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Community Service Through the Implementation of ARMOLT Based on Augmented Reality to Enhance Molecular Chemistry Learning in Vocational High School

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Abstract. Augmented Reality (AR) offers interactive learning experiences and helps visualize complex scientific concepts such as molecular structures. However, pre-survey results showed low exposure to AR among high school students and teachers, limiting the technology's educational application. This community service program aimed to introduce and apply ARMOLT (Augmented Reality Chemical Molecule on a T-Shirt) as an alternative chemistry learning media for vocational school students. The program was conducted at SMK Widya Manggala Jakarta Timur and involved workshops on AR marker creation, hands-on application testing, and digital literacy enhancement. Evaluation data indicated that students showed increased interest and improved conceptual understanding after using ARMOLT. The program demonstrated that AR-based chemical visualization contributes to more engaging learning activities and promotes technology adoption in the educational environment.

Keywords: Augmented Reality; Vocational Chemistry; Digital Literacy; ARMOLT; STEM Learning

INTRODUCTION

The development of information and communication technology has driven digital transformation across various aspects of life, including lifestyles, patterns of interaction, and the ways in which younger generations express themselves (Souto, 2023). One form of this transformation can be seen in the evolution of the fashion industry, which has increasingly become integrated with social media as a medium of expression and self-existence, particularly among teenagers (Ahmad & Samsugi, 2022). Along with this shift, visual design is no longer static but has evolved to become more dynamic, interactive, and responsive to user experience, indicating a shift in visual culture that is increasingly familiar with digital content (Zen, Kusuma Ayu, & Anjarsari, 2025).

However, the rapid growth of digital technology has not been fully accompanied by adequate technological literacy. Preliminary survey results showed that 61.66% of respondents were unfamiliar with Augmented Reality (AR) technology, resulting in its limited utilization in educational and applicative contexts (Moreira et al., 2024). This condition illustrates a gap between technological potential and its implementation in the daily lives of young generations.

In the field of education, particularly in science and chemistry learning at Vocational High Schools (SMK), problems remain in delivering abstract materials such as atomic structures, molecules, and chemical reactions. Conventional learning media with limited visualization make it difficult for students to understand such concepts spatially. Previous studies have demonstrated that AR technology can improve the understanding of chemical

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concepts through real-time and interactive visualization of three-dimensional objects (Díaz, Álvarez-Gallego, Caro, & Portela, 2023).

Based on literature reviews and partner needs assessments, this community service program offers a solution through the development of ARMOLT (Augmented Reality Chemical on a T-Shirt), implemented at SMK Widya Manggala, East Jakarta. This innovation integrates AR markers into T-shirt designs that can be scanned using mobile devices to display three-dimensional visualizations of chemical molecules (Nelva Saputra, Idhayani, Ophi Ramadhan, & Juliasari, 2024).

As a form of applying Informatics Engineering knowledge, AR technology is developed through the utilization of digital image processing, pattern recognition, and human–computer interaction. Research shows that integrating AR into T-shirt media can be an effective strategy for transferring technology to the community through media that are closely related to youth culture and lifestyle (Sapinatul Bahriah, Agung, & Nur, 2022). This approach not only supports learning but also increases youth interest in recognizing and utilizing digital technology (Octafiona Era, 2024).

Through this Informatics Engineering–based community service activity, students are expected to gain a more interactive, immersive, and relevant learning experience. This program aims to: (1) introduce AR technology to students and teachers, (2) increase digital literacy and understanding of chemical concepts through training and mentoring, and (3) encourage positive and sustainable use of digital technology in educational environments.

METHOD

This community service program was implemented at SMK Widya Manggala, East Jakarta, involving lecturers and students as the implementation team. The lecturers served as facilitators responsible for preparing materials, delivering socialization, and conducting training, while the students were involved in technical support and assisted teachers and students throughout the activities. The partner of this program, SMK Widya Manggala, required technology-based learning media to support chemistry learning.

The implementation of the program was divided into three main stages. The first stage was the preparation stage, which included coordination with the school, identification of participants' needs, adjustment of training modules, and preparation of evaluation instruments such as questionnaires and observation sheets. This stage aimed to ensure the alignment of the program with the needs of the partner.

The second stage was the implementation stage, consisting of socialization on the use of Augmented Reality (AR) in learning, workshops on the development of T-shirt designs as AR markers, and training on the use of applications for molecular visualization. The activities were conducted interactively to ensure participants understood the process from marker creation to the utilization of AR media in classroom learning.

The third stage was monitoring and evaluation, conducted through direct observation, interviews, and questionnaires involving students and accompanying teachers. Formative evaluation was carried out during the activities to ensure process achievement, while summative evaluation was conducted after the program to assess its impact on students' understanding and learning motivation, as well as the usefulness of the program for the partner.

In summary, the stages of this community service program can be illustrated through the workflow diagram shown in Figure 1.

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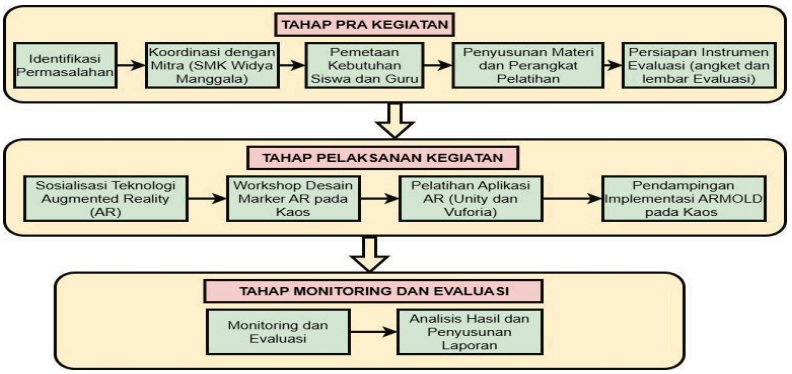

Figure 1. Stages Of The Community Services Activity

RESULTS AND DISCUSSION

The implementation of the community service program at SMK Widya Manggala, East Jakarta, demonstrated that the application of Augmented Reality (AR) technology through educational T-shirt media can provide a more visual, interactive, and contextual chemistry learning experience. The program focused on improving students' understanding of molecular concepts through three-dimensional visualization, increasing digital literacy, and introducing the use of AR technology in vocational learning. The results of the program are presented based on process achievements, program outputs, and its impacts on participants and partners.

The initial phase of the program began with field observation and coordination with the school. Observations were conducted to identify chemistry learning conditions, infrastructure readiness, and the level of technological literacy among students and teachers. The observations indicated that chemistry learning remained dominated by conventional two-dimensional media, causing students to struggle in understanding molecular structures spatially. Additionally, most students had never used AR technology in learning activities, indicating potential for technology-based intervention. Coordination with accompanying teachers was then carried out to agree on program objectives, implementation schedules, and division of roles between the implementation team and the partner institution.

The implementation phase began with socialization sessions explaining the concepts, working mechanisms, and educational benefits of AR technology. The socialization was conducted interactively through material presentations and demonstrations of AR applications using educational T-shirt media. Based on the initial questionnaire, 80% of participants stated that AR technology had the potential to increase learning interest and conceptual understanding, while the remaining participants indicated the need for further technical assistance to optimize its use. These findings show that AR-based learning media can serve as a stimulus for participants to engage in science learning more enthusiastically.

In the technical training phase, participants were introduced to the process of creating graphic designs that function as AR markers and the procedures for visualizing molecular objects through mobile devices. The training consisted of two sessions: graphic material delivery and hands-on practice for marker creation and visualization testing. The results of pre-test and post-test evaluations showed a 45% increase in participants' understanding. In addition to learning design techniques, participants also began to understand the AR visualization workflow, from marker development to the display of three-dimensional molecular objects.

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Figure *2.* Augmented *Reality Visualization Workflow*

The main output of the program was an educational T-shirt designed with a molecular water theme. The design was printed using a digital screen-printing technique and integrated as an AR marker. When the marker was scanned using an AR application, the H_2O molecule was displayed in three-dimensional form in real time and could be observed from multiple viewing angles. This medium combines educational and aesthetic elements, allowing the T-shirt to function not only as a fashion item but also as a contextual learning tool that is closely related to students' daily lives. Accompanying teachers stated that this medium could serve as an alternative for visualizing chemical concepts that are difficult to explain through two-dimensional images.

Figure 3. Implementation of Molecular Visualization

The monitoring and evaluation stage was carried out through observation, interviews, and the distribution of questionnaires to students and accompanying teachers. Formative evaluation was conducted during the implementation to ensure process achievement, while summative evaluation was conducted after the program to assess its impact. The evaluation results showed an 8.16% increase in students' understanding of chemical molecular concepts after the program. In addition, the activities enabled students to become familiar with new technologies, thereby increasing digital literacy and encouraging them to engage with non-conventional learning media.

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Figure 4. Student Field Testing

Overall, this program demonstrates that AR can be used as a supportive medium for teaching abstract chemistry concepts. The integration of AR into T-shirt designs represents an innovative approach that aligns with the visual culture of adolescents, thereby increasing relevance, engagement, and positive participant responses in the learning process. These findings are consistent with similar initiatives in vocational education settings, which indicate that three-dimensional visualization can enhance student engagement and understanding of scientific material. Thus, this community service program provides a meaningful contribution to the utilization of information technology for educational purposes in secondary school environments.

CONCLUSION

The community service program implementing Augmented Reality (AR)–based learning media at SMK Widya Manggala, East Jakarta, contributed positively to the chemistry learning process. The use of AR through educational T-shirt media helped students visualize molecular structures more concretely through three-dimensional objects, thereby facilitating the understanding of abstract concepts. In addition, the program enhanced students' digital literacy and introduced the use of information technology as part of vocational learning.

From a technological perspective, the ARMOLT application was able to display three-dimensional molecular models interactively through T-shirt markers processed using the SURF feature extraction algorithm. The evaluation results indicated that the more complex the marker image, the greater the number of detected feature points, which supported tracking stability and AR visualization performance. User evaluations also showed positive responses, with 70.48% of participants reporting satisfaction, particularly regarding ease of use and visual presentation.

Based on the overall evaluation, students demonstrated increased understanding and learning motivation, while teachers indicated that AR media could serve as an innovative learning alternative that aligns with current learner characteristics. The program also provided practical experience for students in operating interactive technology as part of chemistry learning activities.

This community service program has the potential to be further developed, either through the expansion of visualized chemical materials or through replication in other schools with similar characteristics. Thus, this program is expected to be sustainable and deliver broader impacts in supporting technology-based learning within secondary education environments.

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