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EXPLORING CHEMISTRY TEACHERS' AWARENESS OF FABLAB FOR TRANSFORMATIVE EDUCATIONAL PRACTICES

Syinta Khefrianti[1], Nuryani Rustaman[2], Asep Kadarohman[3], Wiji[4]

[1,2,3]*Science Education Program, Universitas Pendidikan Indonesia, Bandung, Indonesia*
[4]*Chemistry Education Program, Universitas Pendidikan Indonesia, Bandung, Indonesia*

E-mail: kadar@upi.edu

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Abstract: Learning chemistry materials using 2D media is currently unable to provide a clear picture of some abstract and microscopic chemical content. Several studies show that many students have difficulty with chemistry because they cannot visualize structures and processes at the submicroscopic level and relate them to other levels of chemical representation. The purpose of this study was to determine the teachers' understanding of new technology that can be used to help students translate 2D into 3D in real form, namely using FabLab. This research is descriptive qualitative research with the research subjects 39 high school teachers and vocational school teachers in West Java. There are three stages in this research, data reduction, data presentation and conclusion drawing. The results showed that all teachers do not know or understand FabLab, although there are teachers who have attended training related to FabLab. Only 23% of teachers are aware of 3D printing but they do not know what is meant by FabLab. There are two schools that have 3D printing facilities, but they are not utilized, one of the reasons being the lack of technological mastery. This research is useful in designing professional development training for chemistry teachers in the field of technology, specifically in the utilization of FabLab.

Keywords: 3D printing, chemistry teacher, FabLab, learning media

Abstrak: Penggunaan media 2D untuk pembelajaran materi kimia saat ini belum dapat memberikan gambaran yang jelas mengenai beberapa konten kimia yang bersifat abstrak dan mikroskopis. Beberapa studi menunjukkan bahwa banyak siswa mengalami kesulitan dalam kimia karena mereka tidak dapat memvisualisasikan struktur dan proses pada tingkat submikroskopis serta menghubungkannya dengan level representasi kimia lainnya. Tujuan penelitian ini adalah untuk mengetahui pemahaman guru mengenai teknologi baru yang dapat digunakan untuk membantu siswa menerjemahkan media 2D menjadi bentuk 3D yang nyata, yaitu menggunakan FabLab. Penelitian ini adalah penelitian deskriptif kualitatif dengan subjek penelitian sebanyak 39 guru sekolah menengah atas dan guru sekolah kejuruan di Jawa Barat. Terdapat tiga tahapan dalam penelitian ini, yaitu reduksi data, penyajian data, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa semua guru tidak mengetahui atau memahami apa itu FabLab, meskipun ada guru yang pernah mengikuti pelatihan terkait FabLab. Hanya 23% guru yang mengetahui tentang pencetakan 3D, tetapi mereka tidak tahu apa yang dimaksud dengan FabLab. Terdapat dua sekolah yang memiliki fasilitas pencetakan 3D, tetapi fasilitas tersebut tidak dimanfaatkan, salah satu alasannya adalah kurangnya penguasaan teknologi. Penelitian ini bermanfaat dalam merancang pelatihan pengembangan profesional bagi guru kimia di bidang teknologi, khususnya dalam pemanfaatan FabLab.

Kata kunci: 3D printing, guru kimia, Fablab, media pembelajaran

INTRODUCTION

Chemists or chemists' study natural phenomena through certain scientific processes and attitudes. The process can be done in the form of observation or experimentation, while the scientific attitude can be seen objectively and honestly when collecting and analyzing data. Chemistry learning must pay attention to the characteristics of chemistry as an attitude, process and product. However, learning activities that take place so far only emphasize the characteristics of chemistry as a product, less on the attitude or process (Lutfi et al., 2022). An effective and efficient learning process requires the right learning strategy. A teacher, must be able to design and implement good learning so as to achieve the set goals (Purnasari & Sadewo, 2020).

Learning can begin with a learning planning process including learning objectives, learning steps, and learning assessments that are compiled in the form of documents that are flexible, simple, and contextual. educators are expected to organize learning that: 1) interactive; 2) inspiring; 3) fun; 4) challenging; 5) motivating students to actively participate; and 6) providing sufficient space for initiative, creativity, independence according to the talents, interests and physical, and psychological development of students (Anggraena et al., 2022). It aims to make learners have the competence to become democratic citizens and become superior and productive human beings in the 21st century (Sufyadi et al., 2020). The 21st century is characterized by a revolution in education driven by advances in information technology. Creative and innovative learning approaches are increasingly applied using technology in learning such as e-learning platforms, educational applications, and online resources.

The advent of technology has greatly impacted the field of chemistry education. From improving the accuracy of experiments to facilitating a comprehensive understanding of complex concepts, the integration of technology into education has been crucial. However, optimal utilization of technology in education demands clear professional standards to ensure effectiveness and facilitate proper understanding among learners (Alhashem & Alfailakaw, 2023). Technological changes have affected the way we teach, the way students learn and the way chemistry research is conducted. Rapid technological changes have improved laboratory instrumentation, data collection and processing (Nalley, 2021).

Atoms and molecules are the basic entities that chemistry students must understand. In addition, the characteristics of chemistry learning are meaningful when associated with understanding at the macroscopic, microscopic, and symbolic levels. However, research shows that many students have difficulty with chemistry because they cannot visualize structures and processes at the submicroscopic level and connect them to other levels of chemical representation (Rahmawati et al., 2021). Visualizing molecular conformations and structures of complex compounds and chemical transformations in 3D is one of the most difficult things in learning chemistry. Modern computing technology has revolutionized every aspect of our lives, including education. As a result, many researchers and educators seek to improve student learning and enhance knowledge construction by using better technologies in illustrating theoretical concepts, such as molecular geometry visualization in chemistry (Abdinejad et al., 2020). 3D models combined with 2D images help students translate 2D images into 3D objects and 3D visualization techniques, if integrated into teaching methodologies, greatly enhance learner learning (Fatemah et al., 2020).

In the 21st century, there has been a shift towards the incorporation of inductive pedagogical approaches in engineering education not only in traditionally higher education, but also in schools. In school education, the maker movement has been a recent phenomenon. The Fabrication Laboratory, or FabLab, is a rapidly growing type of makerspace (Chan & Blikstein, 2018). A Fab Lab is also a platform for learning and innovation, a place to play, create, learn, mentor, and invent (Santos et al., 2018). One of the tools available in a FabLab is 3D printing, which can transform abstract concepts into more concrete ones and effectively enhance creativity. Additionally, teachers' pedagogical skills in designing lessons and using technology also experience positive changes with the use of 3D printing (Khefrianti et al., 2024).

Engineering will advance materials and devices for 3D printing in FabLabs, while 3D printing can train skilled chemical engineers and solve challenges in the field. Together, chemical engineering and 3d printing can form a powerful duo, helping to bring multitude of ideas and innovations to life (Amores et al., 2022). Teachers can use printers in FabLabs to create custom tools and equipment, improving the quality of laboratory courses (Pinger et al., 2020). Seeing the various benefits of FabLab, this study aims to explore the understanding of chemistry teachers in West Java regarding FabLab and the extent of its use in learning by chemistry teachers.

METHOD

The research approach used in this study is a qualitative approach. Qualitative research is a type of research that is considered to come from social or humanitarian problems and is used to describe, explore, and understand what it means (Creswell, 2013). The research subjects were 39 high school and vocational school chemistry teachers in West Java.

Data collection techniques include: 1) teaching tool documents used by teachers, focusing on parameters such as technology and learning media, taken from one of the teacher platforms; 2) online questionnaires using google forms distributed through MGM whatsapp group, with questions related to the use of learning media, fablab technology and fablab training that has been attended; 3) observation of two teachers who were respondents and willing to be observed, and who already have 3D printing equipment at their school; and 4) interviews with two teachers to reinforce the results of observations. The data analysis techniques were carried out in three stages, namely data reduction, data presentation and conclusion drawing (Rijal, 2019).

RESULTS AND DISCUSSION

In the Merdeka Curriculum, students in grade X are called phase E and students in grades X and XI are called phase F. The documents analyzed in this case are documents on the Merdeka Curriculum for high school and vocational school. High school and vocational school differ in their curricular focus (Nugroho & Paleologoudias, 2020). Vocational schools are designed to provide students with practical skills and

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specialized knowledge related to specific industries or professions. The curriculum emphasizes hands-on training and often incorporates internship or apprenticeships, ensuring that students gain real-world experiences as a key part of their education (Prabowo et al., 2021;Priambudi et al., 2022: Ferdaus & Novita, 2023) The results of document analysis of chemistry teaching devices used by teachers for phase E and phase F are as in Table 1.

Based on the data in table 1, it can be seen that the use of 3D learning media has not been used in chemistry learning activities. With the current two-dimensional (2D) teaching method, students often experience misconceptions, for example in biochemical materials where proteins contain a lot of empty space, that bond angles for different amino acids can rotate evenly, and that product inhibition is equivalent to allostery. To help students translate 2D images to 3D molecules and give meaning to the material content (Howell et al., 2020). The use of 2D media which is still dominantly used by teachers has several shortcomings, especially in the content of chemical materials. Chemical materials often involve three-dimensional structures, such as molecules and crystals. 2D media is not always able to accurately convey these three-dimensional representations, so it can make it difficult for students to understand the concept.

Meanwhile, the results of the questionnaire on the use of 3D learning media by teachers in learning activities are presented in table 2. Table 2 shows that more teachers do not use 3D learning media, namely 20 teachers or 51.3% of the total teachers. Some of the reasons expressed by teachers are time constraints, availability of facilities and infrastructure and difficulties in finding learning media. For teachers who use real 3D learning media, molymod is the only current option that can be used by teachers. Molymod as a teaching aid makes students happy and excited in determining the shape of molecules and students can understand and remember molecular shape material longer by practicing directly (Munika & Kurniati, 2020). The use of molymod as a learning medium for molecular shapes is quite limited in terms of availability in schools so that for other molecular shapes the teacher still uses books, as a result students continue to use space and baying abilities (Atmawinaldi et al., 2019; Prasetiyo et al., 2020).

Table 1. Analysis of media used in teaching tools

Phase	Number of teaching tools	Media used	
		Type of Media	Total
E	34	Video	12
		PPT	3
		Print /2D	19
F	19	Video	2
		Print /2D	17

Table 2. The use of 3D Learning Media

Indicator	Type	Total
Media	Molymod	13
	AR	2
	Practical Tools	3
	Simulation	2
	None	20
Source	Make it yourself	6
	Available at school	9
	Purchase finished products	4
	None	20

Based on an interview with one of the high school chemistry teachers in West Java, information was obtained that learning using 3D media such as molymod was used in hydrocarbon material to show students the shape of molecules in real life. Previously, Augmented Reality (AR) was used, but currently it is no longer used because Phet is better at showing the shape of molecular geometry compared to AR. In order for students to better understand the shape of molecular geometry in real life, students are asked to make molecular geometry using night. This is in accordance with the results of observations on teacher learning activities. In learning activities students are given the task of making molecular shapes using night. The results shown by students are that students focus and are interested in making molecular shapes but forget the principle of molecular bonding.

The integration of AR into chemistry curricula allows for the visualization of complex molecular structures and chemical reactions, significantly aiding students' understanding of abstract concept. For instance, studies have shown that AR can provide 3D visualizations of chemical bonding and molecular interactions, making it easier for students to grasp these intricate topics (Yamtinah et al., 2021; Karnishyna et al., 2022). While AR has the potential to enhance visualization and engagement in chemistry education, its implementation faces challenges like infrastructure limitations, unequal access to technology, content development complexity, and varying effects on learning style and performance (Keller et al., 2021;Akbar, 2024). Additionally, the development process can be time-consuming and costly, potentially diverting resources away from other important educational initiatives (Fombona-pascual et al., 2022). 3D printing a tool in Fablab, allows for the creation on models or prototypes tailored to individual needs (Zhang et al., 2022). This level of personalization is difficult to achieve with AR, which typically relies on pre-existing digital models and may not fully represent the specific characteristics of the object (Salavitabar et al., 2023)

An interview with a second teacher at one of the vocational schools in West Java found that the teacher has not used technology-based learning media even though a 3D printer is available at the school. The learning conducted by the teacher does not intersect with existing technology in accordance with the vocational competencies at the school. The teacher's reason for not using the 3D printer is that they have not mastered the use of the 3D printer. From the observation of the second teacher, it was also seen that technology facilities and infrastructure are very supportive in the learning process for teachers but have never been used.

Table 3. Teacher's Knowledge of FabLab

Indicator	Number of Responses	
	Yes	Not
Get to know Fablab	0	39
Getting to know 3D Printing	9	30
Have attended a 3D Printing workshop at Fablab	2	37

Table 3 shows that there are no teachers who are familiar with FabLab even though there are 2 teachers who have attended workshops on the use of 3D printing. When asked what they know about FabLab, none of the teachers gave an answer which means they do not know or recognize FabLab. Meanwhile, overall, in responses related to the definition of 3D printing, teachers answered that 3D printing is a printer that can create or print 3D media. Two teachers who have participated in workshops at FabLab answered that the tools used are 3D filament printers and CNC routers, respectively. From the results of this response, it is obtained that teachers know what 3D printing is and its functions, but teachers are not familiar with FabLab.

A fabrication laboratory (FabLab) is described as a workshop equipped with a computer-controlled set (e.g., 3D printer) that offers personalized digital fabrication (Togou et al., 2020). FabLab is a design process that involves the use of computers and all digital machines connected to computers as a whole, from the data management stage of the modeling stage to the production stage (Indrawan & Purwanto, 2021). FabLab technology that is increasingly affordable and popular today is 3D printing. Digital technology can be molded into reality in 3D (Rayna & Striukova, 2020; Kit Ng et al., 2022). In FabLab there is a set of flexible computer-controlled tools and machines such as 3D printers, laser cutters, computer numerically controlled (CNC) machines, printed circuit board grinders and other basic fabrication tools that allow students to experiment and prove theoretical concepts by creating prototypes (Cornetta et al., 2019).

Through FabLab, users can utilize their imagination and develop sustainable, social, local and economic innovative solutions to solve real problems, supported by knowledge transfer (Maravilhas & Martins, 2018). Four elements are important for designing digital fabrication for education: 1) consider how people learn as a basis for; 2) provide instructional scaffolds to enhance learning; 3) familiarize teachers with unstructured tasks and digital fabrication; and 4) build collaboration between teachers and facilitators (Pitkanen et al., 2020). One of the technological tools of digital fabrication is 3D printing (Mahendarto, 2020).

The emergence of additive manufacturing (AM) technologies, such as 3D printing and laser cutting, has created opportunities for new design practices that cover a wide range and diversity of learning and teaching settings (Khaki et al., 2022). 3D printing, also often referred to as 'additive manufacturing', is a general term used to describe a range of manufacturing technologies that have emerged since the mid-1980s. These technologies are significantly different from other existing manufacturing technologies, in the sense that the manufactured objects are built 'layer by layer' with the addition of materials (Rayna & Striukova, 2020). As the field matures, its reach into other applications expands, accelerated by its ability to produce 3D objects with complex geometries (Hartings & Ahmed, 2019). 3D printed models can be implemented in many courses, including general chemistry, organic and inorganic chemistry, solid state chemistry, crystal chemistry, and so on (Savchenkov, 2020). The combination of teaching and design strategies to help learners understand 3D printing technology while integrating it into the curriculum should be explored in practical research (Huang & Chun, 2022).

Teachers who participate in professional learning programs show changes in their teaching practices. They tend to adopt more flexible, inquiry-oriented, student-centered and learner-empowering pedagogies which are important characteristics of 3D learning

(Stevenson et al., 2019; Chytas et al., 2019). Although teachers do not have prior knowledge or experience in designing 3D media, increasing teachers' confidence and enthusiasm in trying to make innovations can help in the development of teacher professionalism. Hence, the importance of professional learning, as well as constructivist concepts, thinking methodologies, and 3D design technology (Stevenson et al., 2019). Teachers not only function as facilitators but also as practitioners who actively design learning activities involving 3D printing technology (Leinonen & Virnes, 2020).

FabLabs often incorporate interdisciplinary projects that require collaboration across various fields, such as engineering, design and social sciences. This multidisciplinary approach not only enriches the learning experience but also encourages participants to develop a broader skill set that is applicable in diverse contexts (Jaskiewicz et al., 2019; Morin & Moccozet, 2021). For example, in biology programs have shown high levels of engagement and improved learning outcomes when involved in maker activities that combine scientific exploration with hands-on fabrication skills (Lima et al., 2024). Additionally, the use of 3D printing technology in FabLabs enables students to design and create prototypes, which reinforces concepts in geometry (Harron et al., 2022). Integrating digital fabrication technologies in these environments not only enhances STEAM education but also develop students' critical thinking and problem-solving skills (Georgiev & Nanjapan, 2023).

The pedagogical approaches employed in FabLabs further enhance the integration of content and technology. Collaborative learning is a key feature, where participants work in teams to tackle projects, fostering communication and teamwork skills (Chen & Bergner, 2021; Mizeret et al., 2022). Moreover, the interdisciplinary nature of FabLabs encourages collaboration across different subjects. For example, a project may involve engineering principles, artistic design, and mathematical calculations, thereby fostering a holistic learning experience (Douglass, 2023; Leonard et al., 2023). Therefore, the evaluation of learning outcomes in FabLabs is assesses to practical understanding and application of content. Methods such as project evaluation, peer reviews, and self-reflections provide insight into learning process (Othman et al., 2022). In previous studies, creating a functional prototype to solve a specific problem assesses content knowledge and skills like creativity, collaboration and technical proficiency (Garcia-Ruiz & Lena-Acebo, 2022).

The design of the training model that can be recommended to teachers in accordance with the important elements of FabLab so that they can print 3D learning media is divided into 4 stages, namely: 1) Start by analyzing the context or situation that requires 3D design on chemistry concepts, identifying problems and challenges to be solved in FabLab; 2) planning the design of interventions or solutions to be developed by the teacher with the teacher being provided with instructions by the facilitator. This planning must also contain strategies in achieving the objectives of the design; 3) implementing the design that has been designed in the real context of the FabLab to produce the designed 3D learning media; and 4) creating a FabLab community of chemistry teachers so that collaboration between teachers and wider benefits are built. This will certainly be further research for researchers in applying FabLab as a new technology that helps teachers in learning chemistry.

CONCLUSION

From the research results, it is known that chemistry teachers in West Java are not familiar with FabLab even though there are teachers who have attended workshops on the use of 3D printing tools at FabLab. Therefore, learning conducted by teachers in the classroom is also still using learning media available at school such as molymod and visualization media available on the internet. Whereas the use of learning media has not been able to optimize student understanding of molecular geometry. Although there are schools that have 3D printing facilities, but mastery of technology is an obstacle in its utilization.

This study limited to chemistry teachers in West Java and may not reflect the conditions of teachers in another region. The findings highlight the need for training development to improve teachers' skills in using technologies like FabLab. Future research could focus on integrating these tools into classroom chemistry instruction.

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