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Technological Pedagogical and Content Knowledge: Levels of Practice of Chemistry Teachers

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Abstract. The upsetting 88% of senior high school graduates in the Philippines having difficulty with general college chemistry is further exacerbated by the widely implemented modular distance learning in public schools. Teachers reported challenges on monitoring and validating student outputs as well as giving timely feedback. To assess the levels of practice of chemistry teachers in terms of content, pedagogy and technology was the impetus of this study. Engaging a descriptive-comparative design, an expert-validated rubric was used to cross-validate the COT-RPMS-rated levels of practice on technological, pedagogical and content knowledge (TPACK) among fourteen chemistry teachers in a public schools district in Kalibo, Aklan. The rubric adapted from Technology Proficiency Self-Assessment for the 21st Century (TPSA C21) by Christensen & Knezek (2015) and the department of education mandated pedagogies and chemistry curriculum standards. Intra-class correlation coefficients of 0.842 for content and 0.887 for pedagogy confirmed the concurrence between the scores given by the evaluators on the chemistry teachers' instructional plans. The comparative analysis revealed lower levels of practice in all areas, with pedagogy having the lowest ratings using the rubric. The lecture method and whole class discussion of direct and interactive instruction strategies, respectively, were common among participants. Wilcoxon Signed Rank Tests confirmed significant differences in levels of practice of technological, pedagogical and content knowledge of teachers when COT-RPMS and the rubric ratings are equated against each other. An in-depth investigation on pedagogical levels of practice evident in instructional plans is strongly recommended.

Keywords: chemistry teachers; TPACK; Levels of Practice; Rubric,

1. Introduction

The generation of learners in this time of pandemic has recorded the highest learning loss according to a global study by the World Bank, UNICEF and UNESCO. The learning loss translated to the learners' lifetime earnings in present value amounts to 17 trillion dollars. The study blames the currently unfamiliar and inaccessible ways of learning imposed onto learners, a scenario prevalent among Filipino learners, who continue to miss learning opportunities following a two-year school closure (Business World, 2021). In the basic education, the widely implemented modular distance learning (MDL) has been found to confront teachers in the areas of monitoring and validating student performance, checking students answers in the modules, and giving timely feedbacks (Castroverde & Acala, 2021 and Pokhrel & Chhetri, 2021). The Department of Education (DepEd) has acknowledged these limitations in distance learning modalities, especially that 87% of Filipino parents opted for printed modules for their children, a proof of their inaccessibility to other modalities available (UNICEF, 2021, and Business World, 2021), such as online distance learning, blended and home-schooling (Enclosure to DepEd Order No. 012, s. 2020, p. 30-32). Blended teaching is found to significantly address the unfamiliar learning mode for students (Pandit & Agrawal, 2021), and although this has become the new education norm according to DepEd and UNICEF reports, the Philippine government is yet to intensify distance learning modalities (Business World, 2021). This however, requires teachers to be digitally competent in online learning tools because online modality is effective for a blended approach, a necessity that calls for pioneering an alternative framework for educational delivery. The pandemic has ushered the way for digital teaching and learning to flourish and must be given a try (Lailatun & Drajati, 2019 and Pokhrel & Chhetri, 2021).

In the field of chemistry in the basic education sector, pre-pandemic research by the UP NISMED (2019) reveals an alarming 88% of senior high school graduates having difficulty with key concepts and skills for the general college chemistry. The institute reports that even students in the STEM track lack the significant background and skills for the same subject. Chemistry is difficult to learn because "instruction occurs predominantly on the most abstract level, the symbolic level" (Gabel, 1999, p. 549 as cited by Cardellini, 2012). Additionally, UP NISMED's studies over the years have established that there exists an incongruence between career preparations and teaching assignments for science teachers in public schools in the Philippines. Teachers who have inadequate preparations to teach science subjects still get hired as a result of the lack of competent applicants who are specialized in these fields (SEI-DOST & UP NISMED, 2011). The problem of the mismatch of teacher background is further impacted by the alignment of the K-12 curriculum and the availability of science teachers, so that the possibility of a learning process going on is less interactive for science subjects. The ability to do practical reasoning and experimentation is also limited, while the quality of science literacy is interrelated with their practicum experience (Antonio, 2018). Consequently, abstract science concepts such as chemical changes and reactions in high school chemistry are dodged by the teachers because they reported difficulty teaching these topics, especially that modeling and visualization are required in order to make students understand these topics (SEI-DOST & UP NISMED, 2011). Even in-service teachers who are already into graduate programs were tested in content knowledge in chemistry and were found to have less mastery of topics in solutions, chemical bonding, the mole concept, gas laws, and chemical reactions. Teachers reported they encountered challenges in teaching chemistry in the K to 12 spiral curriculum. The science curriculum under the K to 12 program progresses in terms of level of difficulty and subject areas where integrated science, biology, chemistry and physics are included within a specific grade level science subject. Furthermore, even if teachers are confident they can teach chemistry lessons, their scores in the content knowledge test showed negative departures, thereby supporting their claimed difficulty (Mongcal, et al., 2017). UP NISMED pins down this trend as negatively affecting the performance of our learners.

The same truth is happening anywhere in Aklan. The schools division opted for modular distance learning (DepEd Aklan ManCom Meeting, 2020, August) and teachers openly lament similar limitations and failures because of very limited to totally absent teacher-learner interactions in MDL. Although teachers utilize the most-friendly online platforms such as Facebook, Messenger, SMS and phone calls (Castroverde & Acala, 2021), not all learners or their parents are able to participate in the communication lines, and not all teachers are committed to seriously augment MDL with online means. At present time, a scheduled 2022 PISA has revealed a very low pre-assessment performance of the sampled high school students in one particular high school in Aklan (personal communications). This trend was already seen in the 2018 PISA report where Filipino learners performed significantly lower than the average, scoring only an average of 357 points in Science Literacy compared to the OECD average of 489 points (Cordon & Polong, 2020). Substantial learning opportunities for Aklanon students are still out of reach while limited face-to-face classes are still on hold. Their learning continues to revolve within learner-content interactions, and their performance cannot be validated due to numerous factors such as below passing rate scores or unanswered activities in the modules. As pointed out by Pandit & Agrawal (2021), blended teaching that incorporates online means is viewed as effective and is expected to positively augment the anticipated limited face-to-face instructions in the long run.

There remain several questions in terms of the competence of chemistry teachers to teach the content area, using appropriate pedagogies and technologies in response to the present mode of instruction. These questions provide the impetus for the researcher to pursue descriptive-comparative research to assess the levels of practice of technological, pedagogical and content knowledge of chemistry teachers in Kalibo II. Towards this end, this research anchors on the following objectives:

- Design an analytic rubric for evaluating the levels of practice of TPCK of chemistry teachers;
- Determine the levels of practice of TPCK of chemistry teachers based on:
    - COT-RPMS ratings;
    - rubric-analyzed lesson plan ratings; and
- Determine the significant difference in the levels of practice of TPCK of chemistry teachers between their COT-RPMS and rubric-analyzed lesson plan ratings.

This research anchors on the Technological Pedagogical Content Knowledge (TPACK) framework by Mishra and Koehler (2009). For the purposes of this study, the three main knowledge types of TPACK namely the technological, pedagogical and content were measured. Primarily, the study looked into the chemistry teachers' technology-embedded instruction (Edtech Classroom, 2021) where a teacher is competent in both technological and pedagogical techniques, integrates the technology and instructional strategies to effectively teach content areas to advance learning (Lailatun & Drajati, 2019). These three main knowledge types are defined by Schmidt et al., (2009) as follows:

Technological knowledge (TK) is the overall competency of a teacher to employ a wide array of technologies from the simple low-tech tools like pencil and paper to digital technologies such as videos, interactive whiteboards and software programs. Content knowledge (CK) refers to the actual subject matter that is to be learned or taught” (Mishra & Koehler, 2006, p. 1026 as cited by Schmidt et al., (2009). Pedagogical knowledge (PK) encompasses the methods and processes of teaching and includes knowledge in classroom management, assessment, lesson plan development, and student learning.

For Koehler and Mishra (2009), the challenge with technologically embedded classrooms is that advances in technological applications for classroom use come along with technical considerations that may pose difficulties for the teachers to effectively use them in instruction. Older teachers for instance, tend to behave negatively towards technological advances in instruction (Fuad et al., 2020). To be able to navigate through the complex and interactive domains of content, pedagogy and technology when teaching, translates to effective teaching and learning (Koehler & Mishra, 2009).

The Study Paradigm

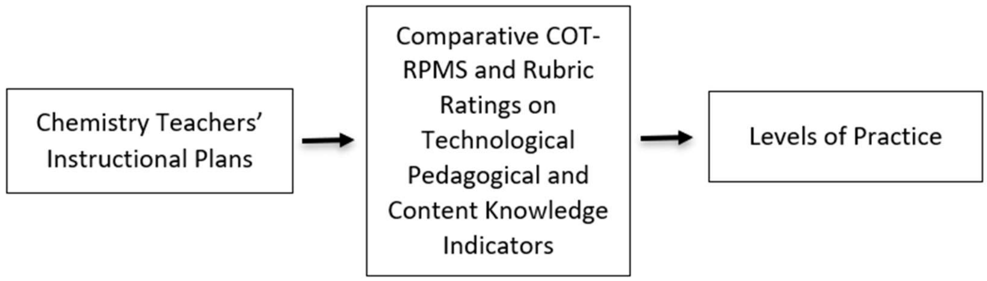

FIGURE 1. The study paradigm.

The comparative analysis of the COT-RPMS and Rubric ratings of chemistry teachers' instructional plans will be central in the establishment of their levels of practice of content, pedagogy and technology in their instructions (Figure 1).

2. Methodology

Research Design

To assess the levels of practice of technological, pedagogical and content knowledge of chemistry teachers in a public schools district in the town-proper of Aklan province in Western Visayas, Philippines, a descriptive-comparative research design was espoused. This research design according to Cantrell (2011) is a "non-experimental quantitative research design also known as causal comparative and pre-experimental research, whose known properties are: independent variable is not manipulated, no random assignment to groups, and inclusion of a control or comparison group." As used in this research, the existing instructional ratings of chemistry teachers in their classroom instruction measured by the COT-RPMS rating tool was used as the 'control data' against which the research data was compared with. In the COT-RPMS rating tool, the domains of content, pedagogy and technology in classroom instruction are the three indicators rated by the school heads or delegated academic heads. The research data, on the other hand, pertained to similar ratings of teachers in the areas of content, pedagogical and technological knowledge measured as levels of practice and rated using the same instructional plans they used in their COT-RPMS evaluation. This time however, a validated analytic rubric was used for such purposes. The rubric instrument is prone to subjectivity and in order to resolve this, an external evaluator was employed to establish the inter-rater agreement via the Intra-class correlation coefficients of ratings for both the content and pedagogical knowledge.

The study involved all the fourteen chemistry teachers in four public secondary institutions in the schools district of Kalibo II, division of Aklan. The consideration of the study population was that, this cluster of schools include a wide-array of educational and curricular programs having one regional center for science and mathematics education or the Regional Science High School for Region VI (Western Visayas), which is selective in terms of student admission. Another was a regular national secondary school and the other two are integrated schools (one being a center for special education). To have gauged the levels of practice among teachers in the domains of content, pedagogy and technology in support of learning at present times, provided field data in this area of research.

Instrument Development

The chemistry curriculum standard implemented under the Department of Education (DepEd) K to 12 basic education program was referred to in the area of content knowledge. The curriculum standard covers content, performance and the most essential learning competencies (MELCs). They were used to select the instructional plans of teacher-participants for rubric evaluation. The DepEd prescribed instructional strategies and their corresponding instructional methods in its department order no. 42, series of 2016, was used as the basis for pedagogical knowledge. The five instructional strategies stipulated in the order are the Direct, Indirect, Interactive, Experiential Instructions and Independent Study (Department of Education, 2016). Each strategy's lists of instructional methods were used to gauge the pedagogical levels of practice. The technological knowledge was measured using the Technology Proficiency Self-Assessment for the 21st Century (TPSA C21) adapted from Christensen and Knezek (2015).

The rubric was submitted for criterion validation by panelists: chemistry education expert, research education expert and a curriculum expert. The instrument was given an overall mean score of 4.76 or Excellent. The suggestions and recommendations by the panel of experts were incorporated in the final rubric as an instrument of the study (Appendices F-I). It was evaluated using nine (criteria) of 1) relevance to the problem ($\bar{x}$ = 4.7, Excellent), 2) organization ($\bar{x}$ = 4.3, Very Good), 3) appropriateness of scale used ($\bar{x}$ = 4.0, Very Good), 4) accuracy ($\bar{x}$ = 4.7, Excellent), 5) application to praxis ($\bar{x}$ = 5.0, Excellent), 6) ethics ($\bar{x}$ = 5.0, Excellent), 7) clarity ($\bar{x}$ = 5.0, Excellent), 8) scope ($\bar{x}$ = 4.7, Excellent), and 9) balance ($\bar{x}$ = 4.7, Excellent).

The analytic rubric (Appendix J) designed adopted three levels of practice in columns, namely, Competent, Proficient, and Highly Proficient as defined by Benner (1982), and three indicators in rows for Content, Pedagogy and Technology.

In the area of content knowledge, the rubric defined the competent, proficient and highly proficient levels of practice as having evident coverage without depth, evident coverage with some depth and evident coverage with depth, respectively, of the chemistry content standard, performance standard and most essential learning competencies (MELCs).

In the area of pedagogy, the rubric defined the competent, proficient and highly proficient levels of practice as having evident use of at least three, four and five instructional methods, respectively, under any of the five instructional strategies prescribed by DO No. 42, s. 2016. Beside the number of methods used, the competent level includes some processing for better understanding, the proficient level with some processing for better analysis and synthesis, and the highly proficient with expert processing leading to the application in real life situations.

The technological knowledge of teachers was gauged using the adapted TPSA C21 which outlined thirty-four indicators and self-rated using a five-point Likert scale of 1-5 for Strongly agree, Disagree, Uncertain, Agree and Strongly Agree, respectively. However, the panelists unanimously suggested to get rid of the 'uncertain' level and instead, use a forced choices of 1-4 that correspond to No knowledge, Struggling to use, Confident, and Very Confident, respectively. It was also suggested to drop items 19 and

23 as one panelist judged it to be impractical to the target participants. The numerical levels of practice were at least a $\overline{x} = \leq 2.0$ for Competent $\overline{x} = 2.1 – 3.0$ for Proficient and $\overline{x} = 3.1$ - 4.0 for Highly Proficient. The adapted TPSA C21 instrument was administered to thirty-five non-target teachers within the district via face-to-face pilot testing. The generated scores were analyzed for internal consistency using the Cronbach alpha. The result showed an $\alpha = 0.948$, equivalent to Excellent reliability (George & Mallery, 2003). This result is due the fact that the instrument "has been used for 15 years in studies regarding technology integration in the classroom in the USA and other nations" when Christensen and Knezek adapted it in 2015. The TPSA C21 survey was conducted via face to face from among the fourteen chemistry teachers for about two weeks. Each respondent was guided about the specific items of the instrument and were asked to be honest about their ratings.

Data Gathering Procedure

Prior to the actual conduct of the study, the researcher requested an approval from the office of the schools district supervisor (Appendix L) to conduct the study among the participants. When approval was secured, copies of instructional plans such as the weekly home learning plans (WHLPs), daily lesson plans (DLPs) and Daily Lesson Logs (DLLs) officially used by the teachers during their rated classroom observation with their respective school or academic heads, were gathered while simultaneously administering the TPSA C21 survey to them. The variation in the instructional plans was due to the use of WHLP in modular distance learning and use of the DLPs or DLLs during their COT-RMPS evaluations. For ethical purposes, these instructional plans are not appended in the paper to espouse privacy of the documents and the identities of the teachers who made them.

An external coder or evaluator in the person of the Senior Education Program Specialist (SEPS) for Planning and Research of the DepEd Division of Aklan was asked to do independent evaluation (Appendix M of the collected weekly home WHLPs, DLPs, and DLLs, officially used by the teachers during their rated classroom observation with their respective school or academic heads

Data analysis included computation of the weighted mean in the TPSA C21 survey and of the rubric ratings (Appendix N). Intra-class correlation coefficient was used to determine the concurrence rubric rating of both the researcher and the external coder or evaluator on the areas of content and pedagogy. Significant difference in the ratings was determined using the Wilcoxon Signed Rank Test. Analyses were carried out using the SPSS ver. 23. Data presentation for the comparative levels of TPCK was generated using the clustered column available in Microsoft Excel, where a line on the secondary axis would highlight the difference in the two sets of data.

3. Findings and Discussion

The data covered revealed the levels of practice in terms of content, pedagogical knowledge of chemistry teachers as shown in their instructional plans and their technological knowledge in terms of their self-report survey using the Technology Proficiency Self-Assessment for the 21st Century tool.

Comparative Levels of Practice of Content, Pedagogical and Technological Knowledge

The comparative levels of practice of the content, pedagogical and technological knowledge of chemistry teachers, measured by the COT-RPMS rating tool are represented by the blue bars and that of the analytic rubric tool are shown by the red zigzag lines. It can be glimpsed that the levels of practice among chemistry teachers were lower when measured using the rubric and compared against the COT-RPMS ratings: Proficient in the Content Knowledge, Competent in the Pedagogical Knowledge and Proficient in the Technological Knowledge. Pedagogical knowledge of teachers is significantly lower. The rubric analyses showed strong subscriptions to the lecture and whole class methods of the Direct and Interactive Instructions.

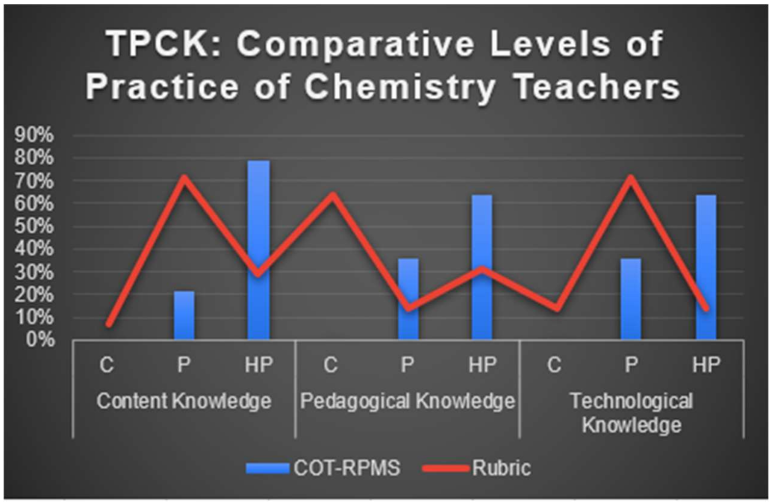

FIGURE 2. The comparative levels of practice of the content, pedagogical and technological knowledge of chemistry teachers

As Johnson et al., (2013) put it, a teacher's desire for their students to learn effectively drives classroom instruction, and if current lesson plans meet the needs of students, there is very little motivation for the teacher to alter them. Educators spend countless hours creating lesson plans that will hold attention and make learning exciting. Revising them means several hours of additional work for the teacher, which is problematic given an already demanding schedule.

Significant Difference in the Levels of Practice of TPCK of Chemistry Teachers Between their COT-RPMS and Rubric-analyzed Lesson Plan Ratings.

Table 1. Results of Wilcoxon Signed Rank Test for Significant Difference Between Ratings in COT-RPMS and Rubric-analyzed Lesson Plan

Indicators		Z value	p-value	Interpretation	Decision
Content	COT-RPMS	-2.236	0.025*	Significant	Reject H_0
	Rubric				
Pedagogy	COT-RPMS	-2.486	0.013*	Significant	Reject H_0
	Rubric				
Technology	COT-RPMS	-.2714	0.007*	Significant	Reject H_0
	Rubric				

Results of the Wilcoxon Signed Rank Tests (Table 1) for significant difference between COT-RPMS and rubric ratings were significant in terms of Content knowledge ($Z = -2.236$, $p = 0.025$); Pedagogical knowledge ($Z = -2.486$, $p = 0.013$); and Technological Knowledge ($Z = -2.714$, $p = 0.007$). It can be glimpsed that the instructional plans when evaluated using the analytic rubric designed in this research showed lower levels of practice for these three areas compared to the COT-RPMS ratings.

Sawchuk (2013), emphasizes that "teacher evaluation is central both to the teacher and to those holding them accountable" because the "quality of education system cannot exceed the quality of its teachers (Barber & Mourshed, 2007). The Quality of teacher evaluation therefore requires a thorough process to ensure the truth of the data.

Implications for Teacher Evaluation

The study opens up to questions of whether the well-researched and well-established standard COT-RPMS tool used to gauge teachers' content, pedagogical and content knowledge is in fact truthfully used in the field. The researcher considers the tool as appropriate and standard, but suggests a deeper investigation on the pedagogical aspect of the chemistry teachers' instruction in the field, otherwise why would national research institutions such as the UP NISMED find a staggering percentage of basic education graduates confronted with difficulty in the general college chemistry? There must be a way around to truthfully measure the depth of content instruction, variety and appropriateness of the instructional strategies used, and the applicability and practicability of the educational technologies employed in the teaching and learning situations.

4. Conclusion

The result of this study has shown another way around to evaluate chemistry teachers' content, pedagogical and technological knowledge using an analytic rubric. The comparative analysis of the COT-RPMS and rubric measured levels of practice of chemistry teachers' content, pedagogical and technological knowledge were significantly different. Rubric analysis showed at least a step lower levels of practice compared to the COT-RPMS rated levels of practice. The findings of the study do not necessarily discount the process of teacher evaluation using the COT-RPMS tool by the academic or school heads. However, it is the hope of this paper to provide current field data on the levels of practice in these areas from the perspectives of the research conducted.

5. Declaration of Competing Interest

The author declares no competing interests that could have otherwise influenced the work reported in this paper.

6. Acknowledgement

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