MARIE PAZ E. MORALES • JOVITO C. ANITO JR.
CELINA P. SARMIENTO • RUEL A. AVILLA • CAESAR P. PALISOC
LEVI E. ELIPANE • THADDEUS OWEN D. AYUSTE
BENILDA R. BUTRON • BRANDO C. PALOMAR

TPACK IN PHILIPPINE STEAM EDUCATION

PHILIPPINE STEAM PROFICIENCY

CHAPTER 1

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ABSTRACT

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Philippine STEAM Proficiency

Marie Paz E. Morales, Jovito C. Anito Jr., Celina P. Sarmiento, Ruel A. Avilla, Caesar P. Palisoc, Levi E.Elipane, Thaddeus Owen D. Ayuste, Benilda R. Butron, Brando C. Palomar

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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