how would you facilitate successful knowledge sharing?
Theme: Inclusive and Relevant STEAM Education		
Main Question	***(For STEAM Teachers)*** *How do you ensure the relevance of STEAM to the learners?* ***(Please customize the questions to the discipline of the interviewee)***	***(For School Heads, College Deans, and Other Officials)*** *How do you ensure that your STEAM faculty discuss and integrate the relevance of STEAM in their lessons?*
Probing Points	1. How do you maintain the relevance of STEAM content and processes to the learners and the community? a. relevance to local needs (issues and problems) and contexts b. relevance to global needs (issues and problems) and contexts 2. Do you think a teacher should consider the different types and backgrounds of learners in his learning plans (i.e. teaching strategies, language, gender, culture)? Why? Any relevant example/situation from your experience? 3. Do you utilize the appropriate tools/technology in teaching STEAM concepts? How do you integrate these tools in the lesson delivery?	1. What management styles do you practice to sustain STEAM faculty's integration of relevance of STEAM content and processes to the learners and the community? a. relevance to local needs (issues and problems) and contexts b. relevance to global needs (issues and problems) and contexts 2. What administrative support do you extend to your STEAM faculty for them to be able to utilize the appropriate tools/technology in teaching STEAM concepts? 3. What are the strengths and weaknesses of the planned and implemented support to your STEAM faculty?
Theme: Classroom Management		
Main Question	***(For STEAM Teachers)*** *How do you promote safe learning environment?*	***(For School Heads, College Deans, and Other Officials)*** *How do you ensure a safe learning environment?*

Probing Points	1. How do you ensure safety in STEAM activities and processes such as laboratory work? 2. How do you monitor student activities and engagement during your class? 3. Do you think student consultation is helpful? Why? Any relevant experience/situation? 4. How do you assign and monitor student responsibilities?	1. How do you ensure safety in STEAM activities and processes such as laboratory work? 2. How do you monitor STEAM classes and their activities? 3. Do you require your STEAM teachers to conduct student consultation? Do you think this is helpful? Why?
Theme: Attainment of Learning Outcomes		
Main Question	***(For STEAM Teachers)*** *How you promote awareness and attainment of learning outcomes?*	***(For School Heads, College Deans, and Other Officials)*** *How you promote awareness and attainment of learning outcomes?*
Probing Points	1. How do you ensure that your learning outcomes are clear to your learners? 2. How do you keep your learning outcomes apparent in your teaching strategies? 3. Do you think it is helpful to engage your learner in formulating your learning outcomes? 4. How do results of your assessment help you plan for your classes? 5. How do you sustain the knowledge in the prescribed curriculum and competencies? 6. How do you select your assessment tools? Do you follow a criteria in the selection of what technology to integrate in a lesson?	1. How do you ensure that the learning outcomes are clearly communicated by your STEAM faculty to the learners? 2. What are the major indicators that you use to determine if STEAM teachers visibly include the learning outcomes in their teaching strategies? 3. Do you advocate involving STEAM learners in the process of formulating the learning outcomes? 4. What scheme (departmental, or school-based) do you implement in using assessment and feedback system to inform improvement of practice and curriculum? What do you think are the probable strengths and weaknesses of this scheme? 5. Do you extend help to your STEAM teachers in selecting your assessment tools?
Theme: Knowledge of STEAM and STEAM related fields		
Main Question	***(For STEAM Teachers)*** *On a scale of 1 to 10 (10 being the highest and 1 being the lowest), how do you rate your content knowledge on STEAM?*	***(For School Heads, College Deans, and Other Officials)*** *On a scale of 1 to 10 (10 being the highest and 1 being the lowest), how do you rate your STEAM teachers' content knowledge on STEAM?*
Probing Points	1. Do you think you have sufficient preparations (in terms of content) to teach STEAM courses? 2. What other fields do you think are necessary in learning and teaching STEAM? How do you rate your content knowledge in each of these fields?	1. Do you think your STEAM teachers have sufficient preparations (in terms of content) to teach STEAM courses? 2. What other fields do you think are necessary in learning and teaching STEAM? How do you rate your STEAM teachers' content knowledge in each of these fields?

PRE-OBSERVATION DOCUMENTS

Philippine Normal University

PRE-OBSERVATION QUESTIONS

Observation Date: _____ Time Start: _____ Time End: _____

School:_____

Teacher: _____

Subject to be Observed: _____

Level: _____

Course Title (if applicable): _____

In the pre-observation session, the researcher-observer should obtain information from the pre-identified STEAM Educator concerning his or her class goals, students, and particular teaching style. An interview schedule provides a brief, structured way of obtaining such information and includes the following questions:

1. Briefly, what will be happening in the class I will observe?

2. What is your goal for the class? What do you hope students will gain from this session?

3. What do you expect students to be doing in class to reach the stated goals?

4. What can I expect you to be doing in class? What role will you take? What teaching methods will you use?

5. What have students been asked to do to prepare for this class?

6. What was done in earlier classes to lead up to this one?

7. Will this class be generally typical of your teaching? If not, what will be different?

8. Is there anything in particular that you would like me to focus on during the class?

Details such as the date for the classroom observation, use of a particular observation form or method, and seating arrangement for the colleague observer should also be decided by mutual agreement at this session.

***

Subject: _____ Date of Observation:_____
No. of Students: _____ Time of Observation: _____

Session Guide	
Learning Goals/Objectives	*(Please list all learning objectives for the session observation)*
Subject Matter	**Lesson** *(Please list the topic(s) for the session observation)*:
	Concepts *(Please list all concepts that you intend your students to learn for the session observation)*:
	Skills *(Please list all skills that you intend your students to learn for the session observation)*:
	Values *(Please list all values that you intend your students to learn for the session observation)*:
	Materials/Tools *(Please list all tools and materials that you plan to use for the session observation)*:
	References:
Learning Activities	**Major Teaching Strategies** *(Please list all teaching strategies that you plan to use for the session observation):*
	Routine Activities:
	Lesson Proper: *(Please sequence in bullet or number format how you will deliver your lesson)*
Evaluation	*Please indicate here (in numbered or bullet form) how will you gauge if your students learned all intended concepts for the session:*

Prepared by:

_____
(Signature over printed name)

_____
(Date)

Dear STEAM Teacher,

This Technology Integration Checklist can be used to document the nature of your and your students' use of technology in the classroom. We request that you take time in identifying which among the identified list you use in teaching STEAM courses.

Thank you very much.

The PNU Research TEAM

TECHNOLOGY INTEGRATION CHECKLIST

Name: _____

Date: _____

Specific Area (Please check): ☐ Science ☐ Technology ☐ Engineering ☐ Agriculture ☐ Math

Directions: Please, check in the box the technology you are integrating or you have integrated in your lessons.

☐	CB	(Chalkboard/whiteboard/SMART board)
☐	OP	(Overhead Projector/Opaque Projector)
☐	PP	(PowerPoint or other digital slides)
☐	CL	(Clicker Response System)
☐	D	(Demonstration Equipment, e.g. could include Chemistry demonstrations of reactions, physics demonstrations of motion or any other material being used for the demonstration of a process or phenomenon)
☐	DT	(Digital Tablet or any technology where the instructor can actively write on a document cameras, as well as software on a laptop that allows for writing on PDF files)
☐	M	(Movie, documentary, video clips, or YouTube videos)
☐	Si	(Simulations that can be digital applets or web-based simulations and animations)
☐	WEB	(Website which includes instructor interaction with course website or other online resource other than YouTube videos. This can also include using website for student responses to questions in lieu of clickers)
☐	LDEM	(Use of equipment (e.g. lab equipment, computer simulation to convey course content)
☐	IAE	(Improvised apparatus or equipment)
☐	LA	(Learning applications, e.g. Kahoot)

Questions:

1. What are your basic intentions in using or integrating these technologies?

2. What were your major considerations in choosing or integrating these technologies?

3. When and what part of the lesson do you use these identified technologies?

Specific Technology	Lesson

Dear STEAM Teacher,

This checklist is aimed at determining the various techniques a STEAM Educator utilizes to assess student performance. We request that you take time in identifying which among in the list you use in teaching STEAM courses.

Thank you very much.

The PNU Research TEAM

ASSESSMENT CHECKLIST

Name: _____

Date: _____

Specific Area (Please check): ☐ Science ☐ Technology ☐ Engineering ☐ Agriculture ☐ Math

Directions: Please, check mark in the box ☐ which corresponds to the technique/s you are using to assess performance of your students.

- ☐ Quizzes (print/online)
- ☐ Long Test (e.g. Mid-term, Final examination)
- ☐ Course Homework
- ☐ Class Seatwork
- ☐ Class Discussion Participation/Recitation
- ☐ Research Project
- ☐ Case Study Analysis
- ☐ Observation of Field work
- ☐ Practical Test (e.g. actual demonstration, actual assembly)
- ☐ Portfolios (working, documentary, showcase)
- ☐ Products
- ☐ Journal (e.g. reflective)
- ☐ Assessment tools znot in the list

_____ _____ _____

_____ _____ _____

_____ _____ _____

Appendix III. Peer Review Form

PEER-REVIEW FORM

Your Name: _____ **Program:** _____

Subject/Course: _____

Topic: _____

Lesson Title: _____

Level: _____ **Lesson Duration:** _____

TPACK Dimension	Attributes	5 Exceeds standard	4 Meets standard	3 Nearly meets standard	2 Does not meet standard	1 No Evidence	Remarks/Suggestions
Content	Provides Clear Lesson Objectives.	☐	☐	☐	☐	☐	
	Exhibits sufficient knowledge of the subject topic/content.	☐	☐	☐	☐	☐	
Pedagogy	Assessments match instructional method.	☐	☐	☐	☐	☐	
	Lesson appears to help organize and manage student behavior—*Explains sequence of events and procedures for students*	☐	☐	☐	☐	☐	
Technology	Lesson plan incorporates at least 1 technology.	☐	☐	☐	☐	☐	

	Discusses possible limitations to technology or potential problems, as well as solutions.	☐	☐	☐	☐	☐	
	Provides clear rationale for technology choice.	☐	☐	☐	☐	☐	
	Demonstrates understanding of technology as teacher tool or student tool.	☐	☐	☐	☐	☐	
Pedagogical Content Knowledge	Selects effective teaching strategies appropriate to subject domain to guide student thinking and learning.	☐	☐	☐	☐	☐	
	Demonstrates awareness of possible student misconceptions.	☐	☐	☐	☐	☐	
	Presents appropriate strategies for developing understanding of the subject content.	☐	☐	☐	☐	☐	
Technological Pedagogical Knowledge	Chooses technologies enhancing approaches (teacher-centered approaches) – *Uses technology to present material.*	☐	☐	☐	☐	☐	
	Chooses technologies enhancing student learning (student-centered approaches) – *Students use technology to*	☐	☐	☐	☐	☐	

	explore content and achieve learning goals.						
	Provides clear rationale for technology choice to deliver instruction.	☐	☐	☐	☐	☐	
Technological Content Knowledge	Chooses appropriate technologies for subject domain (mathematics, science).	☐	☐	☐	☐	☐	
	Link between technology and content is obvious or explicit	☐	☐	☐	☐	☐	
Technological Pedagogical Content Knowledge	Appropriately uses content, pedagogy, and technology strategies.	☐	☐	☐	☐	☐	
	Technology enhances content objectives and instructional strategies.	☐	☐	☐	☐	☐	
General Comments/Suggestions:							

Appendix IV. Rubric for Lesson Exemplars

RUBRIC FOR LESSON EXEMPLAR

Your Name: _____ **Program:** _____

Subject/Course: _____

Topic: _____

Lesson Title: _____

Level: _____ **Lesson Duration:** _____

	1- Below Proficient	2- Proficient	3- Above Proficient	Score/Level
Connection among content, pedagogical approach and technology	There is no apparent connection among content, pedagogy and technology.	Content, instructional strategies and technology are somewhat connected.	Content, instructional strategies and technology are strongly connected AND the lesson plan describes the connections.	
Rationale for Instructional strategy/ies	The rationale for selecting the instructional strategy/ies is/are insufficient OR there is no rationale for the instructional activities in the lesson plan.	The rationale for selecting the instructional strategy/ies used is/are sound.	The rationale for selecting the instructional strategy/ies is/are sound AND is/are tied to a learning theory.	
Appropriateness of technology for instructor use	The rationale for selecting the technology for instructor use is insufficient OR there is no rationale for the instructor use of technology in the lesson plan.	The rationale for selecting the technology for instructor use is sound.	The rationale for selecting the technology for instructor use is sound AND includes reasons for other not selected technologies.	
Alignment to state standards for content and computer skills	Lesson plan is not clearly aligned to state standards for	Lesson plan is clearly aligned to state standards for both content and	Lesson plan is clearly aligned to state standards for both content and	

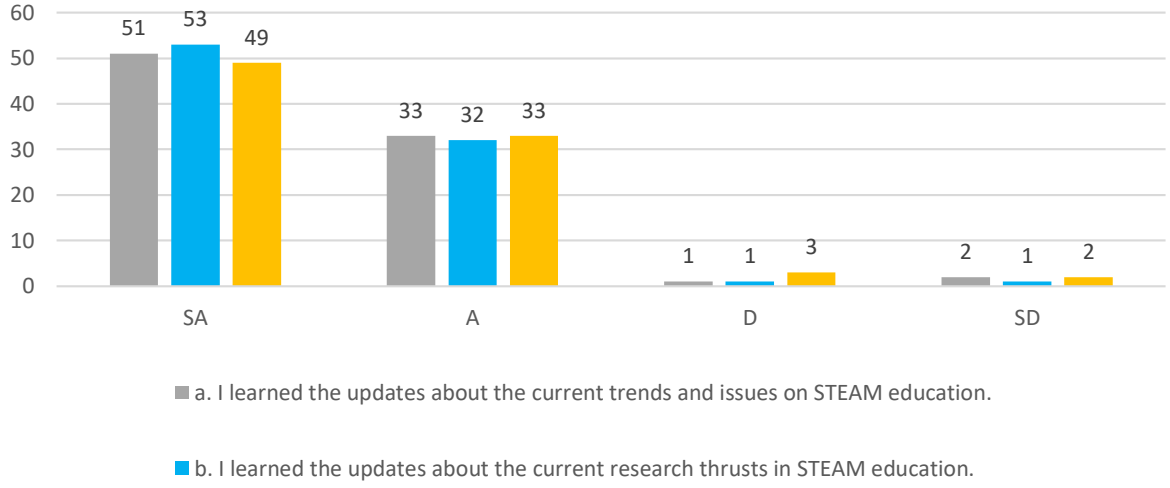
	content and/or computer skills.	computer skills at the appropriate grade level.	computer skills at the appropriate grade level AND is also aligned to one or more other discipline standards (interdisciplinary).	
Completeness	Lesson plan is incomplete. One or more key elements are missing/insufficient.	Lesson plan is complete. It contains all of the required elements.	Lesson plan is complete AND includes at least one of the following: -addresses higher-order thinking as per Bloom's Taxonomy -integrates with other content areas -accommodates students with special needs.	
Language and Mechanics	Lesson plan contains multiple errors in grammar, spelling, punctuation and/or grammar OR word choice is inappropriate	Lesson plan contains no more than two grammar, spelling, and/or punctuation errors. Errors do not affect the meaning of the writing. Word choice is appropriate for the lesson.	Lesson plan is error-free. Writing demonstrates superior understanding of grammar, spelling and punctuation.	
Comments/Suggestions:				

Appendix V. Evaluation Results of Capability Building Program

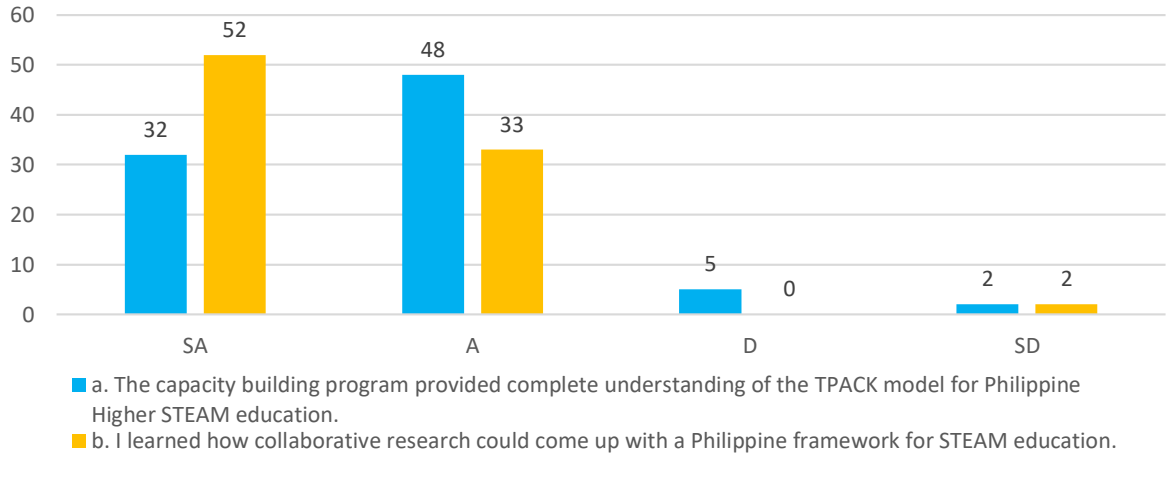
LEGEND:

SA - Strongly Agree
A - Agree
D - Disagree
SD - Strongly Disagree

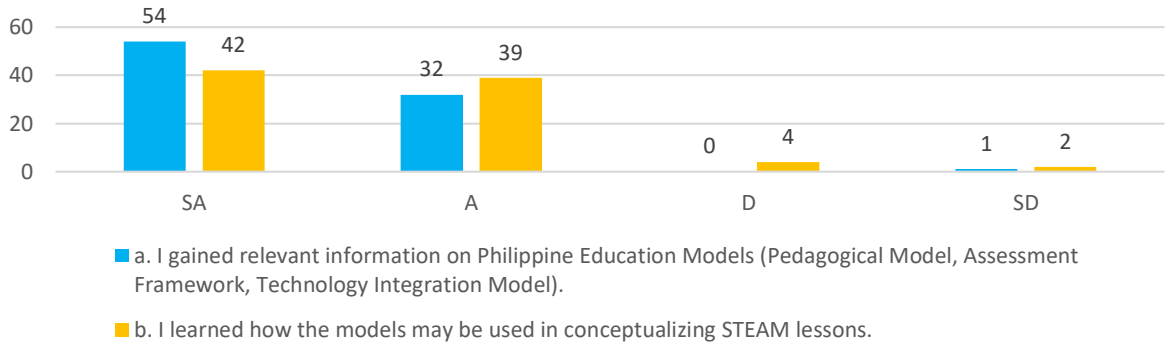
Obejctive 1. Inform PHE STEAM teachers of the general level of STEAM teaching proficiency of PHE STEAM educators.



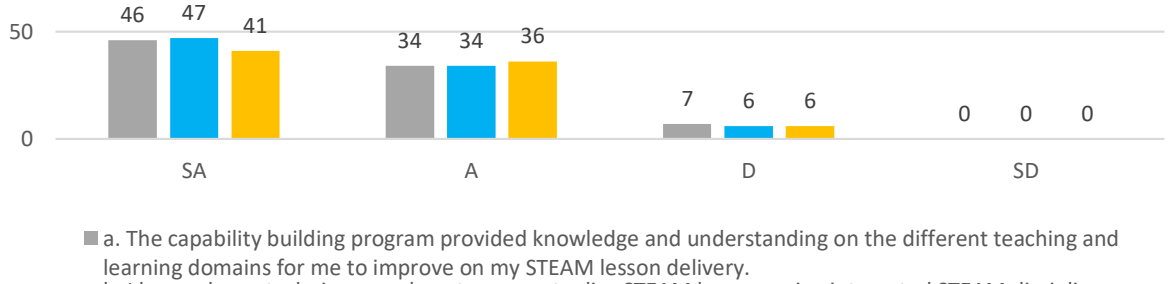
Obejctive 2. Acquaint PHE STEAM Educators with Philippine TPACK model generated from the CHED-funded research titled, TPACK in Philippine STEAM Education



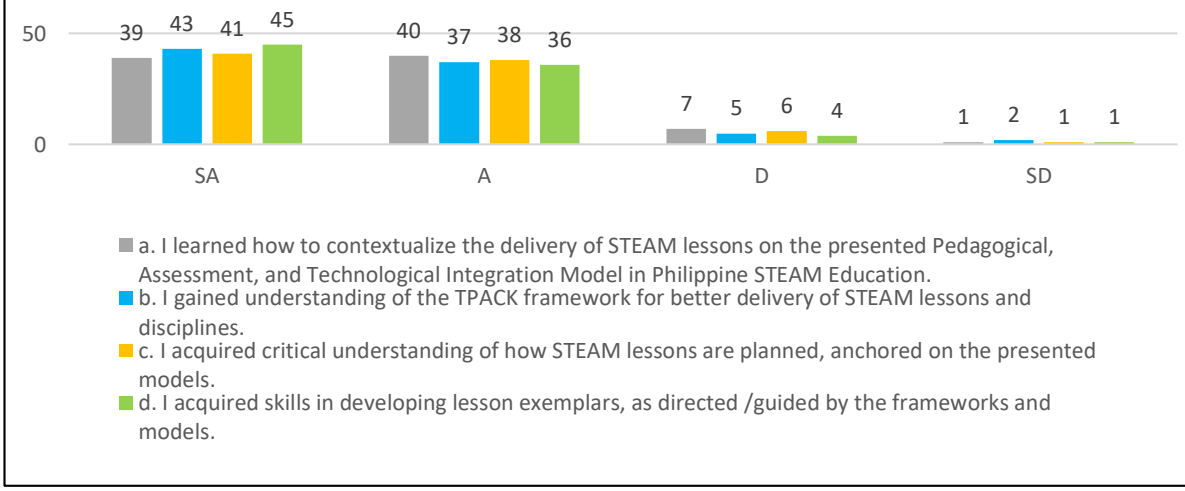
Objective 3: Appraise PHE STEAM Educators with emerging models for Philippine STEAM education such as Pedagogical Model, Assessment Framework and Technology Integration Model



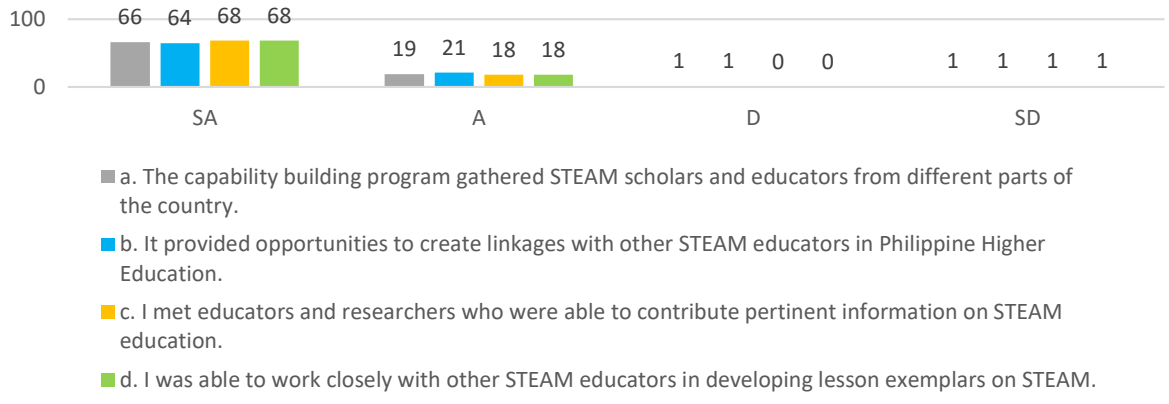
Objective 4. Capacitate PHE STEAM educators on areas of weaknesses as informed by the general STEAM teaching proficiency level of tertiary STEAM teachers.



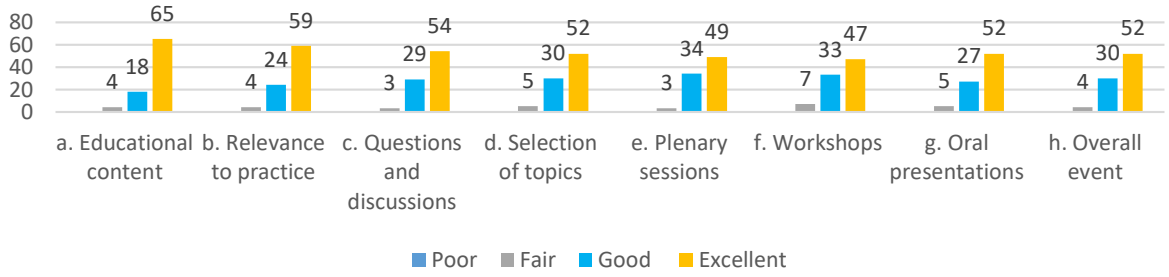
Objective 5. Facilitate the development of Lesson Exemplars to exemplify utilization of the models and TPACK framework in Philippine Higher STEAM Education.



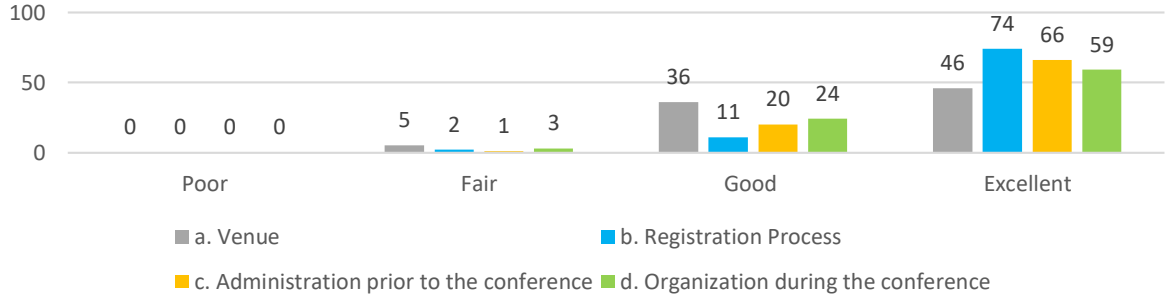
Objective 6. Serve as venue for PHE STEAM teachers and professionals to work together and share their knowledge in teaching approaches and researches that could contribute to quality STEAM education in the Philippines.

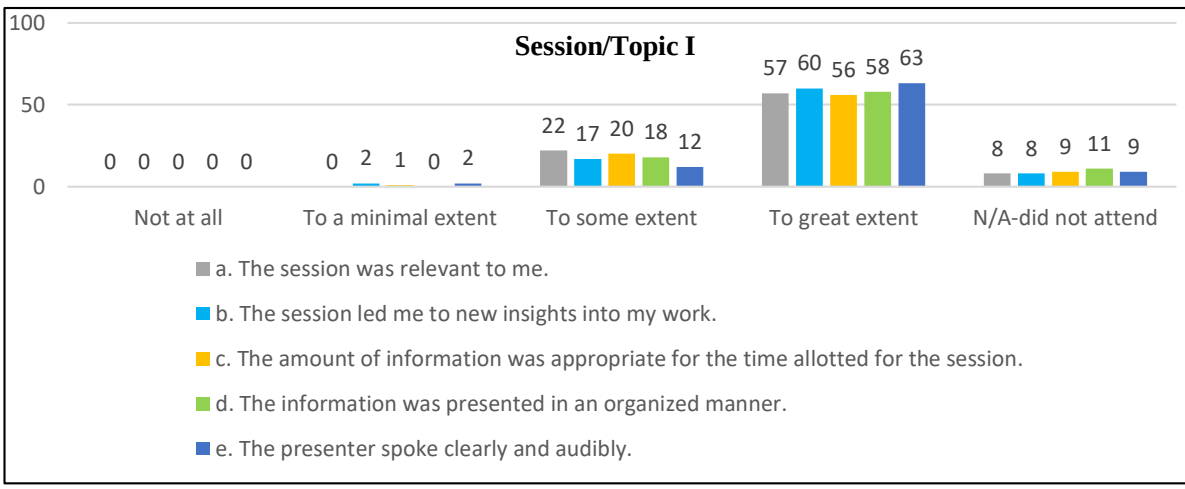


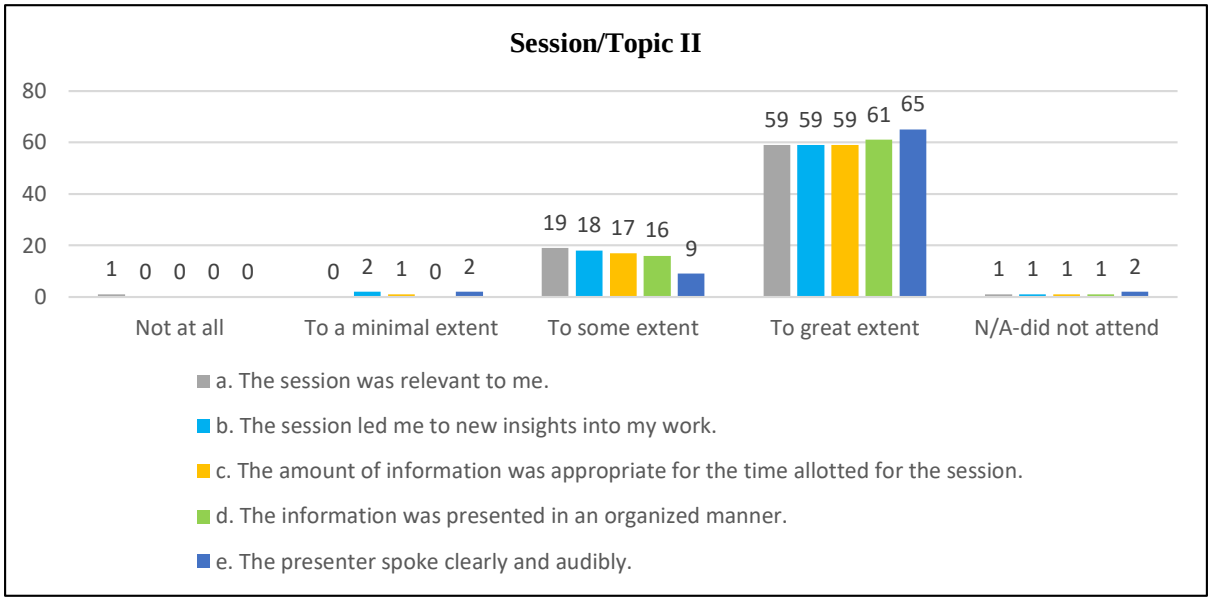
7. Overall Capability Building Program

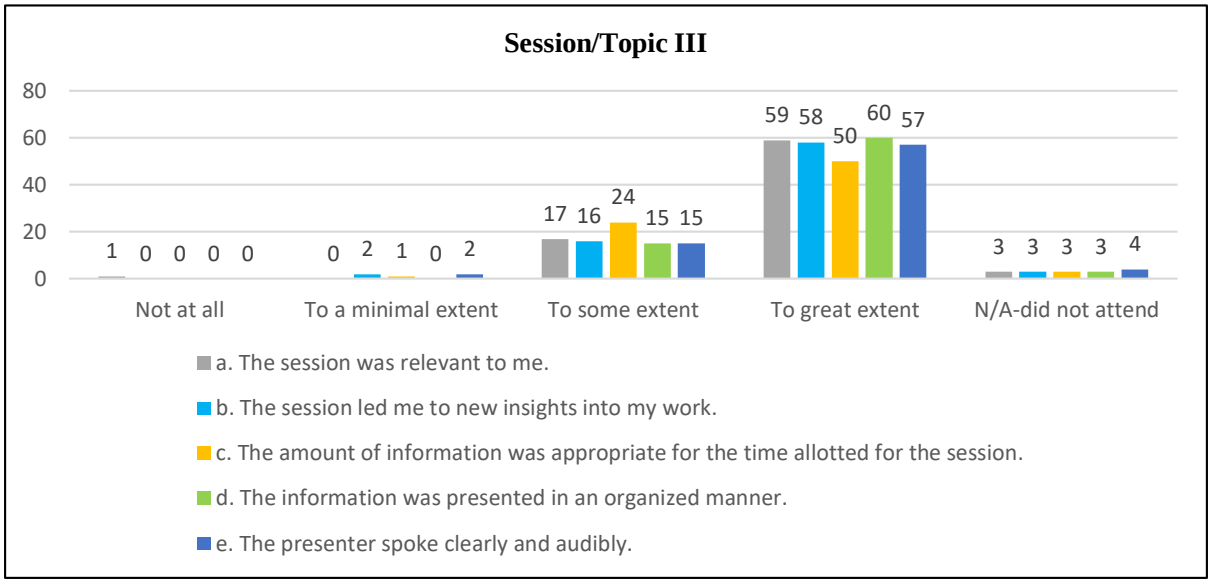


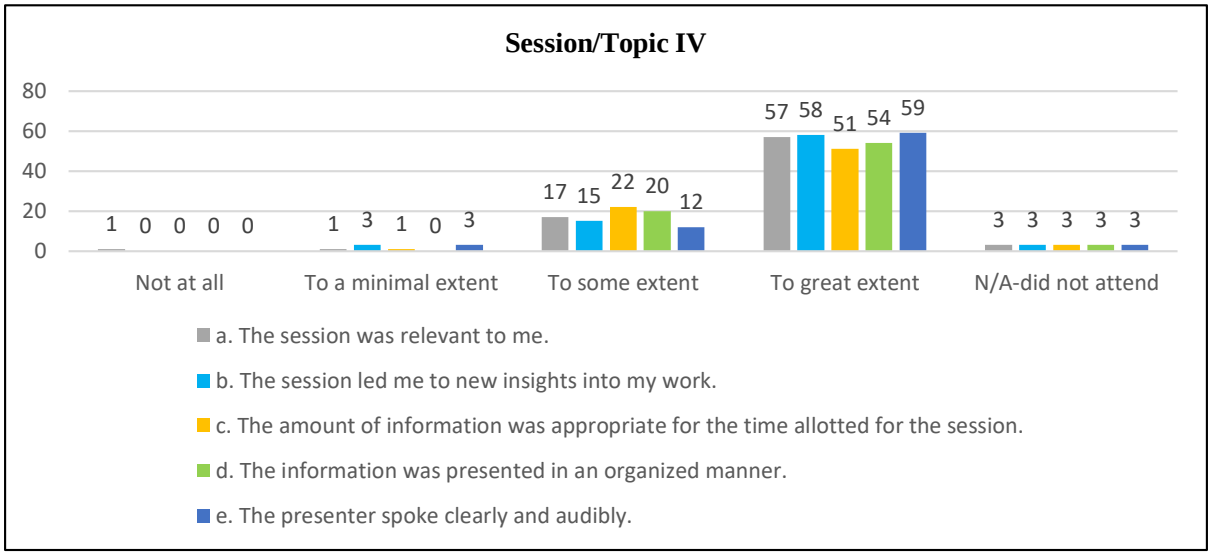
8. Logistics and Communications

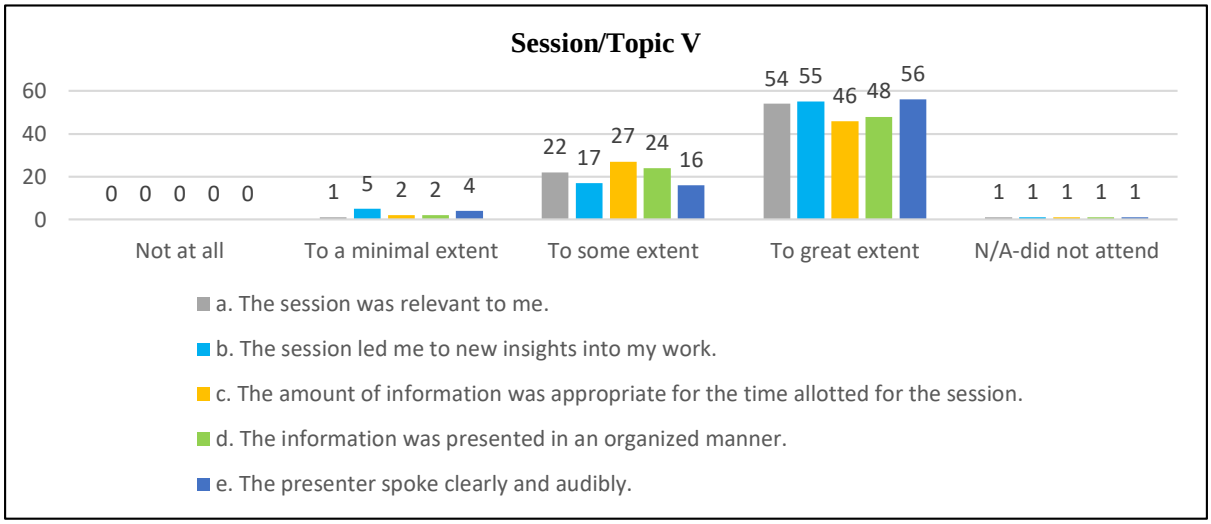


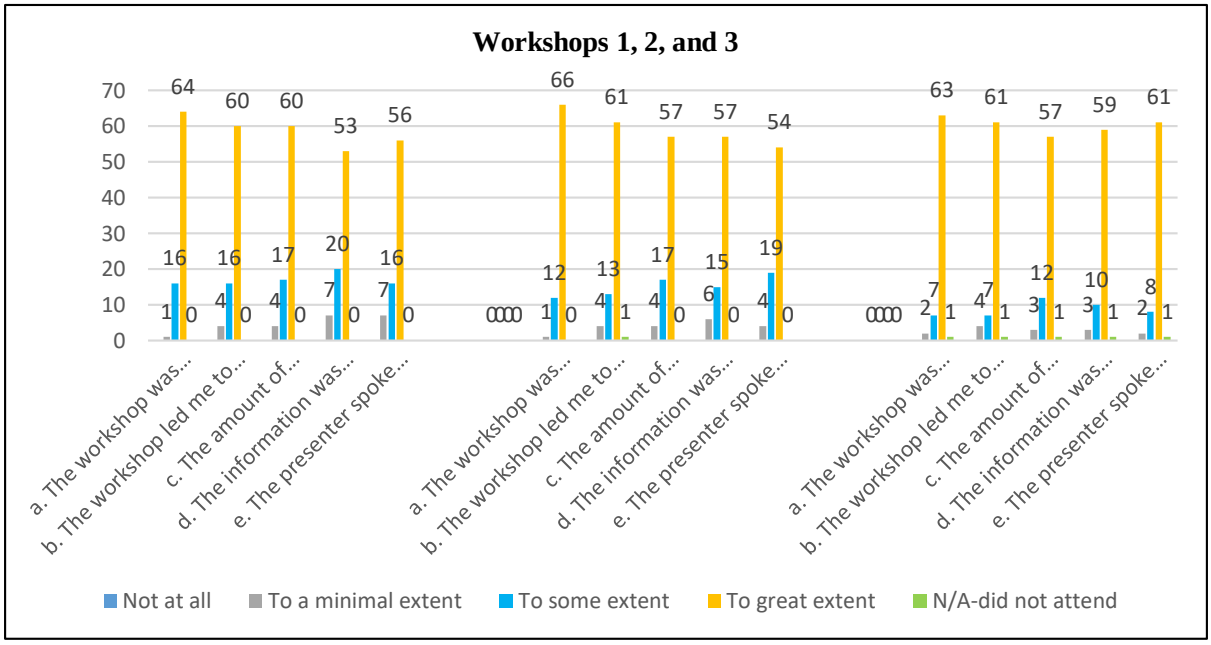


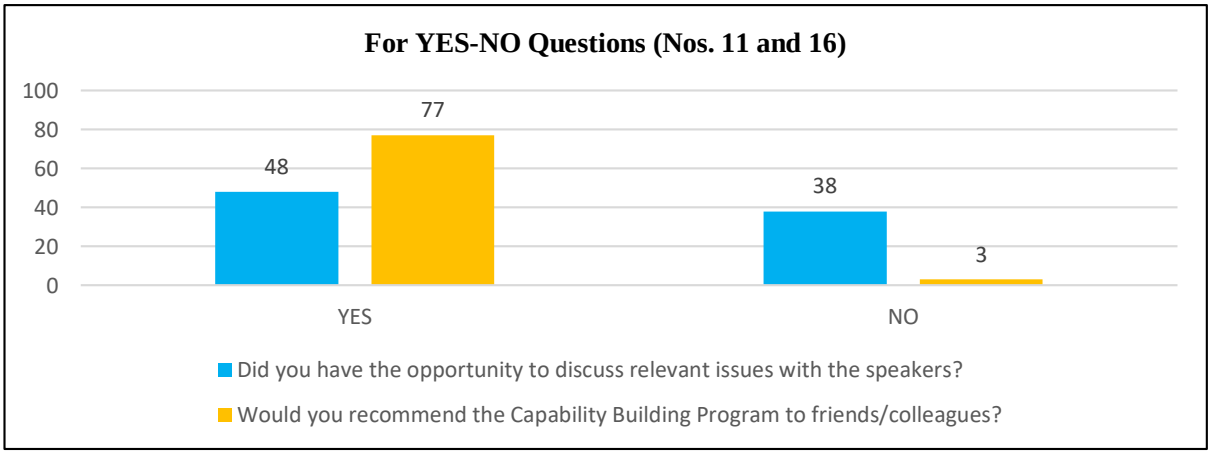

Session/Topic II
80
60
40
20
0
1 0 0 0 0
0 2 1 0 2
19 18 17 16 9
59 59 59 61 65
1 1 1 1 2
Not at all
To a minimal extent
To some extent
To great extent
N/A-did not attend
a. The session was relevant to me.
b. The session led me to new insights into my work.
c. The amount of information was appropriate for the time allotted for the session.
d. The information was presented in an organized manner.
e. The presenter spoke clearly and audibly.


Session/Topic III
80
60
40
20
0
1 0 0 0 0
0 2 1 0 2
17 16 24 15 15
59 58 50 60 57
3 3 3 3 4
Not at all
To a minimal extent
To some extent
To great extent
N/A-did not attend
a. The session was relevant to me.
b. The session led me to new insights into my work.
c. The amount of information was appropriate for the time allotted for the session.
d. The information was presented in an organized manner.
e. The presenter spoke clearly and audibly.


Session/Topic IV
80
60
40
20
0
1 0 0 0 0
1 3 1 0 3
17 15 22 20 12
57 58 51 54 59
3 3 3 3 3
Not at all
To a minimal extent
To some extent
To great extent
N/A-did not attend
a. The session was relevant to me.
b. The session led me to new insights into my work.
c. The amount of information was appropriate for the time allotted for the session.
d. The information was presented in an organized manner.
e. The presenter spoke clearly and audibly.


Session/Topic V
60
40
20
0
0 0 0 0 0
1 5 2 2 4
22 17 27 24 16
54 55 46 48 56
1 1 1 1 1
Not at all
To a minimal extent
To some extent
To great extent
N/A-did not attend
a. The session was relevant to me.
b. The session led me to new insights into my work.
c. The amount of information was appropriate for the time allotted for the session.
d. The information was presented in an organized manner.
e. The presenter spoke clearly and audibly.


Workshops 1, 2, and 3
70
60
50
40
30
20
10
0
64 16 1 0
60 16 4 0
60 17 4 0
53 20 7 0
56 16 7 0
66 12 1 0
61 13 4 1
57 17 4 0
57 15 6 0
54 19 4 0
63 7 2 1
61 7 4 1
57 12 3 1
59 10 3 1
61 8 2 1
a. The workshop was...
b. The workshop led me to...
c. The amount of...
d. The information was...
e. The presenter spoke...
Not at all
To a minimal extent
To some extent
To great extent
N/A-did not attend

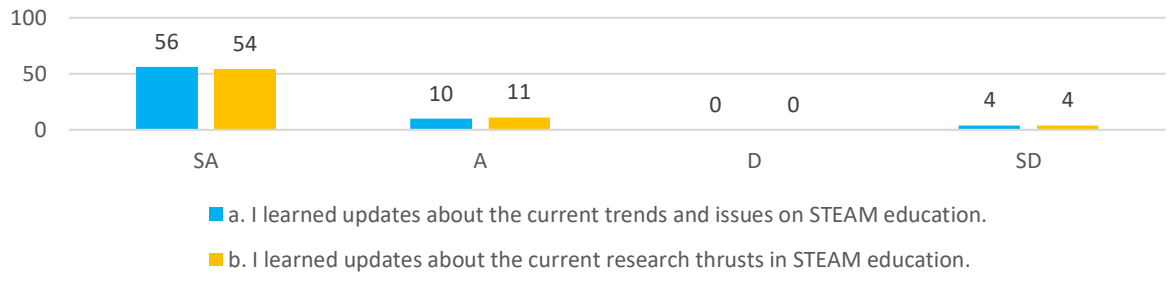

For YES-NO Questions (Nos. 11 and 16)
100
80
60
40
20
0
48
77
38
3
YES
NO
Did you have the opportunity to discuss relevant issues with the speakers?
Would you recommend the Capability Building Program to friends/colleagues?

Appendix VI. Evaluation Results of the National Forum

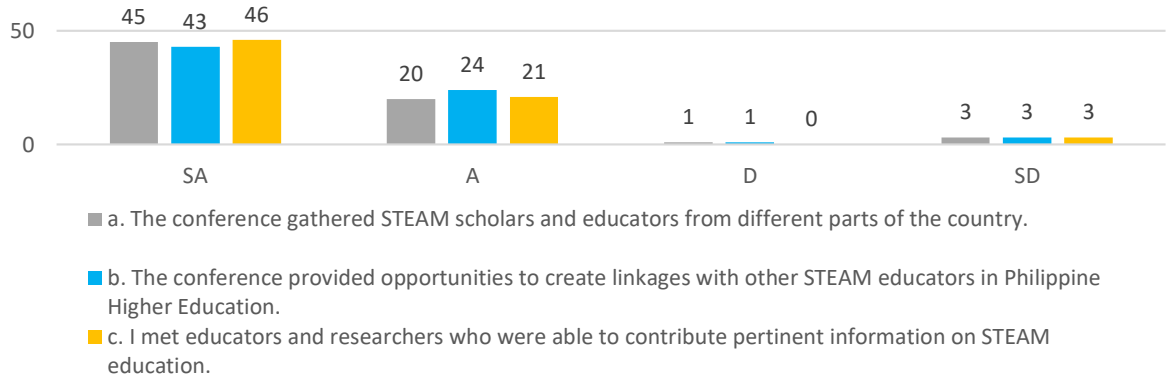
LEGEND:

SA - Strongly Agree
A - Agree
D - Disagree
SD - Strongly Disagree

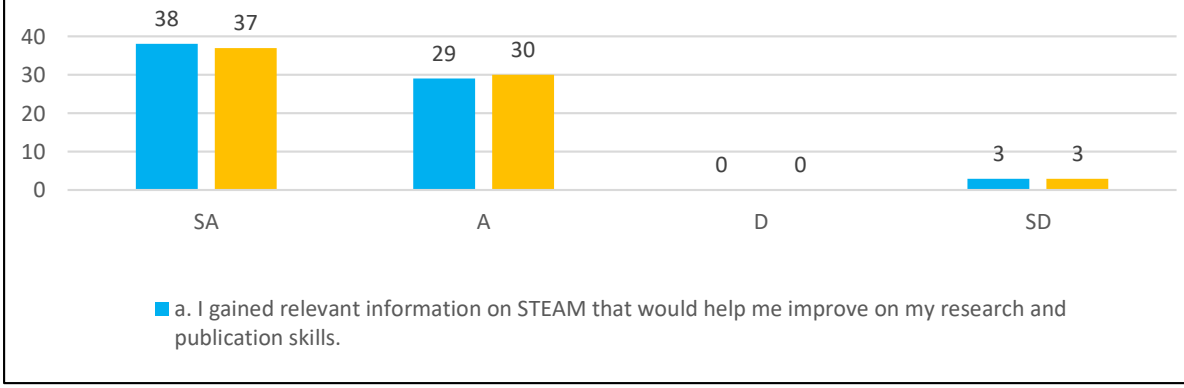
Objective 1: Disseminate the findings and outputs of a CHED-funded research project on TPACK for Philippine STEAM Education.

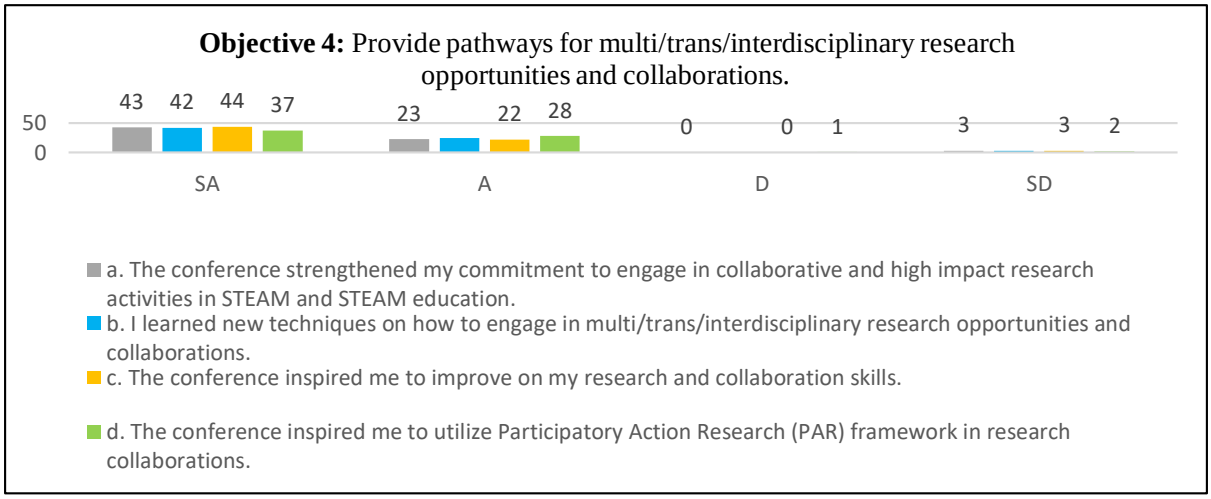


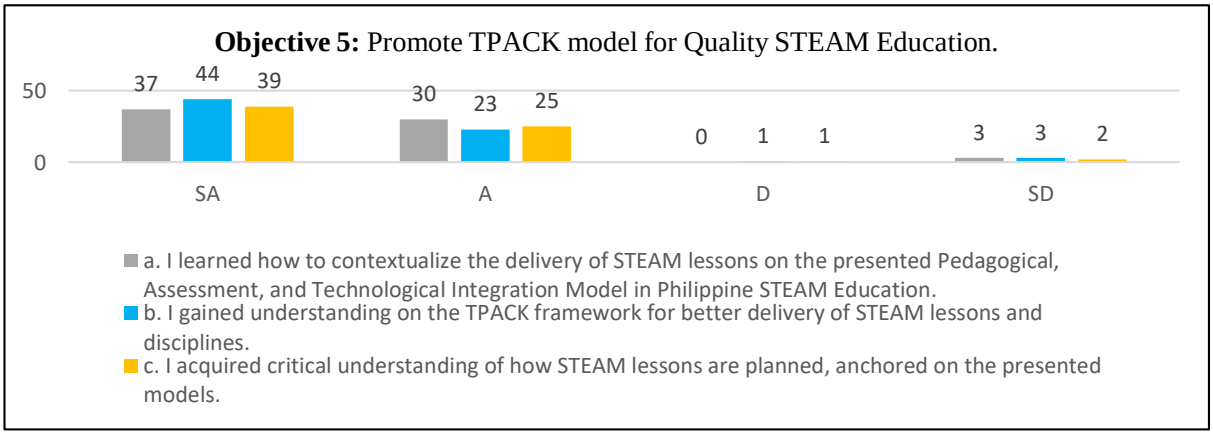
Objective 2: Gather STEAM scholars for academic exchange of views and perspectives on STEAM Education.

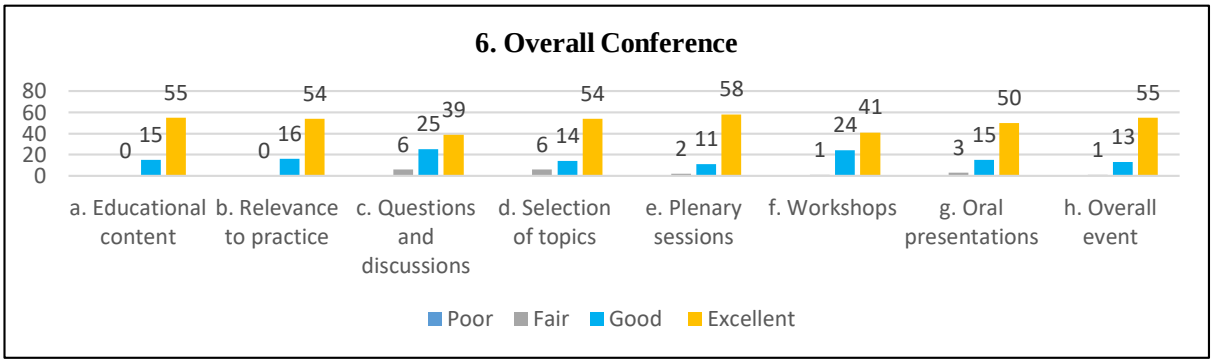


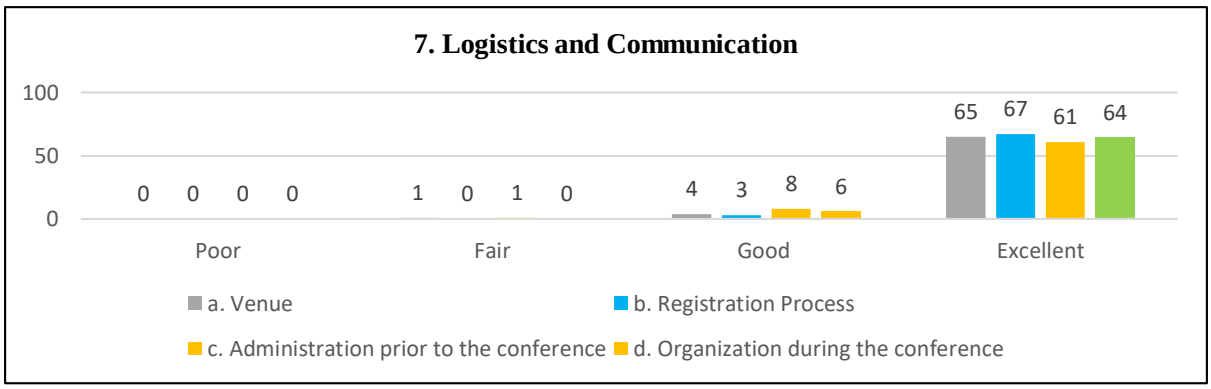
Objective 3: Update STEAM teachers knowledge in research and publication



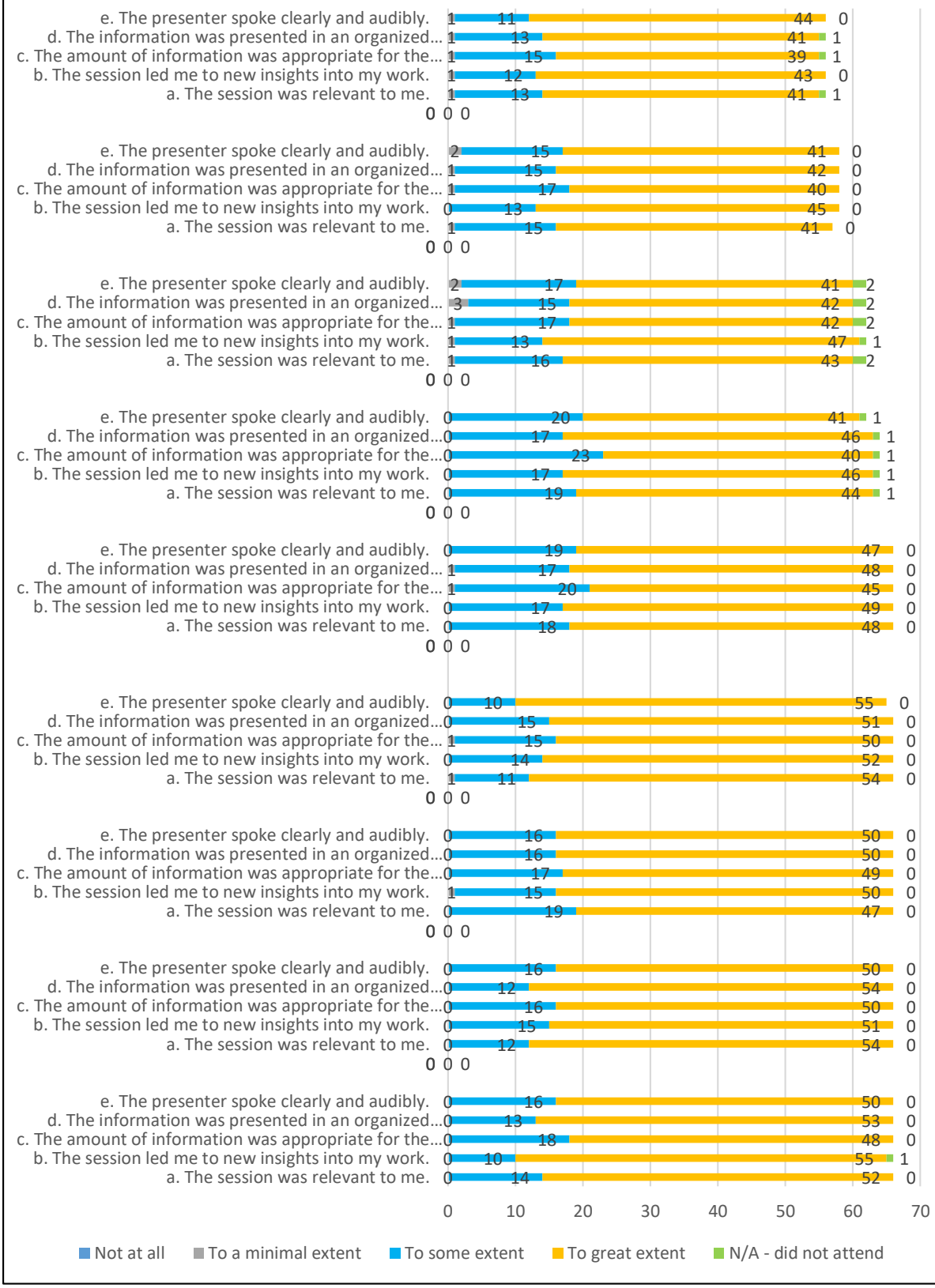

Objective 4: Provide pathways for multi/trans/interdisciplinary research opportunities and collaborations.
50
0
43 42 44 37
23 22 28
0 0 1
3 3 2
SA
A
D
SD
a. The conference strengthened my commitment to engage in collaborative and high impact research activities in STEAM and STEAM education.
b. I learned new techniques on how to engage in multi/trans/interdisciplinary research opportunities and collaborations.
c. The conference inspired me to improve on my research and collaboration skills.
d. The conference inspired me to utilize Participatory Action Research (PAR) framework in research collaborations.

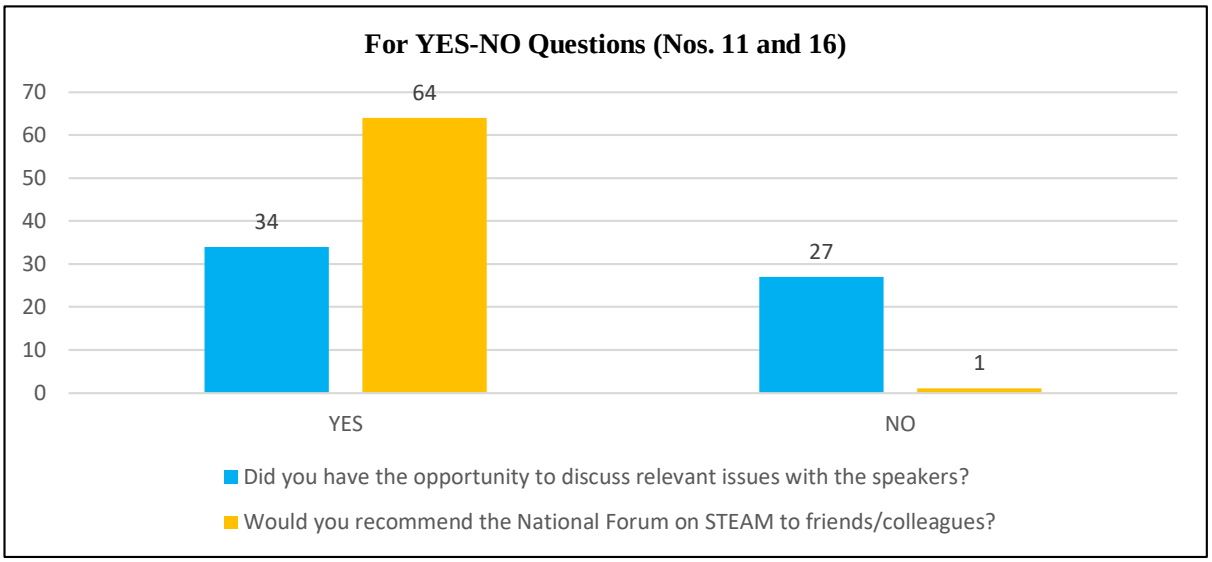

Objective 5: Promote TPACK model for Quality STEAM Education.
50
0
37 44 39
30 23 25
0 1 1
3 3 2
SA
A
D
SD
a. I learned how to contextualize the delivery of STEAM lessons on the presented Pedagogical, Assessment, and Technological Integration Model in Philippine STEAM Education.
b. I gained understanding on the TPACK framework for better delivery of STEAM lessons and disciplines.
c. I acquired critical understanding of how STEAM lessons are planned, anchored on the presented models.


6. Overall Conference
80
60
40
20
0
0 15 55
0 16 54
6 25 39
6 14 54
2 11 58
1 24 41
3 15 50
1 13 55
a. Educational content
b. Relevance to practice
c. Questions and discussions
d. Selection of topics
e. Plenary sessions
f. Workshops
g. Oral presentations
h. Overall event
Poor
Fair
Good
Excellent


7. Logistics and Communication
100
50
0
0 0 0 0
1 0 1 0
4 3 8 6
65 67 61 64
Poor
Fair
Good
Excellent
a. Venue
b. Registration Process
c. Administration prior to the conference
d. Organization during the conference

8. Plenary 1-9


e. The presenter spoke clearly and audibly. 1 11 44 0
d. The information was presented in an organized... 1 13 41 1
c. The amount of information was appropriate for the... 1 15 39 1
b. The session led me to new insights into my work. 1 12 43 0
a. The session was relevant to me. 1 13 41 1
0 0 0
e. The presenter spoke clearly and audibly. 2 15 41 0
d. The information was presented in an organized... 1 15 42 0
c. The amount of information was appropriate for the... 1 17 40 0
b. The session led me to new insights into my work. 0 13 45 0
a. The session was relevant to me. 1 15 41 0
0 0 0
e. The presenter spoke clearly and audibly. 2 17 41 2
d. The information was presented in an organized... 3 15 42 2
c. The amount of information was appropriate for the... 1 17 42 2
b. The session led me to new insights into my work. 1 13 47 1
a. The session was relevant to me. 1 16 43 2
0 0 0
e. The presenter spoke clearly and audibly. 0 20 41 1
d. The information was presented in an organized... 0 17 46 1
c. The amount of information was appropriate for the... 0 23 40 1
b. The session led me to new insights into my work. 0 17 46 1
a. The session was relevant to me. 0 19 44 1
0 0 0
e. The presenter spoke clearly and audibly. 0 19 47 0
d. The information was presented in an organized... 1 17 48 0
c. The amount of information was appropriate for the... 1 20 45 0
b. The session led me to new insights into my work. 0 17 49 0
a. The session was relevant to me. 0 18 48 0
0 0 0
e. The presenter spoke clearly and audibly. 0 10 55 0
d. The information was presented in an organized... 0 15 51 0
c. The amount of information was appropriate for the... 1 15 50 0
b. The session led me to new insights into my work. 0 14 52 0
a. The session was relevant to me. 1 11 54 0
0 0 0
e. The presenter spoke clearly and audibly. 0 16 50 0
d. The information was presented in an organized... 0 16 50 0
c. The amount of information was appropriate for the... 0 17 49 0
b. The session led me to new insights into my work. 1 15 50 0
a. The session was relevant to me. 0 19 47 0
0 0 0
e. The presenter spoke clearly and audibly. 0 16 50 0
d. The information was presented in an organized... 0 12 54 0
c. The amount of information was appropriate for the... 0 16 50 0
b. The session led me to new insights into my work. 0 15 51 0
a. The session was relevant to me. 0 12 54 0
0 0 0
e. The presenter spoke clearly and audibly. 0 16 50 0
d. The information was presented in an organized... 0 13 53 0
c. The amount of information was appropriate for the... 0 18 48 0
b. The session led me to new insights into my work. 0 10 55 1
a. The session was relevant to me. 0 14 52 0
0 10 20 30 40 50 60 70
Not at all
To a minimal extent
To some extent
To great extent
N/A - did not attend


For YES-NO Questions (Nos. 11 and 16)
70
60
50
40
30
20
10
0
34
64
27
1
YES
NO
Did you have the opportunity to discuss relevant issues with the speakers?
Would you recommend the National Forum on STEAM to friends/colleagues?

INDEX

Page references to Figures are followed by the letter 'f', while references to Tables are followed by the letter 't'.

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