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Exploring Chemistry Teacher's TPCK in Rasch Model: A Point of View from Difference of Teaching Stage, Gender, and Ages.

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Abstract: Teachers should have different knowledge types including technological, pedagogical, and content to realize effective learning in the digital era. Technological Pedagogical and Content Knowledge (TPCK) is a framework that explains these knowledge types and the interactions between them. It is considered to enable chemistry teachers' multifaceted teaching. Coping, for this reason, a study to examine chemistry teachers' level of TPCK is needed. This paper reports the level of chemistry teacher's TPCK and their perception in terms of teaching stage, gender, and age. The study involved fifty-three students of chemistry education in a public university in Indonesia. A quantitative method was applied to explore their perspective on TPCK. Data were collected through surveys and interviews. The findings showed that the majority of chemistry teachers' TPCK skills are currently good. They integrate technology into their teaching while conducting online learning due to the COVID-19 pandemic. In terms of teaching stage, age, and gender, provide deep insight into seven indicators of TPCK. However, some indicators still need to be improved, so a TPCK training program for individuals or centralized individuals should be added to the chemistry department program.

Keywords: Chemistry Teachers; Perception; Rasch mode; TPCK

Introduction

Technology collaboration in the world of education is not something new anymore, but it has become a necessity to make learning in the classroom easier to understand (Andyani et al., 2020; Dampil, 2015; Markuna, 2022). In this case, technology can be used as a tool or as a media design, including chemistry subject (Gawlik-Kobylińska et al., 2020). Learning chemistry means combining the concept of chemistry and the principles of education that focus on how student understand chemistry concept that are often considered difficult. Hence, technology is used for visualizing three dimensions of an element (macroscopic, microscopic, and symbolic) which providing representations of concepts that are still abstract through virtual and augmented reality technology (Aw et al., 2020; Munzil & Rochmawati, 2021). Here, the teacher's digital literacy skill – ability to use digital technology are needed.

Implementing information and communication of technology (ICT) in learning has helped to develop and innovate effective and teaching and learning (Mosa et al., 2006). Currently technology become one of the skills needed by teachers not only to master chemistry concepts but also to integrate pedagogical and technological components into learning activities that call technological pedagogical content knowledge (TPCK) (Setiawan et al., 2019; Zimmermann et al., 2021). The framework of TPCK consists of the new three knowledge with the technological elements, namely Technological Knowledge (TK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) (Mishra & Koehler, 2006). It is the teacher's knowledge of what and how technology, applications, and software can be used in their learning that includes technological elements (Habibi et al., 2020).

Nevertheless, technological knowledge is not only to know what kind and how to use technology but also

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to know how to integrate technology within pedagogical and the concept of materials that are called TPCK (Mishra & Koehler, 2006) because teachers' good mastery of TPCK in the learning process can improve students' learning achievement (Paidi et al., 2021).

TPCK's framework drive teacher to know various domain of knowledge contained in TPCK and know the connection between these domains (Aqib et al., 2018). However there is a gap between the role of technology and the ability of teachers to use it (Hatlevik, 2016). There are problems with many teachers in Indonesia who lack digital skills and find it difficult to develop digital learning tools (Kartika et al., 2021). This condition is aggravated by many teachers who experience lack of preparation using technology because they learn technology more simple than today when in bachelor degree (Aqib et al., 2108). This indicates that the education system in Indonesia has a little bit of trouble, especially in the section on teaching material implementation in a classroom (Arifianto et al., 2021; Salehudin et al., 2021).

Further, teacher's role is as a facilitator who will have an impact on the level of learning outcomes (Henry, 2020). It means that teacher should have the ability to create effective learning using technology. If they do not know how to integrate technology with pedagogic and content, it will hard to determine technology used in the classroom (Harris & Hofer, 2011). It leads perspective that TPCK skill is essential for teachers. Before taking action to improve teacher's TPCK skill, we should know the teachers' TPCK level. Those finding are the basis for researcher to investigate teacher's TPCK level to find out how deep the teacher's TPCK mastery. The report will support TPCK education by providing deep insight about level of TPCK in term of teaching stage, age, and gender. For this reason, the measurement of teacher's TPCK level is essential in order to support teacher's TPCK skill.

The main objective of this work is to know the TPCK level of the teachers within seven aspects. To achieve this goal specific objectives are proposed: the teachers' level of TPCK skill and the differences in TPCK skills in terms of teaching stage, age, and gender.

Method

Participant

In research there are 53 chemistry teachers who participated. All the teachers who were involved and volunteered in this study did not have specific criteria, the selection of research subjects was done randomly. They come from different gender, ages, and teaching stages. The participant characteristics are presented in Table 1.

Table 1. Demographic Characteristic of Participant

Variable		Number	Percentage (%)
Gender	Male	19	35.85
	Female	34	64.15
Range of Age	20-24	10	18.87
	25-29	13	24.53
	30-34	11	20.75
	35-39	10	18.87
	40-44	6	11.32
	45-49	2	3.77
	50-54	1	1.89
Teaching Stage	Senior High School	19	35.85
	Vocational High School	12	22.64
	Junior High School	15	28.30
	Private courses	7	13.21

Procedure

This research was developed by a quantitative approach with fully-structured survey and interview. It responds to the importance of teacher's TPCK levels to gain effective learning. In order to investigate the teacher's TPCK level, the researchers conducted three stages that include preliminary research; development of instruments and conducting surveys; data analysis and reporting. The questionnaire of the survey is in the form of statements consisting of the indicator of TPCK. The data were analyzed quantitatively and the result of the analysis was used to process questionnaire data with Rasch Model through differentiation value. Figure 1 describe the procedure of research.

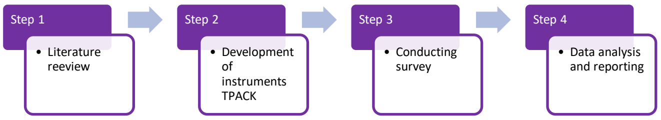

Figure 1. Research Procedure

Instrument

The questionnaires or statements used were prepared based on the previous research and literature review (Fuad et al., 2020; Habibi et al., 2020; Suyamto et al., 2020). Based on the teacher's TPCK indicators, a total of 21 statements in the questionnaire were developed. The statement was designed using 5 answer-choice scales from Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). There are seven indicators of TPCK, technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPCK). Sample questions are shown in Table 2.

Table 2. Sample Question of Questionary

Indicators of TPCK	Components of Questionnaires
TK	I can choose the software (media/application) that suits learning materials.
PK	I find it difficult to choose a learning strategy according to the student's needs.
CK	I have sufficient knowledge about the basic concepts of chemistry subjects.
TP	I am confused about choosing a technology that can improve students' learning outcomes.
TCK	I can explain chemistry material by utilizing technology media, teaching aids, and software.
PCK	I have difficulty connecting the stages of learning with the chemistry materials to be taught.
TPCK	I can teach lessons appropriately by linking chemistry, technology, and teaching approaches.

Research Question

Two main problems as the main focus of this research which need to be discussed are the level of TPCK skill of chemistry teachers and the differences of chemistry teacher's TPCK skill in terms of teaching stage, ages, and gender. TPCK level are explained in seven indicators namely PK, CK, TK, TPK, TCK, PCK, and TPCK.

Result and Discussion

TPCK Skill of Chemistry Teachers

Technology is an integral part of the education sector that enables more effective, efficient, and creative learning in the context of 21st century learning. It also helps students improve their skills for the 21st century (Lambert & Gong, 2010). However, if technology stands alone, it will be difficult to increase learning effectiveness (Goodyear, 2005). Therefore, the role of the teacher is very important here (Kirkwood & Price, 2013) by integrating technology into the material and teaching methods in the classroom (Fuad et al., 2020).

TPCK is a conceptual framework that embraces the knowledge base needed by teachers to integrate technology (Guzey & Roehrig, 2009). From the perspective of the TPCK framework, a teacher masters not only content knowledge, pedagogical knowledge, and technological knowledge, which are mutually exclusive; they also have to master the ability in integrating three aspects as a combination (Guzey & Roehrig, 2009; Li et al., 2022; Mishra & Koehler, 2006). Regarding the importance of TPCK for teachers, the teacher's TPCK skill should be known. The results of the survey linked to the trend of the seven components of chemistry teacher's TPCK skills which is shown in Figure 2.

Figure 2 shows us that the variable of content knowledge and pedagogical knowledge are variables which have the most positive tendency. This indicates that most of the participants have good knowledge of chemistry materials and good skills in classroom management to create effective learning. The reason is that most of the teachers have been teaching for several years, so they have a lot of experience and master the field. Content knowledge (CK) represents teachers' understanding of the chemistry materials that they teach in the classroom (Chittleborough, 2014), while pedagogical knowledge represents how to design a classroom with various teaching strategies and how to manage students so they can be good learners (Kleickmann et al., 2013).

The variable of technological content knowledge (TCK) and technological pedagogical content knowledge (TPCK) is in second place. It is in line with the university program that provides distance learning programs for students who are constrained by time and distance. It is known that their information and technological literacy skills are currently good. Nevertheless, technological knowledge (TK) and technological pedagogical knowledge (TPK) are in the last position. This occurs because one of the teachers was born before the '90s. Senior teachers are digital immigrants who do not have good digital literacy skills (Judd, 2018; Waycott et al., 2010). They are not updated in technological development and find it as a challenge to integrate technology into their learning (Rolf et al., 2019). Most of the senior teachers are incapable of understanding and mastering knowledge related to technology and opportunities to work with technology (Fuad et al., 2020). The conclusions that can be drawn are that a lack of technological knowledge will affect the teacher's TPCK skills in learning chemistry (Chittleborough, 2014).

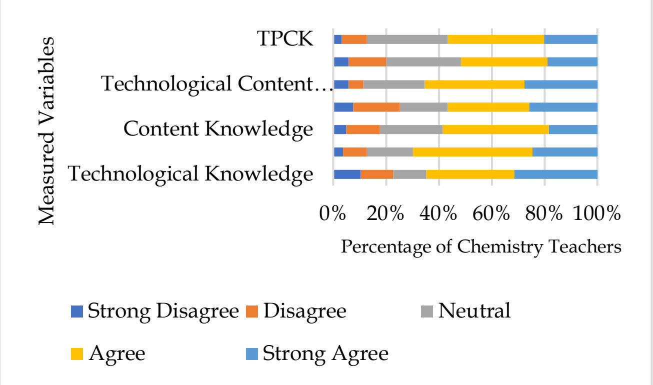

Figure 2. The Trend of The Variable of TPCK Skill for Chemistry Teachers

The technology in this research refers to digital skills required to operate systems and computer hardware (Al-malah & Majeed, 2023). It is also able to operate standard software such as browsers, Google documents, spreadsheets and e-mail (Mishra & Koehler, 2006). The lack of technological knowledge affects the learning process. Moreover, this research is conducted at a university that provides a distance learning program through online learning. For this reason, it is necessary for teachers to always improve their technological knowledge to successfully employ and integrate it into the teaching process (Rakaj, 2023). Several factors influence teachers' knowledge of TPCK, including adequate time and effort to develop risk skills and adequate resources (Chittleborough, 2014). Teachers should have strong motivation and interest in taking risks to improve or change their work (Engida, 2014). Access to resources requires sufficiently reliable and up-to-date infrastructure and equipment (Chittleborough, 2014).

Differences in TPCK Skill in Terms of Teaching Stage, Age, and Gender

Teaching Stage

Teaching stages cover a wider range of environments than grade levels (Bai et al., 2020). Teachers in different teaching stages face different obstacles such as different students, teaching contents, and teaching objectives (Li et al., 2022). Different teaching objectives and different teaching content may affect their TPCK level (Manfra & Hammond, 2008; Voogt et al., 2012). This research analyzes different teaching stages using Rasch Mode based on diff values. The result is given in Figure 3. In this research, the teaching stage is classified into four groups: senior high school is symbolized as number 1, vocational high school is labeled number 2, middle school is labeled number 3, and the private course is labeled number 4.

Based on Figure 3, in general, the private course has the most difficulty in integrating technology into learning. This can be seen in the diff value in the indicators item 1 and 3 (Technological Knowledge); indicators item 11 and 12 (Technological Pedagogical Knowledge); indicator item 15 (TCK), and indicator item 21 (TPCK) that have the highest diff value. Teachers who teach as private tutors, do not interact much with technology. Their goal is to help students to understand chemical concepts that are difficult to understand even after it was explained by teachers at school. They focus only on teaching content, with no need to create a learning media or design a learning strategy using technology, so their digital literacy skill is low. This is strengthened by their lowest diff value at item number 7 and 8 (Content Knowledge) which means they are good at chemical materials. Their PK level is also low, as indicated in item number 4 and 5. This is because they teach chemistry individually or in small groups, so they don't have the skills to manage a classroom. They need more practice to get more experience and improve their pedagogical knowledge (Morine-Dershimer & Kent, 2006).

In second place are teachers in vocational high schools. Their level of difficulty is lower than teachers in private courses. It means they are more mature in the mastery of technology. Most of them used ICT tools mainly for managerial purposes like record keeping, communication with students, and finding e-resources, not for critical ones like designing, teaching and improving the creativity of students (Mutanga et al., 2018). This implies vocational teachers' limited knowledge and skills in using technology to develop students' cognition (Mutanga et al., 2018).

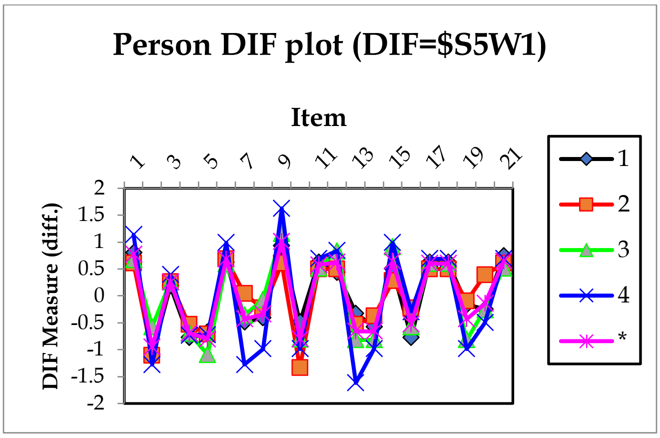

Figure 3. Person DIF That is Based on Difference Teaching Stages.

Teachers in middle schools and senior high schools have the most mature digital mastery of all. The diff value at the aspect of PK (item number 5 and 6), TPK (item number 11 and 12), TCK (item number 14 and 15), and TPCK (item number 19 and 20) are the lowest ones. This means that their technological knowledge and pedagogical knowledge are good. They have already become experts in the use of useful technologies according to certain methods in the classroom (Li et al., 2022). They also specialize in knowledge of instructional processes and methods, including understanding students' learning styles, classroom management, instructional design, and learning assessment (Li et al., 2022).

Teachers in different teaching stages have different strategies on how to integrate technology appropriately and effectively into their subjects (Goodson & Mangan, 1995; Li et al., 2022). Previous research indicates that different teaching stages build up different thoughts in the way of integrating technology into teaching

(Howard et al., 2015). The ability to teach information technology has a direct impact on student learning efficiency and knowledge acquisition (Li et al., 2022). Therefore, teachers should improve not only their technical knowledge but also their literacy skills (Li et al., 2022), so they can apply technology appropriately when they teach.

Ages

Technology is an integral part of 21st century learning in offering an interesting, creative and relevant curriculum (Lambert & Gong, 2010). In fact, teacher competence is considered lacking in the use of technology in learning in their classes (Hatlevik, 2016). One of the reasons is the age gap (Judd, 2018; Prensky, 2001). Currently, there are two generations of teachers: digital immigrants and digital natives (Prensky, 2001). The digital native generation is those who live in a world surrounded by information and communication of technology (ICT) like computers, cell phones, video games, technology tools, and toys. They were born in the last two decades of the 20^{th} century or after the 1980s (Kivunja, 2014). In addition, there is a generation known as digital immigrants – people born before 1980, so when they come into contact with technology, they are in the process of learning a new language (Kivunja, 2014), so they have to struggle harder to use technology than the digital natives.

Based on the demographic characteristic of teachers in Table 1, there are seven groups of ages. Group 1 is teachers with a range age of 20-24 years old; group 2 has a range age of 25-29; group 3 has a range age of 30-34; group 4 has a range age of 35-39; group 5 has a range age of 40-44; group 6 has a range age of 45-49; and group 7 has a range age of 50-54. The result of the diff value is shown in Figure 4.

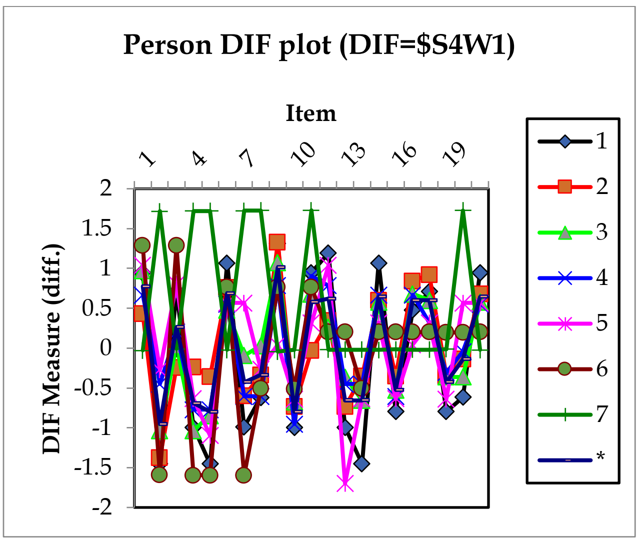

Figure 4. Person DIF That Is Based On Difference Ages

Figure 4 shows that teachers who belong to groups 6 and 7 have the most difficulty in technology mastery, as evidenced by indicator items no 1,2, and 3 (TK); indicator item number 11 (TPK), indicator item 20 (TPCK) that have the highest value. The second place is for teachers who belong to group 5. Teachers in groups 5, 6, and 7 have an age range between 40–50 years old who belong to the digital immigrant category. They encountered digital technologies later in life - are thought to be more challenged by technology, showing less technological affinity and literacy than their younger counterparts (Waycott et al., 2010). This indicates that those teachers lack confidence in technological knowledge as well as technology integration with content and pedagogic (Paidi et al., 2021). One of the reasons may be because of their limited knowledge of technology (Blamire et al., 2006). This influences teachers' decisions on technology integration in learning since they feel reluctant to integrate technology in learning if they do not master the knowledge well (Paidi et al., 2021).

Teachers in groups 1 and 2 have the lowest diff value at the aspect of TPK (item number 11), TCK (item numbers 13 and 14), and TPCK (item numbers 19 and 20). This implies that they have good technology literacy skills. They are the digital native generation and use technology to teach creatively in teaching learning and to guide students to carry out innovative and personalized independent, effective, and creative learning, and complete their unique work (Guan & Wang, 2019). Technological pedagogical content knowledge refers to the skill of using technology to facilitate subject-specific pedagogical methods, to facilitate content representation, and to address learner content understanding (Cetin-Dindar et al., 2018). However, technology is continuously changing (Fuad et al., 2020). Teachers should constantly improve their information technology literacy, learn, and master new information technology in their daily study, life, and work practice, so they can use information technology to improve their teaching ability creatively (Guan & Wang, 2019).

Another fact is revealed when PK (item number 4 and 5) and CK (item number 7 and 8) of teachers in group 7 have the highest diff value. This means that they have difficulty understanding the subject matters taught and pedagogical knowledge. The previous study stated that CK is a prerequisite of PCK development (Kleickmann et al., 2013). It means if the CK skill is low, automatically the PCK is also low. It is proven at the PCK aspect (item numbers 16, 17, and 18), teachers in group 7 have diff values in the middle which means their PCK skill is average. This may be due to their age; They feel difficult to understand chemistry materials which have undergone a lot of development in theories and concepts.

Gender

The result of the latest analysis regarding TPCK skills is based on gender. In this research, gender is classified into two groups: female and male. The result can be seen in Figure 5.

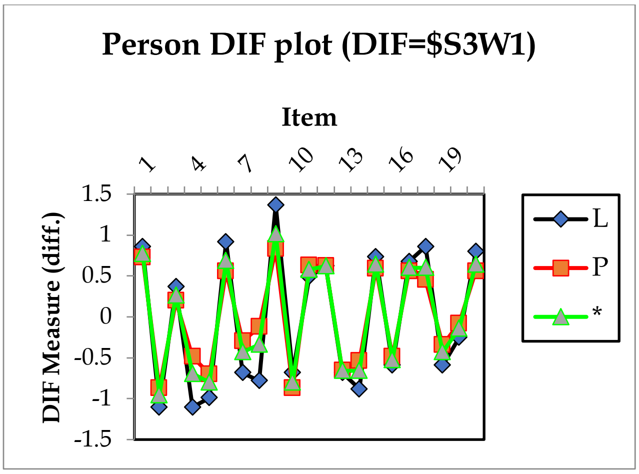

Figure 5. Person DIF That Is Based On Differences Gender

In Figure 5, male teachers have lower diff values than female teachers in the aspect of TK (item number 2); PK (item number 4 and 5); CK (item number 7 and 8), TCK (item number 13); TPCK (item number 19 and 20). This indicates that there are differences in terms of attitudes to ICT, ICT skills, and the use of ICT regarding gender (Kay, 2009). In general, male teachers have better TPCK skills than female teachers. Male teachers are more skillful to use computer applications. On the other hand, female teachers have difficulty and limited skills in the use of computers (Aqib et al., 2018). In terms of learning design, male teachers choose technology that is effective and efficient, whereas female teachers choose technology that is simple and easy. This may be due to female teachers' lack of confidence when using technology (Aqib et al., 2018). This implies that male teachers have abilities to use technology more effectively than female teachers (Aqib et al., 2018; Cetin-Dindar et al., 2018). The differences can be minimized when both male and female teachers use ICT frequently. More and more practice will reduce the effect of differences between male and female teachers (Koh & Sing, 2011).

However, in the aspect of PCK (item numbers 16 and 17), diff values between males and females are the same. This means that there is no difference between male and female teachers. They have the same ability to select effective teaching approaches, develop activities to deal with students' alternative conceptions, and facilitate content representation (Cetin-Dindar et al., 2018).

This research proposes an overview of the problems and readiness of chemistry teachers in implementing technology in learning. This discussion is expected to contribute to chemistry teachers and other subject teachers who are struggling to carry out TPCK abilities in learning. Besides, the results of this study are expected to be useful for evaluation material that can be used by education policymakers in Indonesia to enhance the learning system. However, the lack of respondents and the limited scope of the survey area are the limitations of this study. Enlarging the number and types of respondents such as science teachers, biology teachers, physics teachers, and mathematics teachers is a solution to explore possibilities of overcoming the challenge of applying technology. Besides, expanding the coverage of the survey areas, and using qualitative, quantitative, or mix method techniques with various data collection for further research will increase the validity of the data obtained for generalization. Finally, further studies on the TPCK skill and effectiveness of the implementation of technology are still needed.

Conclusion

The skill of the chemistry teachers' TPCK is currently good. They have the ability to create effective learning activities using various technologies. However, their TPCK skill needs to be improved considering the aspects of TK and TPK that are still in the low-level category. They still lack the confidence to apply technology in learning because of their limited knowledge. Based on the different teaching stages, teachers who use technology more frequently such as senior high school and middle school teachers have greater TPCK skills than teachers in private courses and vocational high schools. In terms of age, teachers who belong to digital natives have a better mastery of technology than those who belong to digital immigrants. Lastly, in the gender category, male teachers can use technology more effectively than female teachers. Therefore, a TPCK training program for individuals or centralized schools should be added to the chemistry department program.

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Author Contributions

Conceptualization, I.S and J.; methodology, E.F.R.K; validation, J and S.W.W; formal analysis, D.S; investigation, X.X.; resources, J and S.W.W.; data curation, D.S.; writing—original draft preparation, I.S and E.F.R.K.; writing—review and editing, J; visualization, E.F.R.K.; supervision, I.S.; project administration, D.S.; funding acquisition, J.

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Conflicts of Interest
The authors declare no conflict of interest

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