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DEVELOPING AND VALIDATING A TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) INSTRUMENT FOR SECONDARY PHYSICS PRESERVICE TEACHERS IN INDONESIA

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Abstract

The purpose of this study is to develop and validate an instrument for assessing secondary pre-service physics teachers' TPACK in technology – supported classroom environments. In order to achieve the purpose, a total of 116 items with a 6–point Likert type scale in 7 domains with 18 items in Content Knowledge (CK), 32 items in Pedagogy Knowledge (PK), 14 items in Technological Knowledge (TK), 20 items in Pedagogical Content Knowledge (PCK), 9 items in Technological Content Knowledge (TCK), 10 items in Technological Pedagogical Knowledge (TPK), and 13 items in Technological Pedagogical Content Knowledge (TPACK) were developed for the instrument. Theoretical framework of survey development process and results from a pilot study on 1005 pre-service and in-service science teachers would be discussed. The construct validity of this instrument was examined through confirmatory factor analysis using principal axis factor (PFA), and multiple PFA method are applied after selecting items without sharing of factor loading to ensure there is no ambiguous of items respective to the formed factors. In terms of those applied, the result shows after the modification and/or deletion of 66 of the survey items, the 50 items-survey is a reliable and valid instrument that will help educators design longitudinal studies to assess physics preservice teachers' development of TPACK.

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INTRODUCTION

Pedagogical Content Knowledge and its extended domain: TPACK

Lee Shulman (1986) raised the concept of pedagogical content knowledge (PCK) to build theoretical framework with regard to what teachers should know and be able to do, asking important questions such as, "What are the domains and categories of content knowledge in the minds of teachers?" and "How are content knowledge and general pedagogical knowledge related?" (p. 9). In order to describe the relationship between content knowledge (or the amount and organization of knowledge of a particular subject matter) and pedagogical knowledge (knowledge relate to how to teach various content), Shulman proposed the idea of PCK. He defined PCK as going beyond content or subject matter knowledge to include knowledge about how to teach particular content. Within PCK, he included "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9).

He also declared that knowledge of what makes a subject difficult or easy to learn is a part of PCK. It means that in order to be able to teach a particular topic effectively, teachers should know the potential pitfalls to which students frequently fall victim, depending on the preconceptions they have developed based on their ages and backgrounds besides to empower any learning support to improve it such as technology. Although the use of technology can empower teaching and learning, it is rarely used in classrooms (Ruthven, 2009). A major reason for that unfavorable state may be found in the fact that teachers lack sophisticated knowledge to support effective technology integration.

Teachers in the virtual classroom needs to be overtly aware of the common misconceptions centered around the particular topic within the content they are teaching, so they can be addressed as part of the curriculum and instruction. Online educators also need to be aware of the importance of encouraging and teaching specific self-regulated behaviors to their students to ensure every possible chance for success.

Many strategies for teaching self-regulated behaviors relate specifically to Shulman's notion of PCK, in that they involve the use of cognitive strategies such as modeling, analogies, and metaphors to aid in understanding the content-related material. Teachers must be able to translate and contextualize information to improve students' understanding and motivation for learning. In order to be able to create such materials and implement these types of strategies, online teachers need to have not only an excellent grasp of their given content area but also an appreciation of how technology and the online environment affect the content and the pedagogy of what they are attempting to teach. To address such issues, Koehler and Mishra (2005) built on Shulman's notion of PCK to articulate the concept of technological pedagogical content knowledge (TPACK; referred to in the paper as technology, pedagogy, and content knowledge or TPACK). This knowledge is indeed sophisticated as it, among other issues, calls for complex interplay involving three types of knowledge: content knowledge to teach, pedagogical knowledge to apply, and technology knowledge to empower the previous two. (Angeli & Valanides, 2009).

As shown in Figure 1 and described by Mishra and Koehler (2006), The TPACK framework, gives researchers and educators with concepts and terms to describe the intersection and interplay of three core teacher domains of knowledge. It is suggested that this conceptual framework could also provide a basis for making predictions and inferences about the consequences of changes made to any one of the components. Most significantly, the TPACK framework offers researchers and educators a common language to bridge the gap between research and curriculum design and provides guidance on how to apply the ideas in education contexts, including teacher pre-service programs. The framework supports an argument against teacher education and professional development programs that simplistically foreground teacher technology knowledge in isolation from content and pedagogy (Mishra & Koehler, 2006).

Shulman proposed PCK to describe the relationship between content and pedagogy. Mishra and Koehler (2006) argue that modern digital technologies (ICT) have changed the nature of the classroom sufficiently to justify extending Shulman's model to incorporate the intersections of technological knowledge (TK) with both content knowledge (CK) and pedagogical knowledge (PK), producing three more intersections (TPK, TCK, and TPCK) as represented in Figure 1. Mishra & Koehler (2006) do not argue that the concepts represented by the TPACK framework are completely new, but what distinguishes their approach is their articulation of the relationships and interplay among the three core domains

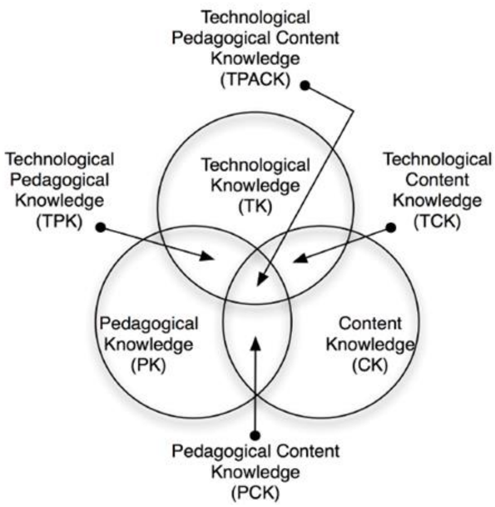

Figure 1. Technological Pedagogical Content Knowledge (TPACK) [after Mishra and Koehler (2006)]

Pre-Service Teacher and TPACK

Teacher educators were challenged to identify preparation for preservice and inservice teachers to extend their PCK to a more robust knowledge for teaching with technologies, where particularly for Pre-service teachers, they need ways to gain an integrated knowledge of content, pedagogy, and technologies that reflects new ways of teaching and learning in the 21st century (Niess:2010). There are several research which emphasize the importance of TPACK in pre-service teacher or research using TPACK as a framework for pre-service teacher. Recent studies include those by Sahin, Akturk and Schmidt (2009) and Terpstra (2009). Sahin et al. (2009) found that TPACK positively affected preservice teacher education students' vocational self-efficacy. Terpstra (2009) reported that the preservice teachers whom she studied demonstrated more Technological Knowledge than Technological Pedagogical Knowledge and Technological Pedagogical Content Knowledge. Interestingly, Terpstra (2009) found that, while the preservice teacher education students used digital technologies in their daily lives, they did not connect this Technological Knowledge with their own teaching.

Teaching Practice and TPACK Framework for Pre-Service Physics Teacher in Indonesia

Most physics teacher education programs in Indonesia have been designed by taking into account PCK, which Shulman described as "the special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8). Shulman's work is reflected in many of the current conversations which the authors, all teacher educators in. A search throughout the National Standard for Teacher by author reveals numerous references to 'content knowledge', 'pedagogical knowledge', and 'pedagogical content knowledge'. There were no references made to TPACK, though some mention about using technology for teaching and learning is made in relation to the Teachers Professional Standards for teachers requiring that teachers need to know and understand "ways of identifying, evaluating and selecting teaching, learning and assessment strategies, resources and technology.

Teaching Practice is an integral component to become a teacher. It grant the pre-service teacher experience in the actual teaching and learning environment (Perry, 2004). During teaching practice, a prospective teacher is given the opportunity to try the art of teaching before actually getting into the real world of teaching profession. As technology using properly are believed improves students learning processess and outcomes, its integration into teaching would become challenge in the teaching practice. Another search throughout Teaching Practice Standard at most teacher education programs in Indonesia conducted by Author also revealed that there is no references used to TPACK, but mentioned using of technology to support the teaching.

METHODS

This paper summarises the development and its properties of the Technological Pedagogical Content Knowledge (TPACK) Survey instrument that was developed for Pre-service Physics Teacher to describe their TPACK development particularly during the Teaching Practice. The instrument is referred to consistently throughout this paper as the TPACK Background instrument. Given that the teaching practice involved all pre-service physics teahers who already passes courses both in content, pedagogy, and technology courses which is held by physics education department; the development of the TPACK Background instrument was an important undertaking and makes a significant contribution to the international literature relating to the measurement of TPACK especially for pre-service physics teacher.

The development of the instrument has progressed through several stages: a) a review of related literature on technological pedagogical content knowledge (TPACK) instrument development, b) a proposal of seven domains of TPACK for the instrument questionnaire, c) drafting and revision of items in each of the seven dimensions, d) conducting item analysis and confirming validity, reliability, and structural soundness of the instrument.

A total of 116 items with a 6–point Likert type scale in 7 domains with 18 items in Content Knowledge (CK), 32 items in Pedagogy Knowledge (PK), 14 items in Technological Knowledge (TK), 20 items in Pedagogical Content Knowledge (PCK), 9 items in Technological Content Knowledge (TCK), 10 items in Technological Pedagogical Knowledge (TPK), and 13 items in Technological Pedagogical Content Knowledge (TPACK) were resulted. Paper-based instrument was developed and administered in this study. This survey adopted a six-point Likert-type scale designed to allow college respondents to rate their perceptions using the following status: "Extremely Poor," "Poor," "Acceptable," "Good," and "Very Good," and "Excellent" corresponding to 1–7 points, respectively.

A numbered of 1215 Science teachers and pre-service science teachers were asked voluntarily to verify the reliability and contruct validity of the whole instrument. A total of 1005 respondents who filled valid responses were recruited from 8 provinces of Indonesia. Because missing responses for any items in a subscale could produce biases in the parameter estimates, respondent that did not finish the instrument were excluded from the dataset.

The research team used quantitative research methods to establish the extent of the validity and reliability of the instrument. Researchers assessed each TPACK knowledge domain subscale for internal consistency using Cronbach's alpha reliability technique. We then investigated construct validity for each knowledge domain subscale using principal axis factor (PFA) of factor analysis with Varimax rotation within each knowledge domain and Kaiser Normalization. In addition, multiple PFA method are applied after selecting items without sharing of factor loading to ensure there is no ambiguous of items respective to the formed factors. Given that the instrument included 114 items when it was administered for the first time, it was clear that our sample size was adequate to perform a factor analysis on the entire instrument.

RESULTS AND DISCUSSION

Results

The researchers created the TPACK survey using an online survey development tool and posted it on Gizmo site for participants to access. When the preservice teachers accessed the survey online the first time, they were presented with an informed consent document that described the study's purpose and were told that their participation in the study was voluntary. All participants completed the survey during break session of the semester. The survey took approximately 15–20 minutes for participants to complete. The majority of responses (79.0%) were from students majoring in physics education, whereas 14.5% of the responses were from biology education majors and 6.5% of the respondents were enrolled in science major such as chemistry and general science. Of the 1005 pre-service and in-service who completed the survey, (70.5%) were female and (29.5%) were male.

Factor analysis involves a series of analyses used to develop a rigorous instrument. For this analysis, the first step involved running a factor analysis on the items within each subscale to ascertain the covariation among the items and whether the patterns fit well into the TPACK constructs. The researchers used the Kaiser-Guttman rule (which states that factors with Eigen values greater than 1 should be accepted) to identify a number of factors and their constitution based on the data analysis. In addition, we calculated reliability statistics for items in each subscale to identify problematic items. We examined questionable items for each TPACK domain subscale and eliminated those that reduced the reliability coefficient for the subscales. We also eliminated those items because it seemed they were not measuring the preservice teachers' knowledge of the related construct. Thus, we dropped the individual items that affected the reliability and construct validity of each knowledge domain subscale. As a result, 48 items were deleted from the survey, including 4 TK items, 9 CK items, 16 PK items, 9 PCK items, 4 TCK items, 3 TPK items, and 3 TPACK items.

After eliminating problematic items, we ran a second factor analysis on the remaining survey items within each of the seven subscales, and those results are presented in this section. The resulting TPACK instrument exhibited strong internal consistency reliability and included 64 items. Reliability statistics were then repeated on the remaining items within each knowledge domain. The internal consistency reliability (coefficient alpha) ranged from.915 to .948 for the seven TPACK subscales. According to George and Mallery (2001), this range is considered to be acceptable to excellent. We report the final items for the TPACK subscales, along with their reliabilities, in the sections that follow.

Content Knowledge (CK)

The first knowledge domain, content knowledge (CK), refers to the knowledge teachers must know about for the content they are going to teach and how the nature of that knowledge is different for various content areas as shown in Table 1.

Table 1. Content Knowlegde

Content Knowledge (CK)	items	Factors ad its factor loadings	
		1	2
Factor 1 Developing Concept for Practice	7. Knowing how far / high physics concept in certain topic	0.67	0.25
	4. knowing the scope of content in curriculum	0.54	0.43
	11. Sufficient knowledge about physics concepts in secondary level	0.69	0.29
	16. Knowing various ways to understand the particular concept	0.76	0.19
	17. Using physics way of thinking to develop understanding of physics concept	0.76	0.15
	18. Using physics way of thinking in the classroom	0.71	0.17
Factor 2: Content Standard in the Curriculum	1. Identify standard of curriculum related with certain concept	0.25	0.73
	3. know about physics content that I want to teach	0.24	0.65
	6. sequencing certain physics concept	0.25	0.70

Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .930

Pedagogical Knowledge (PK)

Pedagogical knowledge (PK), the third subdomain, refers to the methods and processes of teaching and would include fundamental knowledge in areas such as classroom *management, assessment, lesson plan development, and student learning as shown in Table 2.*

Technological Knowledge (TK)

The first knowledge domain, technology knowledge (TK), refers to understanding how to use various technologies as shown in Table 3.

Pedagogical Content Knowledge (PCK)

The fourth knowledge domain, pedagogical content knowledge (PCK), refers to the content knowledge that deals with the teaching process (Table 4).

Table 2. Pedagogical Knowledge

Pedagogy Knowledge (PK)	Items	Factors				
		1	2	3	4	5
Factor 1 Student Classroom Management	29. Adapting various way of classroom management in the classroom to keep student organized, orderly and focus during a class	0.70	0.23	0.12	0.15	0.31
	31. Adapting various way of teaching to keep student academically productive during a class	0.69	0.16	0.22	0.18	0.34
	46. Identifying types of different learners	0.64	0.22	0.13	0.15	0
Factor 2 Teaching for Students Learning	19. Adapting teaching based on currently student understand or do not understand	0.39	0.59	0.17	0.07	0.26
	22. Planning sequencing students to acquire targeted skils	0.14	0.62	0.12	0.2	0.36
	45. Adjust teaching according to the students feedback	0.29	0.71	0.06	0.07	0.06
Factor 3 How Students Learn	32. Design a roadmap of lesson plan related with expected objectives	0.14	0.05	0.66	0.36	0.19
	35. Preparing responses for possible occurred of predicting students response	0.33	0.37	0.63	0.01	0.07
Factor 4 Teaching Methods	38. Knowing teaching methods theoretically	0.16	0.11	0.04	0.78	0.16
	40. Identifying characteristic of various teaching methods	0.22	0.15	0.22	0.75	0.06
Factor 5 Lesson Design	21. Identify students acquire skills needed from standard	0.06	0.39	0.11	0.28	0.53
	23. Knowing habits of mind can be delivered through learning particular concept	0.26	0.15	- 0.02	0.04	0.69
	26. Identifying possible positive dispotition through learning particular concept	0.07	0.08	0.38	0.31	0.6
	27. Familiar with common students understanding and misconception	0.37	0.13	0.22	- 0.06	0.55
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .948						

Table 3. Technological Knowledge

Technological Knowledge (TK)	Items	Factors		
		1	2	3
Factor 1 Intellectual Capabilities	52. Able to assist students with hardware problems witht their PC or laptops	0.85	0.16	0.17
	54. Able to assist students with hardware problems witht their PC or laptops	0.71	0.36	0.24
	56. Able to assist students with hardware problems witht their PC or laptops	0.85	0.09	0.28
Factor 2 Contemporary Skills	58. Frequently play around with computer application	0.22	0.79	0.11
	59. Learn about new digital technology easily	0.24	0.81	0.17
Factor 3 Foundation Concept	62. Knowing how to solve my own computer	0.41	0.29	0.66
	63. Knowing ideas networkig among computers	0.23	0.13	0.88
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .915				

Table 4. Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK)	items	Factors		
		1	2	3
Factor 1 Teaching Concept According to the Standard	72. Selecting appropriate teaching approaches in physics	0.71	0.34	0.26
	73. Produce lesson plan with an appropriate for the topic	0.69	0.21	0.21
	74. Knowing various teaching strategy in particular physics concept	0.73	0.36	0.15
	77. Knowing limitation of concept related with curriculum	0.67	0.34	0.28
	79. Adjusting concept sequencing according to the curriculum objectives	0.71	0.11	0.27
	80. Addressing particular concept with learning objective	0.76	0.36	0.2
Factor 1 Teaching Concept According to the Standard	65. Knowing various representation in particular physics concept	0.18	0.74	0.27
	66. Using a better representation for particular physics lesson	0.37	0.73	0.21
	82. Addressing particular concept with student proximal development while they learn collaboratively	0.48	0.64	0.12
	83. Identifying scientific literacy on particular topic	0.34	0.73	0.16
Factor 1 Teaching Concept According to the Standard	68. Predicting likely students misconception within a particular topic	0.35	0.32	0.62
	69. Distinguish between true concept, not knowing concept and misconception within a particular topic	0.24	0.28	0.83
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .954				

Table 5. Technological Content Knowledge

Technological Content Kowledge (TCK)	Items	Factor 1
Factor 1 Navigating Applied Technology for Representation	85. Selecting proper content of physics related with technology needed (multimedia, visual demo, apps)	0.73
	87. Selecting exist technologies as application of body of knowledge	0.84
	89. Understanding of representations of concepts dealing with available technology	0.81
	90. Knowing specific technologies suited used in the classroom	0.82
	92. Identify content dictates the technology	0.85
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .928		

Technological Content Knowledge (TCK)

The fifth knowledge domain, technological content knowledge (TCK), refers to teachers' understanding of how using a specific technology can change the way learners understand and practice concepts in a specific content area (Table 5).

Technological Pedagogical Knowledge (TPK)

Technological pedagogical knowledge (TPK) refers to teachers' knowledge of how various technologies can be used in teaching and understanding that using technology may change the way an individual teaches (Table 6).

Technological Pedagogical Content Knowledge (TPACK)

The seventh and final knowledge domain, technological pedagogical content knowledge (TPACK), refers to the knowledge teachers require for integrating technology into their teaching—the total package. Teachers must have an intuitive understanding of the complex interplay between the three basic components of knowledge (CK, PK, TK) by teaching content using appropriate pedagogical methods and technologies (Table 7).

Discussion

These results indicate that this is a promising instrument for measuring preservice teachers' self-assessment of the TPACK knowledge domains. With the sample size around 1000, we have good indications that the survey, as revised, is a reliable measure of TPACK and its related knowledge domains. Future work will include further refinement of the instrument through obtaining a larger sample size so a factor analysis can be performed on the entire instrument and then further validation of the instrument using classroom observation procedures.

Table 6. Technological Pedagogical Knowledge

Technological Pedagogical Knowledge (TPK)	Items	Factors 1	Factors 2
Factor 1 Pedagogical Design with Technology	99. Creating an online environment which allows students to build new knowledge and skills	0.75	0.21
	100. Determining different methods of teaching online	0.73	0.32
	101. Communicating online with students in particular online environtment	0.80	0.25
	103. Moderating interactivity among student using ICT	0.85	0.15
Factor 2 Pedagogical Range for Technological Tools	94. Identify using of technologies learned during the course period	0.20	0.76
	96. Choosing technologies that enhance the teaching approaches for a lesson	0.17	0.85
	97. Choosing technologies that enhance students' learning for a lesson	0.22	0.81
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .9878			

Table 7. Technological Pedagogical Content Knowledge

Technological Pedagogical Content Knowledge (TPACK)	items	Factors 1	Factors 2
Factor 1 Effective Teaching with Technology	108. Using appropriate technology for better representation of content for the lesson	0.74	0.37
	110. Modify teaching strategies in terms of involving technology at particular concept	0.77	0.33
	114. Adjusting technologies for possibility reduce student conception problem	0.83	0.20
	115. Adjusting technology to describe better existing knowledge of concept	0.83	0.20
	116. Adjusting technology to describe new epistemologies in particular concept	0.84	0.27
Factor 2 Technology in Pedagogy for Knowledge Building	104. Acquire the knowledge, skills, abilities, and attitudes to deal with ongoing technological change	0.19	0.82
	106. use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom	0.44	0.66
Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.Cronbach's Alpha .943			

This survey instrument was designed with a specific purpose in mind: examining preservice teachers' development of TPACK. Over the years, several instruments have been developed for measuring constructs like teachers' technology skills, technology integration, access to technology, and teachers' attitudes about technology (Becker & Riel, 2000; Keller, Bonk, & Hew, 2005; Knezek & Christiansen, 2004). Although advances were made in developing valid and reliable instruments for these purposes, this instrument is different from others in that it measures preservice teachers' self-assessment of their development of TPACK rather than teachers' attitudes or teachers' technology use and integration. It extends the work of Mishra and Kohler (2005) and Archambault and Crippen (2009) with the creation of another robust survey that specifically targets preservice teachers and thoroughly examines their knowledge development in each of the seven TPACK domains.

Readers are reminded that this survey was specifically designed for preservice teachers who are preparing to become secondary school (PK–7) or high school teachers (PK–12). Thus, the content knowledge domain includes physics, chemistry, biology and general science. Because PK–7 and PK–12 teachers generally teach these subjects in their classrooms, having separate factors for each content area seems most appropriate and supports the idea that the TPACK framework is content dependent (AACTE Committee on Innovation and Technology, 2008; Mishra & Kohler, 2006).

Future work in this area will benefit from efforts that specifically address measuring secondary teachers' self-assessment in the content areas of mathematics, science, social studies, and English. Taking into account the results from this study, it seems realistic that there would be an instrument designed specifically for each secondary content area.

CONCLUSION

The instrument developed for this study provides a promising starting point for work designed to examine and support preservice teachers' development of TPACK. The authors plan on conducting a study to examine the development of TPACK after completing content area methodology courses and teaching practice. Research plans also involve following these preservice teachers during their induction years of teaching. Perhaps most important, we plan to conduct classroom observations of student teachers and induction year teachers to evaluate the level of TPACK demonstrated in their classrooms and then investigate how scores on the TPACK instrument predict classroom behaviors. In addition, the authors plan studies designed to further validate and revise the instrument.

We are also in the process of completing a study of pre- and posttest scores using the instrument with preservice teachers currently enrolled in the teaching practice course to determine what effect the class has on the early development of TPACK (Schmidt, et al., 2009). Use and modification of this instrument should encourage a line of research on measuring the development of TPACK in preservice teachers and ultimately help preservice teacher education programs design and implement approaches that will encourage this development. We plan to administer the survey periodically throughout teacher education programs, using the results to inform researchers of specific times or events when each knowledge domain is developed. This information will provide valuable insight into the development of TPACK and provide program feedback on effective approaches in encouraging this development.

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