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# Technology Integration Traditions, Transitions and Best Practices in Philippine Higher STEAM Education

**Marie Paz E. Morales**[1]*, **Ruel A. Avilla**[2], **Benilda R. Butron**[2], **Thaddeus Owen D. Ayuste**[2], **Dennis B. Masangcay**[3], and **Roselle A. Laureano**[4]

[1]College of Graduate Studies and Teacher Education Research
Philippine Normal University, City of Manila 1000 Philippines
[2]Faculty of Science, Technology, and Mathematics
Philippine Normal University, City of Manila 1000 Philippines
[3]Department of Education Tanauan City
J.P. Laurel Highway, Tanauan City, Batangas 4232 Philippines
[4]Science Department, Panipuan High School
Panipuan, City of San Fernando, Pampanga 2000 Philippines

**The literature's focus on technology integration (henceforth as TI) in the country has been noteworthy and extensive in the use of ICT in the teaching and learning (TL) process. However, studies on TI's aspects such as accessibility, teacher training, tools and equipment, and digital literacy remain underexplored. Through a five-instrument classroom observation protocol, this study explores the traditions, transitions, and best practices in TI of 85 tertiary teachers of STEAM (science, technology, engineering, agri-fisheries, mathematics) disciplines in the Philippines. The findings indicated that TI practices are clustered as conventional, web/software-based, and electronic/computer-based. For instance, the majority of the teachers prefer conventional technology and practice a low level of engagement to web and learning applications in the context of pedagogy and content/discipline, and learners. Specifically, the transition to advocating higher engagement to technology and blending such to pedagogy and content are evident in science, mathematics, engineering, and technology. The analysis also revealed that TI practices, which exhibit fusion of the technological pedagogical content knowledge (TPCK) system also matched the Philippine Professional Standards for Teachers (PPST) domains specific to pedagogy and content, assessment and reporting, and diversity of learners and learning environment. The study further showed that the best practices of TI in terms of eight teacher technological characters emphasize their sustainability literacy skills such as future thinking, values thinking, systemic thinking, and strategic thinking. Correspondingly, Philippine universities and colleges may explore professional development programs for STEAM teachers in preparation for 4IR (fourth industrial revolution).**

Keywords: Education 4.0, learning continuity, Philippine STEAM education, technology, technology integration

*Corresponding Author: morales.mpe@pnu.edu.ph

# INTRODUCTION

Prior to the COVID-19 pandemic, the 4IR propelled by technological evolutions such as the cyber-physical system, the Internet of things, *etc.* has influenced many aspects of life (Hermann *et al.* 2016). This 4IR defines the new job-skill set of future human resources who are labeled as Workforce 4.0 (Boisvert 2018). Such influence necessitated a mandatory transit to a new education paradigm, Education 4.0 (E4.0), as a response to the demands of 4IR (Diwan 2017). Likely, E4.0 caters to the innovation era changing the learning landscape where the concept of lifelong learning and sustainable development becomes the norm (Sinlarat 2016; UNESCO 2017). All these transitions and paradigm shifts exacted by the 4IR entail technology use, awareness, and integration, which penetrate the domains of industry, workforce, and education. With the current setup of instruction within the context of online, distance, or flexible learning (FL) caused by the unprecedented and massive shift in education delivery during the pandemic, technology in education is seen now as an indispensable vehicle towards continuity of learning of students (OECD; Reimers and Schleicher 2020; Reimers *et al.* 2020). Thus, this paper explores these much-needed aspects of technology in Philippine higher education – awareness, utilization, and integration.

## E4.0 and Technology in Education

Education throughout the years has continuously evolved from one paradigm to another to accommodate the required skills for the different economic and industrial eras (Puncreobutr 2016). Specifically, the leap to E4.0 recalibrates the new learning terrain that emphasizes technology in facing the challenges of the 4IR (Ernst & Young 2017). Paramount to higher learning, E4.0 requires new learning spaces to accommodate novel pedagogies that are heutagogy (self-determined learning), paragogy (peer-oriented learning) and cybergogy (virtual-based learning); fluid and organic curriculum; technologies such as smart boards and tablets; and integration of learning and teaching technologies (Ranai 2018).

Permeating technology in education consequently led to the popular term "TI." In the context of TL, TI refers to the use of technology resources in learning, in daily classroom practices, in teachers' major and other duties, and in the management of a school (Education4site 2011; Panda 2017). In fact, educationists believe that successful integration of technology in TL is an indicator of success that can predict student achievement (Warschauer 2011; Werth and Werth 2011) and learning continuity (OECD; Reimers and Schleicher 2020; Reimers *et al.* 2020). Thus, efforts abound to broaden the influence of TI highlighting higher and advanced learning.

## TI in Education

Literature on TI comes in eras, noting the later decade as focused on online learning and higher education, integration of ICT, and full potential of educational technology (2010–2014); and data-driven, smart educational technology, big data, and learning analytics (2015–2019) (Bozkurt 2020). Within this period, research in TI focused on the following aspects: its effects on student learning emphasizing increased student engagement and motivation (Banitt *et al.* 2013), improved academic performance and increased personal and career success (GoGuardian 2019), and deep learning in higher education (Zhou and Lewis 2021). On the feature of teacher preparation and lesson enactment, literature suggests that well-prepared and equipped teachers, professional development on TI (Hew and Tan 2016), and positive perception/attitude of students (Kim and Jang 2020) emerge as indicators of successful TI by teachers in their TL practices. Actually, teachers using technology in their classes have transitioned from using technology as a teaching tool that serves as an extension of their conventional teaching strategies to technology as a learning tool embodying learner-centered principles (Nueva 2019), which vary substantially in their teaching practices (Liu 2016).

In sum, TI in education has induced empirical evidence of its effect on student learning, teacher practices, and other aspects of TL, which have predisposed policies, standards, and guidelines. The early adoption of information technology systems, especially in higher education institutions (HEIs, which are considered as the primary engine for economic growth), is imperative in securing competitive advantage that can allow countries to leapfrog over the traditional pathways into the roads of knowledge-based production and services (Sarvi *et al.* 2015). Such a move might also guarantee the attainment of Agenda 2030 (UN 2020) regardless of the current global health crisis. Nevertheless, the majority of the read literature are contributions to knowledge on TI from developed countries (Bozkurt 2020), and only a minority reflect the TI practices, traditions, and transitions in developing countries like the Philippines. Hence, the potential contribution of the current study to the existing literature on TI in developing nations is apparent in terms of traditions (accustomed and conventional use of technology in the classroom) and transitions (modifications in TI emphasizing blend with pedagogy and content), and best practices (TI exemplifying TPCK system) of Filipino teachers of STEAM disciplines.

Moreover, studies on TI in the country focus on aiding learning in basic (elementary and secondary) education (Balmeo *et al.* 2014; Ramos 2010) and advanced learning (Reston 2013; Tamoria 2016). However, Tomaro and Mutiarin (2018) pointed out that most of the papers they reviewed were on TI in the country emphasizing the use of ICT in the TL process and not much on other aspects of technology such as affordances, accessibility, teacher training, lack of tools and equipment, manpower, digital illiteracy, and teachers' hesitancy in learning the tools (Castro 2016; Raman and Yamat 2014). Additionally, a minority of educationists venture into investigations on TI and much less on research, which focuses on E4.0, thus providing a very crude vision of technology utilization in the Philippine classroom. Such circumstances made it very difficult for the country to institute full online learning as a modality of learning during this pandemic (Magsambol 2020). This condition also marks achieving SDGs as a struggle for developing countries (Ally and Wark 2019). Thus, exploring and describing the TI profile of the country may identify the strengths and weaknesses of the efforts of higher learning to craft strategic plans to address the gap in TI, particularly in STEAM disciplines.

This study theorizes that describing and analyzing the TI of teachers of Philippine higher education STEAM disciplines may be achieved using TPACK (Mishra and Koehler 2006), sustainability education framework for teachers (SEFT) (Warren *et al.* 2014), and PPST. Designed to check and profile the bases of effective teaching with technology, the TPACK framework requires an understanding of how technology applies to concepts, which pedagogical techniques effectively use these technologies, and how technologies can address student difficulties when learning the concepts. The focus on the TPACK model over the other models is due to the former's capacity to determine what knowledge systems teachers possess. Other models such as TIM (technology integration matrix) and SAMR (substitute, augment, modify, and redefine) emphasize specific ways and levels of TI in the classroom, which may not inform knowledge system acquisition and competency development of teachers in weaving technology, pedagogy, and the content. TAM (technology acceptance model), on the other hand, does not focus on TL. Hence, the current study utilized the TPACK model as a unit analysis together with PPST. The PPST is a standard in teaching, applicable to all levels of education, that defines the teachers' proficiency in the different TL domains. It relates to the three major categories of TPACK (technology, content, and pedagogy) and outlines the proficiency of teachers' TI in every domain of education. Finally, SEFT as a dedicated framework for sustainability literacy for teachers embraces four ways of thinking (futures, values, systems, and strategic), which are bi-directional and interconnected (Warren *et al.* 2014).

### Purposes of the Research

Against this background, the present study aimed at exploring the TI in Philippine STEAM education. Specifically, it addressed the following objectives:

1. describe TI traditions and transitions of higher education teachers of STEAM disciplines in the Philippines in terms of TPACK, SEFT, and PPST; and

2. determine the best practices of TI of higher education teachers of STEAM disciplines.

## MATERIALS AND METHODS

This mixed-method study (Creswell 2009), which employed a concurrent triangulation approach, utilized classroom observation protocol to gather data on how the Philippine tertiary teachers (of STEAM programs) integrate technology in teaching the STEAM disciplines. In choosing the participants, the study situated in the low-tier ranked state universities and colleges (SUCs), local universities and colleges (LUCs), and private universities and colleges. These school categories mainly engage in at most two out of the four pillars of Philippine tertiary education – instruction, research, production, and community service – with instruction as their top priority. Tertiary teachers of STEAM disciplines in these schools are either products of education or discipline-based programs.

### Instrument

***Classroom observation protocol for STEAM.*** This pack includes five different instruments (first four sets were used in this study): 1) the STEAM classroom observation rating scale (a 48-item, six-point Likert scale tool), 2) classroom observation notes, 3) TPACK interview protocol (six-items; main questions with corresponding probing questions clustered according to themes), 4) TI checklist, and 5) assessment checklist. 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. The classroom observation note includes questions clustered into the dimension of TPACK. The observation note is designed for use by researchers who would want to collect qualitative data on STEAM education anchored on the TPACK framework. Validation of this set of instruments was done in two tiers: first by the research team members and second by experts sourced from research universities labeled as centers of excellence (COEs) and development (CODs) in STEAM programs. Reliability was established using a descriptive format, ensuring that all items are clear to intended participants.

### Participants

With the set confidence level of 95% and from the Philippine Commission on Higher Education (CHED) data on the total population of Philippine HEI (2,299), the study employed cluster sampling to randomly select 220 HEIs (10% of the population) from 17 regions (to ensure equal representation). Invitations were sent to the sampled HEIs to participate in the collection of data, but the study only generated a positive response from 123 schools (56% of the sampled HEIs) despite extensive calls for participation (with CHED endorsement, emails, formal letters through courier). Since the generated response already reached more than half of the sampled schools, second-tier random sampling was performed taking into consideration the following factors: 1) inclusion of STEAM disciplines in their curricular offerings; 2) school clustering either as SUC levels 1 and 2, LUC, or private colleges and universities; and 3) schools are located in most accessible areas to any means of transportation. Also, schools coming from regions that may pose threats and danger were excluded. The second-tier random sampling produced 31 schools with at least one representative school and a maximum of three per region. Table 1 shows the summary of the number of teachers (of STEAM programs) included in this study. Then, allocation on the number of schools per region followed, which depended on the total number of HEIs in the region and on the financial resources of the study. This process resulted to 106 target samples who were teachers purposively chosen based on the following selection criteria: 1) they are currently teaching any of the STEAM courses; 2) they completed at least a bachelor's degree in any of the STEAM programs; and 3) they are part of the organic set of faculty of the identified institution, are working on a full-time basis, and have class schedule suitable to the agreed date of school visit.

## Data Collection

The data collection process focused on drawing and triangulating evidence from procedural sources such as interviews, observation, the teacher's proficiency profile (in technology), and the information from their submitted session guides to determine their engagement to TI. The data were obtained in 2018–2019 as part of the TPACK in Philippine STEAM education research project.

Eighty-five (85) of the 106 teachers participated in the data collection, particularly on classroom observation. The choice of teachers for the data collection also depended on the recommendation of the HEI's field researcher and the teacher's availability during the scheduled observation. These teachers were observed on the use of technology and other tools in teaching STEAM disciplines, including their practices anchored on TPACK dimensions. The interview in each of the sampled HEI included a session with the dean of the college or the head of the department to which the sampled teachers (of STEAM programs) are mapped. This interview was intended to assess the administrative support to the teachers in terms of their preparedness in STEAM teaching with an emphasis on their practices showcased in TPACK dimensions.

***Preliminaries.*** Before the classroom observations and interviews, a notice of visit was sent (with prior approval) to the school head or university president of the HEI through the representative (field researcher) requesting to accomplish the set of forms that included: 1) the participating institution's reply form specifying the time and day or date of the interviews and classroom

**Table 1.** Summary of the number of STEAM teachers observed and interviewed per region.

| Region | Number of schools | Number of STEAM teachers |
|---|---|---|
| National Capital Region (NCR) | 5 | 10 |
| Cordillera Administrative Region (CAR: Kalinga-Apayao) | 1 | 4 |
| Region 1 (Ilocos Sur) | 2 | 5 |
| Region 2 (Batanes) | 1 | 4 |
| Region 3 (Aurora, Bulacan, Pampanga) | 3 | 15 |
| Region 4 (Laguna, Quezon) | 3 | 16 |
| Region 5 (Camarines Sur, Camarines Norte, Masbate) | 3 | 9 |
| Region 6 (Negros Occidental, Iloilo | 2 | 10 |
| Region 7 (Bohol, Siquijor) | 2 | 4 |
| Region 8 (Southern Leyte) | 1 | 5 |
| Region 9 (Zamboanga del Norte) | 1 | 5 |
| Region 10 (Camiguin, Misamis Occidental) | 2 | 4 |
| Region 11 (Davao del Norte, Davao del Sur) | 2 | 7 |
| Region 12 (North Cotabato) | 2 | 8 |
| Region 13 (Agusan del Norte) | 1 | 0 |
| Total | 31 | 106 |

observations, 2) pre-observation questions (which should be accomplished by the recommended teachers prior to observation), 3) TI checklist, 4) session guide, and 5) informed consent forms. These are accomplished forms sent to the research team for confirmation of the data collection tasks in the identified HEI.

***School/HEI visit.*** Upon arrival at the HEI, the research team conducted a courtesy visit to the school officials together with the field researcher. While the research team made a courtesy visit, the field researcher secured all consent forms from all interviewees (STEAM teachers) for classroom observation. The team interviewed the head of the department or the dean of the college of the STEAM disciplines for about an hour. This interview was audio-taped or videotaped depending on the interviewee's choice.

Classroom observations were also initiated as soon as the team completed the interviews with the officials for the purpose of data triangulation. The team observed each of the sampled teachers (of STEAM programs) in their respective classes in the entire allotted period. The team also conducted a "post-conference" (an interview after the classroom observation) to clarify items in the tools that were not observed to manifest during the observation. Classroom observations were audio-taped or videotaped depending on the choice of the teacher being observed. The team also supplemented the observation per teacher (of STEAM programs) with intensive interviews (about 1 h per teacher with interview validation by their department chairs or superior) and other sources such as lesson guides profile.

***Post-school/HEI visit and data analysis.*** The team placed and organized all accomplished forms (pre-observation and interview), classroom observation rating scales, classroom observation notes, and video and audio recordings in a virtual folder allotted per HEI. For the numerical data, the team used frequencies and percentages while the team transcribed all recordings (interviews and classroom observations) and subjected all transcripts to the coding system using computer software. "Open coding" was performed where the team named specific lines or segments of the data by creating new codes (core codes), which are redefined in the succeeding phases of analysis. Then, "selective coding" was implemented and performed in three iterative rounds of coding. This was done to define the most significant higher-level codes and sort the lower-level codes created during the initial coding phase providing hierarchically grouped codes. Next was to hierarchically group the codes into concepts by sorting the codes into the "parent codes and subcodes" to design the "code tree." Then, the concepts or themes were categorized through relationship identification. Lastly, these categories were grouped together to similar concepts. Traditions, transitions, and best practices in TI among the teachers (of STEAM programs) emerged as the concepts or themes.

***Ethical considerations.*** The study noted some ethical considerations. The team asked for the consent of the participants in the study. Prior to the data collection, consent forms were sent and collected. The anonymity of the participants was observed all throughout the phases of the study.

## RESULTS

### Traditions of TI

The analysis of the generated quantitative data, sourced from collected and tabulated responses using the TI checklist, deduced the percentage of teachers of STEAM disciplines utilizing and integrating the identified technology or tools in their respective classes as per their claims.

Figure 1 shows that more than half of the sampled tertiary teachers of STEAM disciplines integrate conventional technologies in their respective classes, with chalkboard and board activities dominating this list. Coherently, all classroom observations verified the teachers' traditions in using technology in their classes, indicating that the majority of the observed STEAM classes used lecture methods in delivering the lessons. These teacher-participants clarified that they have only chalkboards and no smart boards in their classrooms at all. Such may be the case because of the fact that teachers only utilize available technologies in their respective schools and what is best suited to the kind of students they have (Erişti *et al.* 2012).

Although the majority favor the conventional technologies (chalkboard and projectors), web-based and software-based technologies (PowerPoint or digital slides, clicker, simulations, websites, learning applications, documentary, video clip, YouTube videos) and electronic- and computer-based technologies (demonstration equipment, digital tablets, *etc.*; use of other equipment) take on a third (30 and 31%, respectively) that are indicative of the fact that the sampled teachers try to suit the tools and materials in teaching their lesson to their generation z's learning characters. A participant claimed to teach "students belonging to a different generation who have different learning style," while another teacher reports that as per observation, "students often use gadget, and since I am dealing with millennial students, I believe that through this technology, they will be having a more conducive way of learning, and the discussions will be more productive." However, among the list of web-based and software-based technologies plus electronic- and computer-based technologies, a somewhat low engagement in using the web, demonstration, and improvised materials were observed, probably because the sample participants only utilize such to augment the non-availability of the needed

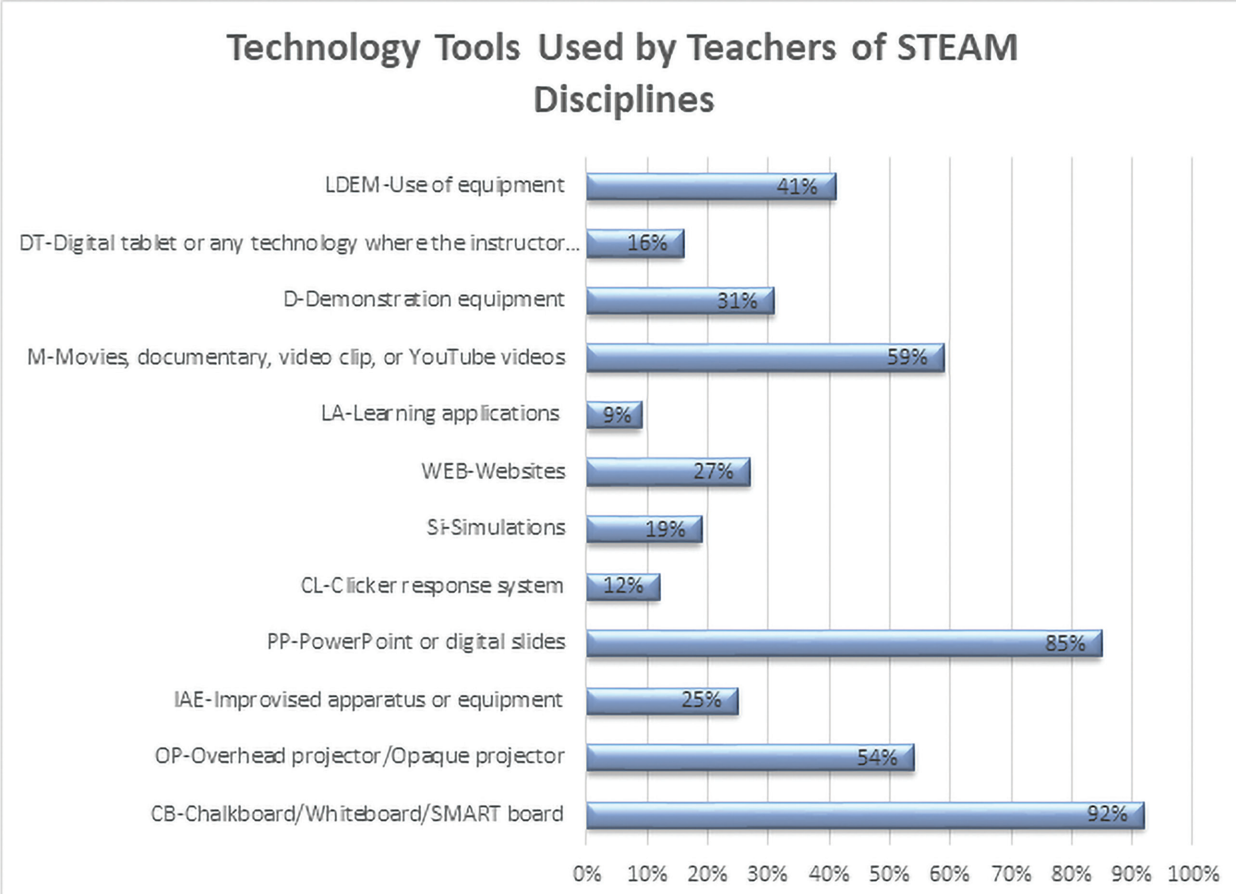


**Figure 1.** Technology tools traditionally used by STEAM teachers.

tools to teach the STEAM course (Akuma and Callaghan 2016). There is also a very low utilization of digital tablets, simulations, and even learning applications, which may be attributed to less contextualization, no internet connectivity in the place, and insufficient funds (Castro 2016; Raman and Yamat 2014).

Accordingly, each of these surveyed teachers provided their basic considerations in the choice of tools to teach the STEAM disciplines. Many teachers say they integrate technology to "make discussion more meaningful and to give students proper examples on how technology works in both theory and in application." They reveal that their basic motivation in integrating technology in their lesson is their belief that the use of technology has the potential to "make class not boring and gain participation," the capability to "promote critical thinking," and the power to stimulate real life applications." Furthermore, they show that what drives them to integrate technology or transition in their TI processes in their lessons may be clustered into four broad themes: usability (65%), pedagogy and content (43%), learners (40%), and others (6%). A better lens may be provided by Table 2, which shows their integration practices analyzed using the three aforementioned frameworks (TPACK, PPST, and SEFT).

**Transitions of TI**

Based on gathered information, the sampled tertiary teachers of STEAM disciplines exhibit varied TI transitions and practices when clustered according to their specialization or STEAM discipline. Table 2 shows the TI transitions and practices characterized by TPACK and PPST frameworks.

Based on PPST (please refer to the Appendix for the equivalent of each domain), their TI practices may be classed within domains 1–5. In fact, domain 1 leads the count in each of the STEAM disciplines, a low tryst of TI in domains 2 and 4, and finally, a non-engagement to TI within domains 6 and 7.

The TPACK framework also acknowledges the TI practices of the teachers as concentrated on TPK (12 out of 36, 33%), TK (11 out of 36, 30%), and TPCK (9 out of 36, 25%). TCK seems to be a minority in the labeled practices stressing the use of technology in delivering content. However, few

**Table 2.** TI transitions and practices among the STEAM teachers.

| STEAM | TI transitions and practices | PPST (D1, D2, D3, D4, D5, D6, D7) | TPACK (TK, PK, CK, TCK, TPK, PCK, TPCK) |
|---|---|---|---|
| Science | Use of PowerPoint presentation in presenting and delivering the lesson | D1 | TPCK* |
| | Models of a cell and/or other improvised model are used to enhance learning | D2 | TPCK* |
| | Use of PowerPoint in presenting and delivering the lesson | D1 | TPK |
| | Use laptops, computers, speakers, and/or LCD projector as an aid in teaching | D3 | TK |
| | Use flash, clicker response, android dictionary, and/or computer software to deliver a lesson | D3 | TK |
| | Blended learning and computer-aided learning are used to augment learning | D4** | TPCK* |
| | Technology is integrated with the use of PowerPoint, flash, videos, models, the internet, and the use of technology tools such as whiteboard, LCD projector, and/or computer software in delivering lessons. | D1 | TK |
| | These technology tools are used as part of the teachers' pedagogical practices such as content-based instruction, lecture, laboratory, and integration to other disciplines (D1) | D3 | TPCK* |
| Technology | Use animation with integration to other disciplines | D3 | TPCK* |
| | Aided with simulation and computer graphics and computer software to enhance learning activity | D3<br>D4 | TCK<br>TCK |
| | Read online materials | | |
| | Integrate human anatomy in teaching body animation | D4 | TPCK* |
| | Aided with use simulation and computer graphics and computer software | D3 | TCK |
| | Use of PowerPoint in presenting and delivering the lesson | | |
| | Use laptops, computers, speakers, LCD projector, and/or smart TV as an aid in teaching | D1 | TPK |
| | Feedbacks were immediate with the use of computer | D1 | TK |
| | Hands-on with computer activities | | |
| | Technology is integrated with the use of PowerPoint, flash, videos, models, the internet, and the use of technology tools such as whiteboard, LCD projector, and/or computer software to delivering lessons (D3 and D1) | D5<br>D3<br>D1 | TPK<br>TPCK*<br>TPK |
| Engineering | Integration of Galton board | D1 | TPCK* |
| | Use visualization like graph/dot matrix | D1 | TPK |
| | Use laptops, computers, speakers, and/or LCD projector as an aid in teaching | D1 | TPK |
| | Use of PowerPoint in presenting and delivering the lesson | D1 | TPK |
| | Equipment and tools are used to enhance the delivery of the lesson | D1 | TPK |
| | Technology integrated activities like a strategy game and/or graph activities interactive video are used. | D3 | TPK |
| | Lecture-discussion coupled with PowerPoint and/or video (D3 and D1) | D3 | TPK |
| Agri-Fisheries | Use PowerPoint (computer-aided learning) *but limits teacher's interaction with students | D2 | TPK |
| | Use of PowerPoint in presenting and delivering the lesson | | |
| | Teaching lessons is aided with a PowerPoint (D2 and D1) | D1<br>D1 | TPK<br>TPK |
| Mathematics | Use flash quiz | D5 | TK |
| | Use Excel in solving matrices/linear problems | D5 | TCK |
| | Use computer-aided learning | D2 | TK |
| | Software like SPSS is used | D3 | TK |
| | Visualization of graph function | D3 | TK |
| | Use laptops, computers, speakers, and/or LCD projector as an aid in teaching | D1 | TPK |
| | Teaching tools such as whiteboard, PowerPoint, videos, LCD projector, calculators, and/or computers | D3 | TPK |
| | Integration of the topic to the real world and to other related disciplines using TI (D3, D5, and D1) | D1 | TPCK* |

Legend: D – domain; *best practices; **transitions to new normal

transitions (**) were already evident in fields of sciences, mathematics, engineering, and technology – advocating higher engagement to technology and blending such to pedagogy and content. Among all the STEAM disciplines, science teachers seem to achieve a higher number of TPCK practices of TI compared to the other disciplines, while all the others rest on TPK.

**Best Practices of TI**

Table 2 also shows some of the best practices (*) of TI of the sampled teachers of STEAM disciplines. Labeling their identified TI as best practices emphasize their technology utilization that weaves and blends well with their pedagogical practices in delivering their respective content. Hence, these identified best practices of TI showcase the complete TPCK systems of the teachers of STEAM disciplines. As verified from the codes derived from the qualitative data analysis of TI practices of STEAM teachers, the resulting eight themes – collectively termed as teacher technological attributes – may be considered as their best practices. Such best practices include: 1) ensures ethical use of online resources, 2) use of technology in predicting future trends and processes of STEAM, 3) familiarization to the STEAM profession database, 4) use of technology in teaching STEAM content knowledge, 5) development/improvisation of new technology, 6) promotes proper care and handling of technology, 7) utilizes technology in the TL process, and 8) adapts technology in the TL process.

## DISCUSSION

### Traditions and Transitions

The generally low optics of TI traditions of teachers of STEAM disciplines in Philippine higher education may be attributed to several factors and reasons. Note that their respective schools are clustered in the lower tiers and may have limited funds in this regard. Some basic considerations in the choice and use of technology for integration in classrooms that define low engagement may also be attributed to the challenges for Filipino learners and teachers to transition to online learning. In fact, most HEIs that participated in this study are currently using printed modules and/or electronic modules for learning continuity in this time of the pandemic. Collectively though, the results indicate that more than half of the sample teachers of STEAM disciplines are transitioning to using the two latter clusters of technology (web-based and software-based technologies and electronic- and computer-based technologies). Such results imply that probably, although teachers in a developing country like the Philippines use conventional technology as their TI tradition, they are starting to move forward and are transitioning to a more mature use of technology in the classroom. Evidently, the sampled teachers are starting to blend their modules with online capabilities. This may inch the way to the global trend of using 4IR technologies in E4.0 to develop the country's envisioned workforce in the era. However, being categorized in lower-tier universities with low budgetary appropriations may not yet warrant such. Thus, the current emphasis of their transition should be on the concept of "appropriate technology" as a sustainability principle for developing countries like the Philippines (Beder 2000; Fressoli and Arond 2015). Apparently, the sampled tertiary teachers of STEAM disciplines venture into this sustainability concept while they try to transition and make use of available materials and tools to teach their respective lessons. It may also be considered as a strategy in utilizing specific technology in specific parts of the lessons according to the assessed need by the teacher: "I use chalk and board almost every time. For PowerPoint presentation, I use it when I cannot show them a visual material or Lab equipment in times of laboratory activities. Specific technology: chalk and board, microscope, Lesson: cell and its organelles and its parts." Appropriate technology may be cued as the use of skills and technology, which they also exhibit while they improvise tools that may aid their TL activities using local materials and contextualized in their culture. It may also be noted that within lessons, these sampled teachers exhibited the use of conventional tools but eventually transition to other technology as the need arises and when technology is available.

In terms of the domains of PPST (see Appendix), the sampled teachers' traditions and transitions in TI may be defined by four broad themes: usability (Castro 2016; Raman and Yamat 2014), pedagogy and content (Cetin-Berber and Erdem 2015; Tanak 2018), learners (Davis 2013), and others. Such reference to pedagogy and content theme associates with how the sampled teachers negotiate with TI when viewed according to their specializations (science, technology, engineering, agri-fisheries, and mathematics), as indicated in Table 2. In fact, the lead position of domain 1 in each of the STEAM disciplines implies that most teachers traditionally practice TI in content and pedagogical knowledge, although there seems to be a need for enhancement to bring them all to higher levels of engagement and integration. Their low engagement to TI in domains 2 and 4 may mean that they usually resort to their traditional and conventional processes of dealing with diverse learners and in assessment and reporting, which may lead to lower student engagement (Darling-Hammond *et al.* 2014). But apparently, it is their way of sustaining their culture, local practices, and tools of technology as per the appropriate technology principle (Erişti *et al.* 2012). Finally, their non-engagement to TI within domains 6 and 7 may confirm their young and low maturity level of TI tradition inside and outside their classrooms. They may have a single-minded view that TI may only be beneficial in content and pedagogy, and may hamper their arrangements in other domains of the university or in the collegiate practice of their profession as teachers of STEAM disciplines.

In terms of TPACK, results in their TI traditions still match their claim that content, discipline, or subject matter is a major consideration in choosing which technology to integrate, and that content knowledge vitally influence the development of TPCK (Cetin-Berber and Erdem 2015; Tanak 2018). One key transition that these teachers exhibit is their TI practices, which have gone beyond mastering the discipline or content even if they are discipline-based trained professionals. In fact, this marked shift leads them to focus on exploring pedagogical entities and delivery strategies of the discipline using technology (Solis 2009), leading them to exhibit TPCK and TPK. They (especially those who are new in tertiary or university teaching) even further seek to advance their professional competence through in-service training on pedagogy (Ödalen *et al.* 2019).

**Best Practices**

Although a minority of the TI practices of the sampled teachers are labeled as best practices, it should be noted that these are their practices that exhibited a complete TPC knowledge system, which the TPACK model envisions for TI to be successful. Additionally, themes generated from the coded interviews and observations confirm that their technological attributes considered as their best TI practices conform to the TPCK and PPST frameworks, and sustainability principles (systemic, values, strategic, and futures thinking).

The teachers' comfort in using technology in teaching (utilize technology in the TL process and adapts technology in the TL process) empower them to determine the identified technology's appropriateness to attain the learning goals and objectives (Koehler *et al.* 2012). Seemingly, they focus on lesson learning goals (utilize technology in the TL process), and how learning is enhanced, engaged, and extended *vis-á-vis* their TPK. These are evident in the use of technology beyond the classroom and their emphasis on the utility of technology in the TL process, including its adaption. Also, teachers' confidence in TI is attributed to their influence on peers who they even mentor and coach in the use of technology to develop and assess the TL resources in and out of the school (Holland 2018). This technological teacher character evidently indicates systemic thinking as a sustainability literacy skill. In fact, Wiek and colleagues (2011) describe such sustainability skill as the ability to collectively analyze complex systems across domains and across different scales. As one participant claimed: "The use of technologies as part of the delivery of the lesson helps in visualizing Chemistry concepts that seem abstract or difficult to grasp and connects to other fields in science." Systemic thinking may also be observed as disclosed by another participant: "Usually, I use these technologies to show them some machine reagents or tests that are not available here in the Philippines but are available in other countries. Also, for example, to show them what are the different things that can be seen inside our bodies," emphasizing a grasp of concept and content across different scales (national and global) (Wiek *et al.* 2011).

Additionally, these teachers advocate ethical use of online resources, which is a necessary teacher attribute in today's utilization of online resources, especially during this time of the pandemic. Seemingly, these teacher attributes in terms of practices in TI conform to the changes in society and education system toward a technology-driven 4IR through technology use and adaptation in the classroom. But these teachers still believe that they need to emphasize the development of a solid moral compass for the students to successfully thrive in 4IR (Mattison 2018). Commitment to ethical and moral use of resources by these teachers is also indicative of their values thinking as a sustainable literacy skill (Warren *et al.* 2014).

A number of these teachers also advocate and focus on the use of technology in predicting future trends and processes of STEAM. In fact, one participant emphasized that technology use "enhances my instructions as a teacher and enhances the learning experience of my students, and provides them the opportunity to actively engage with the learning; to develop critical thinking, creativity, and collaboration; and prepare them for their future careers in STEAM." Note that future thinking as a sustainability literacy skill manifests in STEAM teachers' use and integration of technology in their respective disciplines as well. Additionally, themes such as the use of technology in teaching STEAM content, utilization of technology in the TL processes, and familiarization to the STEAM profession database may also manifest "strategic thinking, that emphasizes being able to develop a strategy or a plan to achieve a particular vision" (Wiek *et al.* 2011).

Lastly, teachers of STEAM disciplines highlight the development and improvisation, proper care and handling of technology, and insinuate that they guarantee the use of ICT in TL. They even reiterated the significance of online information to students. This TI scheme exhibited by teachers confirms how the "appropriate technology" principle of sustainability is visibly practiced in STEAM higher education.

## CONCLUSION AND RECOMMENDATIONS

This study explored the TI in Philippine STEAM education to profile the traditions and transitions of higher education teachers of STEAM disciplines in the Philippines, and to determine the best practices of TI in each of the STEAM disciplines.

The study found that majority of the tertiary teachers of STEAM disciplines favor conventional technologies, web-based and software-based technologies, and electronic- and computer-based technologies in their teaching of STEAM disciplines. Moreover, teachers of STEAM disciplines show varied TI transitions and practices when clustered according to their specialization or STEAM discipline; particularly, technology is integrated with the use of PowerPoint, flash, videos, models, internet, and the use of technology tools such as whiteboard, LCD projector, or computer software in delivering their lessons. Lastly, best practices of TI – which exemplified complete TPCK dimensions of the these teachers – include the ethical use of online resources, use of technology in predicting future trends and processes of STEAM, being familiar to the STEAM profession database, use of technology in teaching STEAM content knowledge, development/improvisation of new technology, promotion of proper care and handling of technology, utilization of technology in the TL process, and adoption of technology in the TL process.

It may be noted that there is an increasing demand for technology use for TL. The current situation brought by the COVID-19 pandemic – including the demands of new normal in education, E4.0, and other drivers that may change the landscape of education – poses HEIs to reflect on their TI practices and capacities. The capacity to offer FL modalities may depend on its ability to support technology infrastructure and the TPCK-related practices of the teachers. The profile of the traditions and transitions of the tertiary teachers (of STEAM disciplines) suggests that TI practices lean towards the conventional technology but closely tags along with the more advanced ones. This is indicative of how we fare in the online and remote classes being conducted during this pandemic. Although this result may seem to label the practices as young compared to country counterparts in terms of PPST domains and the TPACK model, the insistence of utilizing the conventional technology indicates teachers' advocacy to "appropriate technology" as a sustainability measure. Furthermore, the eight teacher technological characters – defined as best practices – strongly indicate sustainability literacy skills labeled as future thinking, systemic thinking, value thinking, and strategic thinking. Apparently, our STEAM teachers have mutual concessions in maintaining sustainability and going technologically advanced to emphasize the use of local materials and preserve the cultural constructs of their locale. In fact, most teachers (of STEAM programs) are currently implementing experiments that can be done at home using local and available materials within the areas of their students.

However, teachers (of STEAM programs) seem to project a personal aspect in TI, rather than viewing such from the perspective of the learners. TI maturity, though, may be a relative aspect since countries and even institutions of higher learning within countries have different affordances, tool resources, connectivity and culture, and even practices – which may define the technology used to aid the TL process, as well as the level of engagement in other technologies such as web and other learning applications. Our reliance to improvised and substitute tools, equipment, and even solutions and chemicals may be exploited to augment usability and availability constructs of TI of teachers (of STEAM programs) to aid their TL processes. Furthermore, disciplinal requirements and complexity of technology for TI matter. Also, technology courses may require a lot of computer- and web-based tools and equipment than the other STEAM discipline, suggesting a relatively greater number of TI practices in the Technology courses. Sciences and Agri-fisheries may be needing more sophisticated and complicated tools that may not be currently available in schools compared to other STEAM disciplines – a probable cause of the medial or low level of technology engagement in these disciplines.

The observed "just above" the lowest level of integration of the teachers may establish a linear progression of TI. Note that the curricular programs of the country focus on disciplinal content; thus, it is expected that the outcomes (STEAM professional) are discipline-driven. However, most people who choose teaching as a career in higher and advanced learning may have just started to immerse in the pedagogical aspect; thus, it may need a little more time and professional training to improve their levels of TI.

We assumed that teachers of STEAM disciplines in Philippine higher institutions, labeled as COEs and CODs, have more advanced levels of TI belonging to universities that exhibit good affordances, teacher training, and accessible locations within the cities and capitals in the regions of the country. Thus, the team did not account for them in this investigation. Instead, the team focused on the current situation of TI of the remaining 2,000 schools not classed as either COE or COD. Additionally, the team only used survey forms, classroom observations and notes, and interviews with 85 teachers for this study, which may not be enough for a conclusive general TI attribute of teachers of STEAM disciplines in the Philippine higher education. Replicate studies may dwell on increasing the number of observed cases and other means of data sourcing such as technology audit for richer data sets.

With the advent of 4IR and E4.0, the results of the study are seemingly fitted to rethink our policies, standards, and guidelines in terms of technological infrastructure to STEAM disciplines. Since E4.0 envisions to recalibrate learning systems that highlight technology to address the challenges of 4IR including the demands of new normal in education brought by the COVID-19 pandemic, the practices, traditions, and transitions of the teachers of STEAM disciplines are essential to be determined and gauged. This is to further enhance and promote STEAM disciplines amidst the demands of E4.0 and the new normal in education. Furthermore, the results of this study may provide insights to vision the strategic plans and develop capacity-building programs to promote TI and FL for teachers of STEAM disciplines. Moreover, there may be a need for holistic (inclusive of discipline and pedagogy) professional development for tertiary teachers of STEAM as an offset to the generally low level of TI in this study. Universities may also venture industry partners to help them capacitate their teachers and have access to highly complex technology. Through such ways and means, we envision a linear progression of TI and better STEAM education in the country.

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## STATEMENT ON CONFLICT OF INTEREST

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## NOTE ON APPENDIX

The complete appendix section of the study is accessible at http://philjournsci.dost.gov.ph

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# APPENDIX

## PPST

| Domain | Domain equivalent |
|---|---|
| Domain 1 [D1] | Content knowledge and pedagogy |
| Domain 2 [D2] | Learning environment |
| Domain 3 [D3] | Diversity of learners |
| Domain 4 [D4] | Curriculum and planning |
| Domain 5 [D5] | Assessment and reporting |
| Domain 6 [D6] | Community linkages and professional engagement |
| Domain 7 [D7] | Personal growth and professional development |