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

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The study aimed to develop a self-rating tool to determine the proficiency of Philippine Higher Education (PHE) STEAM (Science, Technology, Engineering, Agri-Fisheries, Mathematics) Educators. This design and development research emphasized elaborations of 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, appropriateness, 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 analysis. These seven factors matched the seven TPCK dimensions: Factor 1 (TPACK [Technological Pedagogical Content Knowledge]), Factor 2 (TPK [Technological Pedogogical 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 as per 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

INTRODUCTION

In this era, knowledge and education are considered as key capitals for economic progress and social development. This knowledge-based society and knowledge economy seek new and appropriate skills to meet countries' growing global and economic development (Morales 2017). Thus, to keep abreast of these developments, novel and suitable learning outcomes may be needed, which call for quality learning and education to provide the country with good manpower and human capital (Blankley and Booyens 2010, Lane 2014, EDB 2016). Most developed and developing countries believe that training, education in all fields including STEM, research and innovation,

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development of e-services, and digitization are the main pillars of knowledge-based society and economy (Government Office of the Slovak Republic 2018). In fact, most first world countries believe in STEM education to provide them skilled human resource and bring economic prowess (Wise 2015, Oberoi 2016, Fiddis 2017). Developing countries including the Philippines share the same vision through a similar paradigm, emphasizing STEM education as a roadmap to innovation and country progress (Padolina 2014, Ahmed 2016).

Quality STEM Education

Quality STEM education emphasizes the preparation of the future workforce with strong background on the meta-discipline (combining STEM disciplines to solve a particular problem or learn a specific STEM lesson) (Tsupros *et al.* 2009, Ejiwale 2013) and applicable skills (hard and soft skills) across the STEM discipline (DAE 2014) matched with new skill demands of the new era. This new era known as Industrial Revolution 4.0 (industry 4.0 [IR4.0]), also tagged as the 21st century era, traces back from the first three era (18th century-industry 1.0, 19th century-industry 2.0, 20th century-industry 3.0). Industry 1.0 features mechanical production powered by stem engine. Industry 2.0 and 3.0 highlight mass production using electrical energy and automation utilizing electronics and information technology, respectively (i-SCOOP 2016). IR4.0 is a technological trend also termed as "industrial internet" and "digital factory" (Vedso *et al.* 2016) that brings forth the idea of converging and combining human and the cyber world (van Duuren 2017). The workings of this cyber-physical and human system highlight utilization of 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). Apparently, this trend demands highly complex systems and processes that require specific and highly intricate skills (design thinking, time management, and programming skills) that STEM field as a meta-discipline perpetuates. Consequently, this technological revolution skill requirement will definitely impact labor strategies, resulting to "a job market with strong demand at high and low-end skills, but hallowing out of the middle" (Evans 2011). Although companies pay attention to developing the competencies of their employees (van Duuren 2017, Evans 2011), they still rely on the existing education system (Renjen 2018) to innovate and come up with trained and highly skilled workforce for IR4.0.

In response to IR4.0, countries delve into STEM education assessment (Ejiwale 2013) to strategize curricular reforms and establish new standards. Several research across countries (Ejiwale 2013) found that the current STEM education (from K to University) has several limitations and weaknesses that include: 1) poor preparation and shortage in supply of qualified STEM teachers; 2) poor content delivery; 3) poor content preparation; and 4) lack of investment in teacher professional development (Charette n/d, NGA 2011, Ejiwale 2013, Kaing 2016). To note, teacher professional development refers to the entire spectrum of specialized training, formal education, or advanced professional learning intended to help administrators, teachers, and other educators improve their professional knowledge, competence, skill, and effectiveness (Hidden Curriculum 2013). Thus, efforts are focused on enhancing and developing STEM education through quality teachers.

Apparently, characteristics of a quality teacher are in consonance with the teacher's pedagogical content knowledge (PCK) attributes as Shulman (1986) defined. Accordingly, Shulman acknowledged that merely understanding the subject matter is not sufficient to teach a subject. It is the teacher's PCK that makes quality and effective teaching (Shulman 1987, Park and Oliver 2007, Karaman 2012). Today, PCK is widely accepted as a crucial knowledge base for teachers (Solis 2009, Enfield 2012). Consequently, marrying PCK with technology directs a meaningful integration of technology (Mishra and Koehler 2006, Clark 2010) also known as TPACK. As a framework, TPACK (described as Total Package of technology, pedagogy, and content knowledge) focuses on the complex interactions between the teacher's knowledge of content (CK), pedagogy (PK), and technology (TK). Mishra and Koehler (2006) further claimed that a teacher who can navigate between these interrelations act as an expert who is 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, the 21st century skills with the other skill demands of IR4.0 dictate the significance of technology infiltration in education (Yemothy 2015). Termed as "technology integration," this instruction-oriented practice relies on various technological resources to achieve improved learning outcomes through frameworks of integration (*e.g.*, TPACK; SAMR [Substitution, Augmentation, Modification, Redefinition]; TIM [Technology Integration Matrix]). Among these popular frameworks of technology utilization, TPACK serves the most due to its capability to build teacher's ability to integrate technology with the pedagogical strategies that best serve the content they are teaching (Koehler and Mishra 2009), compared to the two others that focus on level of technology integration (Edyburn 2013).

Philippine STEAM Education and Teacher Quality

Similarly, the Philippine government acknowledges the capabilities of STEM education and careers to meet the demands of the emerging technological revolution that eventually influences the citizen's quality of life. Improved STEM education in the country may eventually lead to a strong and skilled STEM workforce for IR4.0 and a better economic stance of the country. In fact, the Commission on Higher Education (CHED) initiated a strong meta-discipline grounded on STEM (*e.g.*, through grant-in-aid programs) to strengthen the relationship of STEM to Agri-fisheries and the Arts fields, consequently establishing the STEAM meta-discipline in the Philippine context (CHED 2015, Deocaris 2018). Hence, the education sectors (higher education and advanced higher education) in the country strongly pursue quality in this aspect (Philippine STEAM Education) through national development plans such as the Philippine Development Plan [NEDA 2017]); curricular reforms, specifically the K to 12 program [DepEd 2012] and Outcome Based Education (CHED 2012); quality assurance labeled as the Philippine Quality Framework (PQF) (TESDA 2012); and teacher quality tagged as the PPST (DepEd 2017a).

Pillar 3 of the PDP (NEDA 2017) expounds strategies to achieve globalization, internationalization, IR4.0, and the country's economic growth through technological innovations, research and innovation, and the acceleration of human capital. This pillar fortifies PQF, 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 (TESDA 2012). Drawing from the concept of quality assurance and pursuit of economic growth, internationalization, and IR 4.0; the two national policies (PDP & PQF) illustrate qualities of the Philippine human capital – specifically extracting elaborations of these policies in teacher quality that PPST defines (DepEd 2017a).

PPST (DepEd 2017b) outlines the needed competencies and skills of quality teachers to enable them to manage and handle emerging global frameworks. 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" (DepEd 2018). However, aside from initially targeting teachers of K to 12, PPST only includes general attributes of teacher quality, proficiency, and career stages but with no elaborations on subject matter or content – as well as teaching and learning of complex skills in the tertiary level.

The study theorizes that the competencies spelled out in PPST mapped with all the policies, standards, and guidelines of all Philippine tertiary STEAM programs (disciplines) charted with the theoretical underpinnings of the TPACK agenda may deduce a significant TPACK framework of proficiencies and competencies for PHE STEAM educators. This TPACK framework will emphasize the elaborations of PPST for Philippine STEAM Educators, which may concretely establish standards, and unique proficiencies and competencies for Philippine STEAM Educators. Thus, this study emphasizes the development of a standard self-rating tool known as proficiency indicators to determine proficiencies of PHE STEAM Educators.

The study aimed to design, develop, and validate a standard self-rating proficiency indicator tool for PHE STEAM Educators. Specifically, the study sought concrete outputs for the following:

1. design and develop the Self-Rating Proficiency Indicators for PHE STEAM Educators anchored on PSGs and PPST; and
2. validate the Self-Rating Proficiency Indicators for PHE STEAM Educators.

METHODS

This study employed design and development research by undertaking the following steps:

Literature Review and Alignment of PSGs for Higher Education

Extensive literature review traced all preliminary information on tertiary teachers' teaching proficiency (inclusive of technological, pedagogical, and content proficiencies). This process reviewed available indicators of teaching proficiency for STEM and STEAM (where A refers to Arts), although most of deduced data are from first world countries. The main source of significant information to initiate the development of a local indicator that suits Philippine STEAM (where A refers to Agri/Fisheries and Arts [Deocaris 2018]) included the PSGs of CHED for STEAM degree programs, and the PPST.

PSGs. PSGs are CHED documents labeled as CHED Memorandum Order (CMO) specifying pertinent provisions in the Philippine Republic Act No. 7722 (Higher Education Act of 1994) and how these provisions align with the outcomes-based quality assurance system (CMO 42 s. 2012) to rationalize education of individual STEAM disciplines. These PSGs contain the core competencies expected of every graduate in the Philippines, from which PHE Institutions reference their curricular decisions and programs alongside their specific contexts and institutional missions. The current study reviewed a total of 46 STEAM (science – 22, technology – 7, engineering – 10, agriculture – 5, and mathematics – 2) degree programs and deduced the common competency standards across all programs. Other than the specified teacher competencies in the PSG for a specific STEAM discipline, rewording of all the proficiency indicators as teacher quality standards aided the development of indicators. This process emphasized that the development of students' core competencies is a contingent of possession of the same competencies by the teachers themselves.

PPST. PPST provided vital information that outlines the needed competencies and skills of quality teachers across and in all education levels to enable them to manage and handle emerging global frameworks. This document also includes general attributes of teacher quality, proficiency, and career stages but with no elaborations on subject matter or content, and teaching and learning of complex skills in the tertiary level. These documents served as bases in framing the STEAM educators' technological, pedagogical, and content novelties towards quality STEAM education in the Philippines primarily influenced by the seven domains (DepEd 2017b).

To initiate the development of the proficiency indicators, the study identified all common tertiary teacher competencies based on the PSGs of all STEAM disciplines.

The study then compared and aligned CHED PSGs and the teacher standards (stipulated in PPST initially clustered according to PPST's seven major domains with 37 strands/indicators per domain). This process intended to check if all the PPST indicators are affiliates of specific PSG competence. Affiliates were reworded to match tertiary teacher competencies as specified in the PSG. Additional indicators were also developed to complete the identified competencies in all STEAM disciplines. Critically scrutinizing each of the indicators in each PPST domain resulted to either deletion or aggregation of items, thereby yielding the 90-item initial draft (*version 1*) of the Self-Rating Proficiency Indicators for PHE STEAM Educators. The 90-item initial draft of the instrument underwent a two-tier validation process of its structural and psychometric properties. Table 1 illustrates sample items in the initial draft of the questionnaire.

Obtaining Expert Opinions for Assuring Content Validity

Fourteen STEAM experts analyzed the content validity of *version* 1 (90 items) and then *version* 3 (60 items) of the proficiency indicator. The committee of experts consists of tenured professors and associate professors of any of the STEAM disciplines pooled from PHE institution with the greatest number of STEAM programs recognized by CHED as Centers of Excellence (COE). The invited expert must have the following qualifications: has been teaching any of the STEAM discipline aligned to his/her discipline for at least five years, has completed doctorate degree aligned with his/her baccalaureate and master's degree, and has publications and citations in his/her area of specialization. Succeeding validation procedures classified the indicators into factors that eventually matched 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) after tagging and clustering each of the retained and modified items/indicators according to the seven dimensions of TPCK.

Through an online platform, invited experts retrieved the initial list of proficiency indicators and evaluated these indicators according to the level of appropriateness of each item using a four-point Likert-type scale: 1 (not appropriate), 2 (slightly appropriate), 3 (moderately appropriate), and 4 (highly appropriate). The validators also provided comments (a second tier) to each indicator in order to complement their numerical rating that generally tendered feedback as regards the aforementioned criteria. Furthermore, their comments and mean scores for each indicator after the core team tallied the validators' rating determined whether to retain, delete, or modify indicators – resulting to 86 indicators for *version* 2.

Pilot Testing of the Proficiency Indicators

After confirming the content validity of the indicator by the committee of experts, the study modified and supplemented the proficiency tool by determining unsuitable, ambiguous, and low-reliability item through a pilot test for *version* 2 (86 items). Over a hundred (n = 102) STEAM teachers from several privately-owned colleges and government-supervised universities representing the three major islands of the country joined this stage. These participating universities and colleges are tagged as comprehensive HEIs in the country carrying a COE or COD badge. Furthermore, the study noted a minimal sample (at least 50) required for exploratory factor analysis (Kline 2004, Rowe *et al.* 2010, Hair *et al.* 2014). Inferential exploratory factor analysis (Cudeck and O'Dell 1994, MacCallum *et al.* 1999), specifically Principal Axis Factor (PAF) analysis, determined the factor structure framework of the derived indicators. This statistical process directed the understanding of relations among variables by understanding the constructs that underlie them. In comparison, PCA is simply directed towards enabling one to derive fewer variables to provide the same information that one would obtain from the larger set of variables (AWS n/d, Yong and Pearce 2013). The proponents employed both the PAF and the PCA for the initial extraction. They then compared the results consequently ensuing PAF to return the least

Table 1. Sample Proficiency Indicators for Philippine STEAM educators drawn from PSG and PPST.

PSG Competency	PPST Standard	Proficiency Indicator(s)	PPST Domain
Apply knowledge of physical, social, natural, and health science in the practice of Nursing (***from the PSG of BS Nursing Program)***	Model exemplary practice to improve the applications of content knowledge within and across curriculum teaching areas	Possesses Content Knowledge on STEAM Content Courses and STEAM-related fields	Domain 1: Content Knowledge and Pedagogy
Facilities and Equipment a. Class size b. Educational Technology Center c. Laboratory requirements d. Classroom requirements Assist in waste management for environmental safety (***from the PSG of BS Mathematics and Food Technology Programs)***	Exhibit effective strategies that ensure safe and secure learning environments to enhance learning through the consistent implementation of policies, guidelines, and procedures	Ensures a safe STEAM learning environment Observes precautionary measures in the laboratory rooms and classrooms (fire extinguishers, fire alarm system) and campus security	Domain 2: Learning Environment
Develop an instructional plan appropriate to identified learners, as follows: students; patients (age group, cognitive, and communication considerations); family and caregivers; general public (social status, education status, and gender considerations); peers; and other healthcare providers and professionals. (***from the PSG of BS Physical Therapy Program)***	Model exemplary teaching practices that recognize and affirm diverse linguistic, cultural, socioeconomic, and religious backgrounds to promote learner success	Develops instructional plan appropriate to the identified learner 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	Domain 3:Diversity of Learners
Communicate decisions to stakeholders (***from the PSG of BS Statistics Program)***	Lead colleagues to explore, design, and implement effective practices and programs using information derived from assessment data	Utilizes student data to recognize behavioral problems and plan for appropriate action	Domain 5: Assessment and Reporting
Develop a mature, sensitive, and effective ethical relationship (compassion, integrity, interest, motivation) with individuals, families, and groups from a variety of political, social, emotional, cultural, and intellectual backgrounds (***from the PSG of BS AgroForestry Program)***	Lead colleagues in the regular review of existing codes, laws, and regulations that apply to the teaching profession, as well as the responsibilities as specified in the Code of Ethics for Professional Teachers	Practices STEAM profession in accordance with the existing laws, legal, ethical, and moral standard	Domain 6: Community Linkages and Professional Engagement
Engage in life-long learning and an understanding of the need to keep current of the developments in the specific field of specialization (***from the PSG of BS Industrial Engineering Program)***	Demonstrate leadership within and across school contexts in critically evaluating practice and setting clearly defined targets for professional development	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	Domain 7: Personal Growth and Professional Development

cross loadings, hence the decision to report PAF. Fitting these factors to the paradigms of TPACK framework by labeling each retained or modified indicator according to dimensions determined the matched deduced factors and TPCK dimension. Specifically, this validation process aimed to examine the factor structure congruence and conclude whether the preset seven-factor structure may be generalized across Philippine data.

Full correlation matrix, Bartlett's test of sphericity, communality, and the Kaiser-Meyer-Olkin inform this study whether or not enough items are predicted by each factor. Specifically, the Bartlett test showcased that the variables are highly correlated (Chetty and Datt 2015, AWS n/d), which determined the factorability of the data. This process screened the datasets (after subjecting the dataset to PAF) if there is a substantial number of meaningful relationship among the items (the study used Pearson's correlation coefficient of 0.3 or greater). The analysis also included the calculation of Cronbach's alpha to determine the reliability of the instrument and with some item deletion as hinted by the results. The validation process resulted to *version* 3 of the Self-Rating Proficiency Indicators for PHE STEAM Educators (*version* 3, 60 items).

Data Analysis

Participants logged on and took the online survey through Google form (sent links through their email or via text messages). Data analysis instituted for all deduced data included descriptive statistics, discrimination analysis, correlation analysis, and reliability. Cronbach's alpha analysis measured the internal consistency of indicators, and PAF determined the validity of the self-rating tool. Both principal axis factoring and principal component analyses were conducted for the initial extraction. Results were compared and PAF returned the least cross loadings, hence the decision to report the PAF- as per suggestion of Pett *et al.* (2003) it is best to compare the PCA solution to the PAF solution and then use the one that makes the most intuitive sense.

RESULTS

Self-Rating Proficiency Indicators for Philippine HE STEAM Educators

Review and analysis of the PPST articulated *vis-à-vis* the PSGs of 46 STEAM programs drew specific proficiency indicators of teachers mapped in the seven domains of quality teacher practices in the PPST. Table 2 shows the initial draft of the proficiency indicators tagged in the seven domains.

Table 2. Item distribution in the initial draft of the Self-Rating Proficiency Indicators for Philippine STEAM Educators.

PPST Domain	No. of Items
Domain 1: *Content Knowledge and Pedagogy*	22
Domain 2: *Learning Environment*	17
Domain 3: *Diversity of Learners*	13
Domain 4: *Curriculum and Planning*	12
Domain 5: *Assessment and Reporting*	10
Domain 6: *Community Linkages and Professional Engagement*	8
Domain 7: *Personal Growth and Professional Development*	8
TOTAL	**90**

The content knowledge and pedagogy domain returned the greatest number of proficiency indicators. This result is reflective of how the Philippine standards place a high premium on mastery of content knowledge and appropriate pedagogy in the teaching of STEAM programs. Apparently, the Philippine government requires research to be a major category in the professional career of tertiary teachers. As such, the self-rating tool highlights research in Domain 1 to exemplify generating and sharing new STEAM knowledge to learners. Furthermore, research is also a major category in Domain 7 – underscoring professional advancement through knowledge creation, sharing, and sustainability in research.

Experts Review for Content Validity

The analysis of the content validity (Table 3) by our 14 experts shows that the items rated as highly appropriate pertain to content and pedagogy, while items with the lowest mean appropriateness rating pertain to community linkages. The former is consistent with the previous argument on the emphasis of content and pedagogy in Philippine STEAM programs over other domains. The later offers opportunity to enhance related programs to comply with global standards, acknowledging community linkages and professional engagement as among the global metrics for quality tertiary teaching (Henard and Roseveare 2012).

It is also noteworthy to mention that the indicator on developing gender-sensitive materials received the lowest mean rating, which suggests that – as per expert evaluation – promoting gender sensitivity may not be a pedagogical consideration in the STEAM programs. As disclosed by one of the evaluators, "*All my instructional materials do not consider gender as a factor.*" Appendix I shows the sample comments by the committee of experts on the draft proficiency indicator.

Collated experts' comments considered as complementing their numerical rating helped determine whether to retain, revise/modify, or discard the indicators. Clusters of comments generally pertain to the similarity and variance, appropriateness, phraseology, and ambiguity of indicator. Similarity and variance refer to indicators of the same teaching proficiency. As argued by the validators, maintaining them in the questionnaire poses redundancy and unnecessarily lengthens the questionnaire. The validators also evaluated the appropriateness of the indicators in the context of Philippine HEIs and STEAM teachers. For example, rating the teacher's ability to maintain a reasonable faculty-to-student ratio was deemed inappropriate as this is accordingly an administrative concern. Other comments pertained to the manner the

Table 3. Items in the draft instrument with the highest and lowest mean appropriateness rating as evaluated by the research collaborators.

Item No.	Statement	Mean
2	Possesses content knowledge on STEAM Content Courses	4.0
3	Acquires content knowledge on STEAM-related fields	4.0
19	Facilitates development of reflective and critical thinking among students	4.0
17	Communicates effectively across multiple platforms both oral and written, especially in English language	3.9
31	Promotes seamless transition of topics and establishes relevant relationship of concepts	3.8
35	Utilizes teaching strategies suited to diverse learners	3.7
81	Models existing general policies, rules, and regulations to promote welfare of STEAM profession	3.6
28	Facilitates lectures in plenary classes	3.0
62	Designs, communicates, and implements STEAM-related activities in partnership with the community	2.9
43	Develops gender-sensitive instructional materials	2.7

items were worded and suggestions were provided to generally improve the questionnaire's phraseology. For example, it was suggested to revise the phrase "proper ethical," which describes the use of online resources – contending that "*using something properly is tantamount to using it ethically, and vice versa.*" Finally, as indicated in their comments, the validators further looked at the clarity of the statements and tendered suggestions to elaborate vague items. For example, they suggested that examples of STEAM-related fields must be indicated in the statement assessing the teacher's "content knowledge on STEAM-related fields." Alongside with the quantitative assessment of the items, these comments served as complements for the core researchers' decision to retain, revise/modify, or discard the indicators. There were items, however, that the core researchers decided to keep, pending results of the factor analysis. This process settled the identified equal disagreement of validators on these specific items. This phase of the assessment and validation process returned 52 items retained and 34 items revised, yielding a revised questionnaire (86 items) to advance to the next level of the assessment process.

Factor Structure of Philippine STEAM Proficiency Indicators by Pilot Test

This study employed the PAF analysis as the factor extraction method, and the retained factors were rotated to a simple structure using the oblique rotation algorithm – promax (Fabrigar *et al.* 1999, Russell 2002). The KMO test (.698) as shown in Table 4, measured greater than .50 (AWS n/d), reveals that there are enough items predicted by each factor. Connectedly, Bartlett test showing significance (.000) notes that the variables are highly correlated and the obtained communality values are within the range of .902–.995 (which is above .3) that provide a reasonable bases for factor analysis (AWS n/d).

Table 4. Results of the KMO measure and Bartlett's test of sphericity.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.698**
Bartlett's Test of Sphericity	Approx. Chi-Square	10539.114
	df	3655
	Sig.	.000

Shown in Table 5 is the validation of the seven-factor structure based primarily on Kaiser's criterion (Gorsuch 1983) for factor retention and the "scree test" (Cattell 1966, Cattell and Jaspers 1967), alongside with our other contingent decisions based on theoretical plausibility. The Kaiser's criterion recommends that only factors that account for more variance than a single variable should be extracted (Gorsuch 1983). Hence, in this analysis, only factors with eigenvalues greater than 1 were considered. In fact, the first seven factors returned eigenvalues ranging from 1.806 (2.1%) to 40.012 (46.5%), which explained about 63% of the total variance.

Cattell's scree test, which is also a plot of eigenvalues of the full correlation matrix, further validated the Kaiser criterion. The scree plot reveals that the plot begins to level off at point 7, which supports the previous result as initially theorized.

The proponents labeled each indicator as per TPCK dimension, then carefully examined each of the indicators loaded on each factor as indicated in the rotated factor matrix for conceptual plausibility, especially for indicators that load on more than one factor. Table 6 presents the summary of the factors with the indicator and TPACK label or tag per item in the factors. The summary table also includes the dominant TPACK dimension, which may be considered as the theme for the factor.

Table 5. The initial eigenvalues and the total variance explained.

Factor	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
1	40.012	46.526	46.526	17.361	20.187	20.187
2	5.474	6.365	52.890	11.339	13.185	33.372
3	3.441	4.002	56.892	10.492	12.200	45.572
4	2.335	2.715	59.607	6.679	7.767	53.339
5	1.965	2.237	61.892	4.492	5.227	58.565
6	1.923	2.100	64.128	2.459	2.859	61.425
7	1.806	1.951	66.229	1.615	1.878	63.302

Table 6. Summary of factors and indicators.

Factor	Theme (same sequence as item number)	Domain(s)	Item #	Reliability Index (Cronbach's α)
Factor 1 (46.526%)	TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC, TPC (TPCK)	D6 = 5 D7 = 4 D2 = 3 D5 = 1	25, 27, 37, 63, 67, 78, 79, 80, 81, 82, 85, 86, 89, 90 (14, 23.3%)	.933
Factor 2 (6.365%)	TP, TP, TP, TP, TP, TP (TPK)	D3 = 3 D4 = 2 D1 = 1	17, 41, 43, 45, 56, 64 (6, 10%)	.820
Factor 3 (4.002%)	TC, TC, TC, TC, TC, TC, TC, TC, TC, TC (TCK)	D1 = 8 D4 = 1 D5 = 1	7, 8, 10, 11, 12, 14, 15, 18, 65 (9, 15%)	.898
Factor 4 (2.715%)	PC, PC, PC, PC, PC, PC, PC, PC, PC, PC, PC (PCK)	D1 = 5 D4 = 3 D6 = 1 D5 = 1 D2 = 1	3, 6, 20, 21, 31, 54, 57, 62, 69, 76 77 (11, 18.3%)	.892
Factor 5 (2.237%)	T, T, T, T (TK)	D2 = 2 D7 = 1 D1 = 1	4, 24, 30, 88 (4, 6.67%)	.758
Factor 6 (2.100%)	P, P, P, P, P, P, P, P, P, P, P, P (PK)	D3 = 4 D1 = 2 D2 = 4 D4 = 3 D5 = 1	19, 22, 28, 36, 35, 38, 42, 44, 48, 50, 53, 55, 58 (13, 21.6%)	.924
Factor 7 (1.951%)	C, C, PC (CK)	D1 = 3	1, 2, 5 (3, 5%)	.691
Overall/Total			60	.985

Notes: D1 – Content Knowledge and Pedagogy, D2 – Learning Environment, D3 – Diversity of Learners, D4 – Curriculum and Planning, D5 –Assessment and Reporting, D6 – Community Linkages and Professional Engagement, D7 – Personal Growth and Professional Development

DISCUSSION

STEAM educators' proficiency dictates significant STEAM learning outcomes. By providing STEAM educators with means to reflect on STEAM education practices, STEAM educators may be able to provide quality learning to emphasize the process of fostering convergent talents by improving students' interests, connecting STEAM concepts with real life, and enhancing convergent thinking (Park *et al.* 2016). Thus, our study features developing a standard self-rating tool to aid STEAM educators to reflect on the entire aspect of STEAM education theories and practices that they observe to improve the delivery of STEAM instruction.

The study grounds the design of the self-rating tool on significant information provided in the PSGs available in higher education from (CHED). In fact, this investigation sources 46 STEAM programs (Science – 22 [48%], Engineering – 10 [22%], Technology – 7 [15%], Agri/fisheries – 5 [11%], Mathematics – 2 [4.3%]). Specifically, science and engineering incurred the greatest number of programs with decoded PSGs. All information derived from these 46 programs mapped with the seven domains of PPST developed the first version of the self-rating tool, with 90 indicators with domains 1 to 4 as the most represented domains based on the developed indicators clustered in PPST's seven domains. More than half of the indicators are statements pertaining to content knowledge and pedagogy, learning environment, diversity of learners, and curriculum and planning – which are identified as common STEAM educators' teaching competencies in other standard teaching competency evaluation tools (Kim and Kim 2013, Corbett *et al.* 2014, Kim 2014). On a positive note, the rest of the indicators represent other domains such as assessment and reporting, community linkages, and professional growth – which are also deemed necessary in developing holistic and proficient STEAM educators (Baek *et al.* 2012).

As a self-rating tool (Appendix II), items or indicators of proficiency were phrased in a way that STEAM Educators are in a perspective of rating themselves to initiate individual level of assessment and induce reflective practice (Desjarlais and Smith 2011, ECA n/d). Although there are limited indicators clustered in assessment and reporting domain, these indicators cover the entire spectrum of the expected assessment framework for STEAM learners (NILOA 2012). Furthermore, imperative inclusion of research, STEAM research, and research-related activities in the indicators of proficiency (Medley and Crook 1980) highlight a significant number of domains – specifically domains 1–4 and 7. Additionally, an emerging concept within these four domains emphasizes professional growth and development as a mean to exude TPACK framework in delivering STEAM programs.

Validation of the first draft of the self-rating tool by a committee of experts and statistical method of validation using PAF analysis drew 60 vital proficiency indicators. Note that indicators are localized to suit PHE STEAM Educators. PAF generated seven factors that explained 63% of the total variance (Table 6). The first four factors account for more than half (58.5%) of the variance. In fact, the first four factors elucidate 40 out of the 60 (67%) indicators of proficiency. Injecting TPACK framework into the analysis of the proficiency indicators highlights that the designed and developed proficiency indicators emphasize dynamic interrelation and interactions of teacher's knowledge on pedagogy (PK), content (CK), and technology (TK). The seven factors (Table 6) confluently identify 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). This may mean that proficiency of PHE STEAM educators definitely depends on how they combine and interrelate technology, pedagogy, and content in delivering STEAM lessons. Furthermore, the greatest number of indicators is loaded on Factors 1, 3, 4, and 6 – which almost congruently registered the greatest number of domains (Factors 1, 4, 5, 6). Apparently, domains generally have 4–6 assigned factors. These are evident in D1 (15), D2 (8), D4 (7), and D5 (4) – which relatively emphasize teaching and learning process, the learning environment, the curriculum, assessment and feedback system, and the learners parallel with most teaching competency evaluation tools (Kim and Kim 2013, Corbett *et al.* 2014). Thus, it may be inferred that the indicators of proficiency clustered in the seven identified factors that match the seven hierarchically arranged TPACK dimensions (TPCK, TPK, TCK, PCK, TK, PK, and CK) are in cognizance with the intentions of the domains of PPST (DepEd 2017). Thus, the study infers that STEAM educators prioritize appropriate blending of the basic TPCK dimensions (PK, CK, TK) – exuding a sense of balance that exemplify TPCK paradigm. Also, the indicators may be able to completely describe the proficiency level of PHE STEAM Educator and the constructs of the self-rating tool generated high reliability indices.

Consequently, the use of the self-rating tool may give a positive look on the STEAM education at the basic education level. This self-rating tool may serve as a guide for the basic education teachers in their teaching practices inside a STEAM classroom. Similarly, teacher education institutions may look at how their respective curricular offerings are producing teachers in teaching STEAM. At this level, teachers may also reflect on their teaching practices as against the TPACK dimensions. Moreover, programs may be designed and developed to capacitate the teachers as STEAM educators and to challenge themselves to achieve the indicators in the domains of the PPST in advancing and strengthening the STEAM education in the country.

CONCLUSION

The major goal of the study is to develop a self-rating tool that will be able to determine the proficiency level of PHE STEAM Educators. Through the rigors of design and development research, the study was able to come up with a valid, reliable, and standardized content with 60 indicators of STEAM Education proficiency clustered into seven major components based on experts and statistical validation. The crafted indicators suit the culture and context of PHE STEAM Educators, which make the self-rating tool an appropriate self-assessment tool mapped within the seven dimensions of TPCK framework. With this special feature of the self-rating tool, STEAM educators may utilize the instrument as a tool for reflective practice in higher and advanced learning. Furthermore, these indicators of proficiency may aid the senior high school STEM teachers in the basic education level in crafting plans and actions to successfully enact the STEM for Senior High School curriculum for the college entrants in any of the STEAM disciplines. Apparently, these indicators may be considered as the elaborations and illustrations of practice of the PPST framework and domains for the STEM track, from which the basic education STEM teachers (elementary and secondary) may refer to for insightful practice of their STEM profession. Consequently, generated TPCK levels of STEAM educators may inform education leaders and policy makers of the strengths and weaknesses of PHE STEAM educators. These may also serve as inputs to policy generation of STEAM education, crafting of PSGs, and the curriculum. The results of the study may also have implications for designing capability building programs to strengthen STEAM educators' proficiency within the context of TPACK framework, as well as in promoting professional development among the STEAM educators. However, the PSGs of the 46 STEAM courses emphasized content and learning of the content, with a minimal focus on feedback system. Thus, for policy revision, the study endorses accentuating on assessment and feedback system in higher education to specifically track the progressive improvement of learners in developing them to achieve the intended STEAM learning outcomes and be part of the strong workforce 4.0 of the country.

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