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Mobile Augmented Reality in Vocational Education and Training

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Abstract

In Vocational Education and Training (VET) institutions, teachers face important difficulties in the teaching process due to a wide variety of student's special educational needs as well as student's lack of: the adequate level of basic competence, motivation, concentration, attention, confidence and background knowledge, among other aspects. Regarding the attention to these aspects, many studies have reported positive impact of Augmented Reality (AR) applications in primary, secondary and higher education in terms of student's motivation, learning gains, collaboration, interaction, learning attitudes and enjoyment, among others. However, very little has been done in terms of AR applications in VET as well as their impact on wide variety of student's special educational needs such as learning difficulties. This paper introduces a marker-based mobile AR application named Paint-cAR for supporting the learning process of repairing paint on a car in the context of a vocational education programme of car's maintenance. The application was developed using a methodology for developing mobile AR applications for educational purposes from a collaborative creation process (Co-Creation) and based on the Universal Design for Learning (UDL). A cross-sectional evaluation study was conducted to validate the Paint-cAR application in a real scenario.

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1. Introduction

Vocational Education and Training (VET) is defined as: “education programmes that are designed for learners to acquire the knowledge, skills and competencies specific to a particular occupation, trade or class of occupations or

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trades” [1]. At this educational level, students are prepared to supply the needs of the labour market in specific occupations. In the Spanish educational system, some examples of VET programmes are: logistics, transport, manufacturing, building, electricity and tourism, among others.

Students that enrol in VET programmes have completed secondary education or at least most of it. After finishing the VET programme they can go to university or to the labour market in order to work in a particular occupation. Some students also enrol in VET programmes many years after finishing secondary education when they need to obtain a certification for a particular occupation. According to the statistics of the Spanish Ministry of Education, Culture and Sport, 68,1% of the students enrolled in VET programmes in 2013 came from secondary education, 1,5% came from special education schools, 13,9% had dropped out of other educational levels and 16,5% enrolled due to other reasons [2].

According to the results of the Survey of Adult Skills conducted by the Organisation for Economic Co-operation and Development (OECD), 3 out of 10 adults in Spain and Italy perform at or below the level 1 (in a scale from 1 to 5) of literacy and numeracy. Besides that, only 1 out of 20 adults is proficient at the highest level of literacy (levels 4 or 5). The report also states that “large proportions of young people leave school with poor skills in literacy, numeracy and problem solving” [3].

As a result, there is a wide variety of students in Higher Education Programmes and VET programmes with different levels of basic competences, backgrounds, needs, interests, motivation, preferences, etc. In particular in VET programmes, teachers have identified student’s lack of: motivation, concentration, attention, confidence and background knowledge, among other aspects [4].

Many studies have reported positive impact of Augmented Reality (AR) applications in primary, secondary and higher education in terms of student’s motivation, learning gains, collaboration, interaction, learning attitudes and enjoyment, as reported in the literature review conducted by Bacca, Baldiris, Fabregat, Graf, and Kinshuk [5]. However, very little has been done on the benefits of AR applications in VET as well as their impact for addressing a wide variety of student’s special educational needs such as learning difficulties [5].

This paper introduces a marker-based mobile AR application named Paint-cAR for supporting the learning process of repairing paint on a car in the context of a VET programme of car’s maintenance. A methodology for designing and developing mobile AR applications was also proposed in order to design and develop Paint-cAR application. The methodology brings together students, teachers and software developers in the design and development process taking into account the special needs of the actors in the educational system, teacher’s requirements, interests or pedagogical/didactic preferences, as well as diverse students’ needs such as knowledge backgrounds, experience, context, learning styles, functional diversity and various students’ preferences. Besides that, the Universal Design for Learning (UDL) framework was considered as an inclusive learning approach for addressing student’s needs and overcoming any barriers and difficulties in the learning process.

Paint-cAR application was tested with a group of VET students in Spain and the Instructional Materials Motivation Survey (IMMS) [6] instrument was applied to evaluate student’s motivation, in particular, attention, relevance, confidence and satisfaction dimensions. The results show that participants were motivated by the use of Paint-cAR application. Although the results are promising in general, confidence and satisfaction dimensions rated higher.

The rest of the paper is organized in 7 sections. The second section describes the related work; the third section describes the methodology proposed for developing the AR application. Then, the design of the Paint-cAR application is described in section four. Fifth section describes a cross-sectional evaluation study, followed by the sixth section discussing the results obtained. Finally seventh section presents the conclusions and future work.

2. Related work

The concept of AR was coined in contexts of maintenance tasks when Caudell and Mizell [7] proposed the head-mounted display for assisting maintenance in the aircraft industry. Since that moment, AR has been extensively used for assisting maintenance and repairing tasks in a wide variety of fields in industry [8]. Besides that, many studies have reported experiences about using AR in educational processes at primary and secondary educational levels as well as at university. However, very little has been done in terms of AR in vocational education institutions as a support for the learning process [5].

Cuendet, Bonnard, Do-Lenh and Dillenbourg [9] developed three AR learning environments that rely on the TinkerLamp hardware that was also designed by them. Two of the developed learning environments cover VET domains, one is for teaching logistics and the other one is for training carpenters in the topic of 3D visualization. The authors suggest 5 design principles to make an AR system work well in the classroom: integration, empowerment, awareness, flexibility and minimalism [9]. On the other hand, Delic, Domancic, Vujevic, Drljevic and Boticki [10] developed a location-based AR application called AuGeo for geodesy vocational education. The application displays geographical information about surrounding land parcels based on the student's position. In terms of the AR application design, the authors point out that a "co-design iterative approach is preferred", which means that cooperation between teachers and developers is needed in order to specify the amount and sort of information that should be presented.

Cubillo, Martin, Castro and Boticki [11] developed an AR authoring tool for teachers to create AR learning experiences. The learning experience created with the tool was tested with a group of VET students and the results show that students who studied with the AR experience had better results than the students who did not use it. However, all of the studies mentioned do not consider the student's special educational needs in the learning process. In addition, as pointed out by Westerfield, Mitrovic and Billingham [12], most of the systems have focused on improving the user performance rather than focusing on teaching how to perform the task. In order to tackle this problem an AR system that combines an ITS (Intelligent Tutoring System) with an AR interface was developed by the authors and the results showed that the system improved the learning experience in the process of assembling a computer motherboard.

Moreover, there are some European projects that have been studying AR in VET institutions. For instance, in the Learning Augmented Reality Global Environment (LARGE) project [13] a platform was developed to create educational AR applications. Findings of the project identified that teachers and students think AR to be beneficial in terms of student motivation. Moreover, in the ARAVET (Augmented Reality in the field of Vocational Education and Training) Project, three AR applications were developed in the field of informatics, electronics and textile [14]. However, these studies have not considered the issue of addressing the student's special educational needs from an inclusive learning perspective in VET domains, so that all students can benefit from AR in order to overcome any barrier in the learning process.

AR has also been used for addressing some special educational needs of students in different educational levels. For instance, in their study, Aziz, Aziz, Paul and Yusof [15] conclude that AR could help to capture the attention and encourage active participation of students with attention deficit and hyperactivity disorder (ADHD). Lin, Hung, Lin and Lun [16] studied the use of AR to make the learning process more interesting and interactive for students with cognitive impairments. The authors conclude that AR and VR technologies could be used to reduce some barriers in the learning process. Likewise, Tobar-Muñoz, Baldiris and Fabregat [17]; Tobar-Muñoz, Fabregat and Baldiris [18] developed an AR-enriched inclusive videogame to support the development of basic mathematics skills in kids and proposed a set of design principles for designing inclusive AR games. In terms of user interaction, Boletsis and Mccallum [19] developed an AR game for cognitive training and introduced an AR cube as the interaction technique in the "magnifying glass" metaphor. The results show that novice AR users were able to quickly adapt to the system using the interaction technique.

Together these studies provide insights into the use of AR for addressing special educational needs but none of them were focused on VET institutions. However, in recent years, some authors have begun to study the impact of AR in vocational education considering special educational needs. Chang, Kang and Huang [20] developed ARCoach, a marker-based AR system for vocational skill-training for people with cognitive impairments. The results show that participants increased their success rate in the tasks and maintained their skills after the intervention. Similarly, Y.-J. Chang, Kang, and Liu [21] developed a marker-based AR game for vocational skill-training for people with cognitive impairments in the context of recycling. The results show that the gaming system has potential for facilitating training in vocational jobs.

3. Design methodology

A methodology for designing an operator training process was reported by Ginters and Cirulis [22]. However it did not involve the students in the design process. In order to overcome this situation and foster the active

participation of the actors involved in the design and development of the Paint-cAR application, a methodological approach for developing mobile AR applications for educational purposes from a collaborative creation process (Co-Creation) has been proposed and applied in this research. The methodology combines a user centred and collaborative design process and draws upon the research on the Universal Design for Learning (UDL) as an inclusive educational approach. The phases of this methodology are as follows:

1. **Definition of a co-creation team:** A multidisciplinary team (thereinafter co-creation team) is created. The team includes experts in the VET domain (teachers), software developers, graphic designers and educational technology experts with an extensive background in the Universal Design for Learning (UDL).
2. **Preliminary meetings:** A first meeting between the members of the co-creation team is needed in order to identify the main characteristics of the educational need and the characteristics of the students. The co-creation team needs to have a general idea of the learning environment and the possibilities for using AR in that context.
3. **Deep understanding of the learning domain:** It is also important to understand what the learning domain is, what its characteristics are and how the learning process is conceived. To create Paint-cAR application, teachers record videos so that software developers and educational technology experts can understand how the learning domain is and how the processes that should be taught are performed by the experts in a real context. Initial ideas about the use of AR in the learning domain could be identified at this point.
4. **Identify and select the educational need to be addressed:** In this phase, several educational needs are identified. The educational needs are analysed and multiple educational proposals are evaluated in order to provide a solution. It is important to note that some educational needs could be solved by using other technologies different from AR. Software developers and teachers should evaluate if AR is the best option. Characteristics of the students are also identified in terms of their strengths, qualities, weaknesses, preferences and interests. For the purpose of creating the Paint-cAR application, the difficulties faced by the teachers and described in section 4.1 were analysed at this point.
5. **Designing the AR application:** Developers and educational technology experts propose a design. The design should follow an inclusive learning approach such as the Universal Design for Learning (UDL). According to Meyer, Rose and Gordon [23] the following principles are recommended in order to create a learning environment for all:
 - a. **Provide multiple means of presentation:** In the Paint-cAR application, for example, the information is presented by using icons with alternative texts, images, texts, videos with subtitles, etc. Since AR is not only restricted to the sense of sight but it can be applied to other senses such as smell, hearing or touch [24], AR is a good option for providing multiple means of presentation.
 - b. **Provide multiple means of expression:** An AR educational application should have mechanisms that allow students to express their knowledge in different ways. For example, in the Paint-cAR application there are some modules that provide different means of expression, such as self-evaluation, personal notes and Ask Your Teacher (AYT). These modules provide mechanisms for students to express their knowledge and keep in touch with teachers.
 - c. **Provide multiple means of engagement:** In Paint-cAR application, students are challenged on each step in the process of repairing paint on a car. Besides that, the videos included in the application show how other students and experts carry out the repairing process. In the evaluation mode (described in section 4.2), for example, students are challenged to organize the phases and steps of the process in a puzzle. Maintaining an appropriate degree of challenge could encourage students to complete the tasks.

Software for creating wireframes and mock-ups could be used in order to design the interfaces and the interaction mechanisms. This could be very useful in order to have a more realistic idea about the application.

Some meetings of the co-creation team are necessary in order to reach a consensus. After each meeting, an improved version of the design is desirable. If possible, students can participate in this phase by providing opinions about the user interface and interaction mechanisms that are being proposed. It would be desirable to have the opinion of students with special educational needs in order to improve the design.

6. **First prototype of the AR application:** After reaching a consensus in the design, a first prototype of the AR application is implemented. Teachers provide the contents that should be included in the application such as texts, graphics, videos, etc. Sometimes graphical designers are needed in order to create 3D models of objects that will be augmented or to address user interface issues. A collaborative work between teachers, graphical designers and developers is needed at this point. Developers should evaluate available technologies, frameworks, libraries, etc., in order to choose the best options. After the first prototype is ready, a meeting with the whole co-creation team is needed so that they can evaluate the prototype. Educational technology experts should evaluate the prototype on how it addresses special educational needs from the UDL perspective. The aim of this evaluation is to identify whether the application effectively addresses students' special educational needs. If something is missing, a redesign process is needed in order to improve the application. If the redesign is needed, the process needs to start again from phase 4 or 5.
7. **First testing with students:** After the first prototype is approved by teachers and educational technology experts, the first testing is carried out with students in a real scenario. It is important to gather as much information as possible during the test in terms of user interaction, engagement (a test for measuring motivation would be useful), attention to the educational needs and how the application addresses students' special educational needs. The real scenario should be prepared accordingly for the testing, considering markers, light conditions, time for the testing, etc. The first testing of the Paint-cAR application is depicted below in section 5.
8. **Evaluation:** After the first testing with students, the information gathered is evaluated in order to identify issues in the design. The results of the evaluation will allow teachers, experts in educational technology and developers to redesign the application and make the appropriate changes in order to overcome the educational needs. If a redesign is needed, the process needs to start again from phase 3. In sections 5 and 6, the results of evaluating the Paint-cAR application are shown and discussed.

These steps could be repeated iteratively in order to improve the AR applications.

4. Mobile AR Paint-cAR application design

4.1. Design Team and Learning Needs

Paint-cAR is a mobile marker-based AR application developed to support the learning process of repairing paint on a car in the context of the VET programme of car's maintenance. Repairing paint on a car is a complex process that involves a sequence of 30 steps and the use of many chemical products and tools. According to the teachers, due to this complexity, students often experience various difficulties during the learning process:

- Students do not remember the sequence of steps in the process nor the chemical products and tools they need to use for each step in the process.
- Students have attention difficulties and lack of motivation.
- Some students do not have the appropriate background knowledge for the topic.

In order to overcome these difficulties, Paint-cAR application was designed and developed according to the methodology described in section 3. In order to analyse the difficulties mentioned above, phases 1 and 2 of the methodology were applied at this point. The co-creation team was defined. For this purpose, two teachers that teach the topic of repairing paint on a car from a vocational education institution in Spain participated in this process. One

software developer with skills for developing mobile AR applications and web applications, and two experts in educational technology were also part of the team. In addition, the difficulties faced by teachers were analysed by the team and the characteristics of students were identified. The following sections describe the main features and modules of the Paint-cAR application. Currently the user interface of the Paint-cAR application works in Spanish language but with minor changes the application can support internationalization features.

4.2. Selection of Mode

Paint-cAR application works in three modes and students can choose one of them when the application starts (Phases 3 and 4 from the methodology were applied at this point):

1. **Guided Mode:** In this mode, the application guides the students step by step through the process so that they can follow the correct sequence of the 30 steps. The steps are organized into 6 phases. Each step includes some activities that students should complete in order to continue. The phases are enabled as long as students successfully complete all the activities from the previous phase.
2. **Evaluation Mode:** In this mode, the students are required to complete the process without clues or additional help. This means that they do not have additional information about the order of the steps in the process and they do not have information about the tools and products they need to use for each step in the process.
3. **Informative Mode:** In this mode, the students access all the information without any restriction. They can browse any phase and any step at any time. This means that they do not need to complete the previous step or previous phases in order to see the information for a particular step. The purpose of this mode is that the students can read the information for a particular step to remember some specific details about the process or review some information of their interest without following the whole process.

The application stores students' progress in the Guided and Evaluation Modes so that students can resume the process from the last completed step or phase.

4.3. Overview of process and steps

After selecting the mode and taking into account that students should understand the sequence of steps, the application shows an overview of the all 6 phases of the process (Fig. 1a) as well as the steps included each phase in the correct sequence (The phases appear in the correct sequence only in the guided and informative modes). Moreover, when students are learning about each phase, in this interface they can see the phases they have already explored, the current phase they are exploring and the rest of the phases they have not explored yet. This is useful for them to understand the sequence of phases in the process. This decision was made in phases 4 and 5 of the methodology.

4.4. Activities and modules for each step in the process

For each step in the process, a set of activities and modules are available to help students understand and rehearse each step of the process. Figure 1b shows the interface in which students can choose one of the activities in one of the 30 steps of the entire process. Phases 4 and 5 from the methodology were applied in order to design these activities:

- **Tools and Chemical Products:** In this activity, students are required to search for the tools and chemical products they need to use in that step in the process. In the guided and informative modes, the application provides hints and help so that students can find the chemical products or tools they need to use. In the evaluation mode, students are challenged to find the chemical products or tools without any help. In this activity, marker-based AR is used. The AR markers are stuck to the real chemical products or tools in the workshop. The students

use their smartphones' cameras in order to scan the markers and identify the chemical products or tools for that step in the process. If they make a mistake, appropriate feedback is shown in order to foster reflection and understanding about the correct decision. The following augmented information is shown superimposed for each chemical product or tool: Information about the chemical product or tool, Safety measures and Technical Datasheet and the Safety sheet data. Fig. 1c shows the augmented information that is shown when one of the markers is identified in the AR mode.

- **Videos about the process:** In this activity, students can see some videos recorded for each step of the process, so that they can see some examples of how that step is performed by the experts. This will help students to have a clear understanding about the way each step should be carried out.
- **Self-Evaluation:** In this activity, students are required to answer multiple choice questions. These questions are problem-based and are defined by the teacher using a web application that works as a repository of questions. By using this activity, students can evaluate if they understood the information provided in that step of the process.
- **Simulations:** In this activity, students can use a simulator based on AR of some tasks involved in the step, such as using the sand paper, cleaning the surface with solvent, painting, etc.

Additional modules will be available for each step in the process are: Personal Notes, Frequently Asked Questions (FAQ's) and Ask Your Teacher (AYT).



Fig 1. (a) Interface of the overview of the process; (b) Interface of activities for each step; (c) Augmented Information in the AR mode.

5. Cross-sectional evaluation study

Paint-cAR application was tested using a cross-sectional study. This evaluation study corresponds to phases 6 and 7 of the methodology described in section 3. Participants (N=13) were students from a VET institution in Spain

enrolled in the car's maintenance programme. The procedure of the study was as follows. First, an initial questionnaire was given to the participants to gather information about user characteristics and the use of mobile devices in daily activities as well as information about each participant's smartphone's model and brand in order to test the Paint-cAR's responsive design. This questionnaire was completed in 15 minutes. Then, the intervention took place, which lasted for 1 hour. During the intervention, students used the Paint-cAR application as part of an exercise for the topic of repairing paint on a car. The exercise took place in a workshop, where the AR markers were stuck to the real chemical products and tools in different places of the workshop. The students used the Paint-cAR application to follow the process step-by-step guided by the instructions of the application. During the intervention, the exercise was recorded and two researchers gathered data from direct observation.

After finishing the exercise with the Paint-cAR application, the motivational measurement instrument Instructional Materials Motivation Survey (IMMS) [6] based on the ARCS (Attention, Relevance, Confidence and Satisfaction) model was given in order to evaluate the motivation considering the attention, relevance, confidence and satisfaction dimensions. The questionnaire was completed in 40 minutes.

6. Results and discussion

Regarding the initial questionnaire, 100% of the students were male (age 16 - 25) and owned a mobile device (tablet or smartphone) with internet connection (3G, 4G or Wi-Fi). Moreover, 71,4% of the students frequently used laptop or PC. Students were asked about the "uses of mobile devices". For this question students were able to choose from multiple options, so each option could appear and be counted more than once. The results show that the students used the mobile devices for chatting (100%), making calls (92,8%), social networking (85,7%), searching on the internet (71,4%), playing games (57,1%), using maps - GPS (57,1%), and sending emails (50%).

Most of the students used mobile devices with Android operative system (78,6%) whereas 14,3% used Windows Phone and 7,1% used iPhone. It is worth noting that 85,7% of the students stated that they would like to use the mobile device for learning some topics related to their studies in the VET institution. In addition, 71,4% stated that they had previously used educational applications on their smartphone. But 50% of the students reported that they hardly ever install new applications. Overall, the results provided an overview of some conditions that may affect the study, such as the user acceptance, diversity of devices and common uses of mobile devices.

Regarding the IMMS motivation measurement instrument (applied after the intervention), the results are summarised in table 1. The four dimensions in the ARCS model provide an overview of the human learning motivation [6]. For this study the instrument was applied to measure students' motivation in terms of the four dimensions. The instrument uses a 5 points Likert scale.

Table 1. Results of the IMMS instrument applied for each dimension of the ARCS model.

Dimension	Mean	Standard Deviation
Attention	3,97	0,95
Relevance	3,90	0,92
Confidence	4,02	1,09
Satisfaction	4,19	0,86

Overall, the results are promising since they indicate positive impact on all four dimensions. Confidence (M=4,02; SD=1,09) and satisfaction (M=4,19; SD=0,86) dimensions rated better than the other two. On the one hand, according to Keller [6], confidence dimension is about helping students feel they can succeed and control their success. Besides that, providing the possibility of succeeding in the challenging tasks is important to foster motivation. This result can be explained due to the design of the Paint-cAR application because students are not only challenged to repair the paint of car's hood but are also guided to accomplish that challenge hence increasing the opportunities for succeeding in the task. This reinforces confidence in students since they can succeed in the process. On the other hand, satisfaction (rated 4,19) is about reinforcing accomplishments. One of the best ways to do that is to use meaningful opportunities to use the acquired knowledge such as experiential learning activities [6].

Paint-cAR application provide this opportunity by using AR since students are guided through the process of repairing paint in a real workshop scenario having the opportunity of interacting with real tools, products and augmented information.

Attention dimension ($M=3,97$; $SD=0,95$) is about engaging the learners and capturing their interest. Keller [6] claims that activating curiosity and creating problem-based situations could help to increase attention factor. The analysis of the recorded videos of the test suggests that the Paint-cAR application captured the interest of the students. Nevertheless, since the process is sequential, students tend to move to the same place in the workshop almost at the same time to search for the AR marker. This caused distraction in some of the students while they waited for their classmates to scan the AR marker. Even more, some of the students tried to search strategies for scanning the markers from the mobile devices of their classmates to speed up and avoid waiting for their turn. This needs to be revised for future testing.

Finally, relevance dimension ($M=3,90$; $SD=0,92$) is about meeting personal needs and goals and discovering the meaningfulness of the learning activity [6]. Although the results of the current study are positive, the time that students spent on using the application was not enough to establish a clear relationship between the concepts they were learning and rehearsing and their applicability in the real environment. This is a clear evidence of the need for longitudinal studies using the application.

7. Conclusions and future work

The main contributions of this paper are as follows: 1) We introduced an iterative methodology based on a collaborative creation (Co-creation) process integrating the Universal Design for Learning (UDL) as the inclusive learning approach for creating mobile AR applications for education; 2) The Paint-cAR application provided an experience of designing and developing mobile AR applications applying the methodology proposed for addressing student's needs in VET educational level from an inclusive learning perspective and finally; 3) We corroborated the impact of mobile AR applications in VET for increasing motivation, especially in confidence and satisfaction dimensions. This study is different from other studies reported in the literature in terms of the methodology proposed and the application designed that was based on AR technology and the Universal Design for learning to address special educational needs and overcome barriers in the learning process.

The research has provided insights on how AR can be used to support the three main guidelines of the Universal Design for Learning: a) provide multiple means of presentation b) provide multiple means of expression and c) provide multiple means of engagement. Thus, AR applications can be designed to address special educational needs of students in VET institutions. As a result, not only students with special educational needs will benefit from the inclusive learning design of the AR application, but all students can also take advantage of a good design. It means that AR could help to overcome some barriers of the one-size-fits-all curricula and support expert learning [23]. A good design could be achieved by integrating students, teachers, educational technology experts and software developers in a collaborative creation (Co-creation) process.

A limitation of this study is the small sample size and the cross-sectional nature of the study. Notwithstanding these limitations, this study suggests that an AR application increases motivation in VET students especially in confidence and satisfaction dimensions of the ARCS model. When students are in a real environment (like a workshop) with real objects and guided by augmented information seems to be an activity in which confidence and satisfaction are increased and therefore motivation is increased.

Another important practical implication is that the introduction of AR in VET institutions for supporting the learning process could help students to become familiar with this technology that they could use in the future when they go to the industry. This is mainly because the use of AR in the industry for maintenance tasks is increasing.

This research has resulted in identification of the need for a longitudinal approach as further research direction in order to explore the impact of AR in VET institutions to avoid the novelty of technology factor. Besides, the need for further studies in other VET fields has also been identified.

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