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Factors affecting the use of "Maker Route" E-learning management systems for the development of digital manufacturing skills in higher education - Engineering

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Abstract*– The objective of the research was to explore needs, systematize interests, and show results that were achieved by students of the Universidad Continental during the 2023-10 period. The "Route Maker" program aims to provide knowledge of digital manufacturing 4.0 in virtual contexts that emerged from the pandemic as a necessity to reach students. During this academic cycle, students took advantage of the Fablab resources to enhance their experiential education and applied research, both within and outside the COVID-19 context. The research has an experimental design that used a sample of 220 students from the Faculty of Engineering and Health Sciences and Humanities. Qualitative measurement tools were applied through a focus group where the "Ruta Maker" Program was presented and information was systematized in 5 dimensions: Perception of online classes, motivation attitude on the teaching methodology, work and collaborative synergy, evaluation of the Route Maker and student expectations; as a quantitative measurement tool, surveys were applied on the Likert scale in 4 dimensions and their level of influence: attractiveness, reliability, content and academic quality, and purchase intention. The results show that visual appeal impacts the purchase intention of the "Route Maker", confidence in online courses influences the perception of attractiveness, and academic quality influences the confidence to take digital courses. The "Route Maker" program includes successful cases of the application of digital manufacturing tools applied to health, biomedicine, social development, among others. The methodology used was non-experimental and had two well-defined phases. First, an exploratory factor analysis was performed. This analysis aimed to condense the information in the original variables into smaller series. Second, a confirmatory factor analysis was performed, using structural equation modeling. The structural model proposed, which uses academic achievement as a mediating variable, is explained by its variance by 63.6%. In conclusion, the content of the "Route Maker" Tele-education Program influences academic quality, because it allows students to learn about the scope of the Fablab, acquire technological skills, and ultimately consolidate themselves in projects with a positive impact.

Keywords - Tele-Education, Digital Fabrication, E-Learning-Course Design and E-Learning - Massive Open Online Courses (MOOC)

I. INTRODUCTION

According Zhang [1] Online education is important in these digital times and should be used as a practical support tool in higher education. There are relational aspects that guarantee the success of an initiative in digital education, such as MOOCs (Massive Open Online Courses) and LMS learning management systems. It is also detailed that the course design (visuals) has a positive impact on the student's interest in taking the course, as well as the automation of the course itself to streamline self-directed learning by students [2].

A key factor in the development of online learning is self-efficacy, that is, focusing on the agility that courses should take, especially for careers that involve technical knowledge of engineering and 4.0 skills Milićević [3] argues that higher education institutions should not use online education in MOOCs to develop theory, but rather should use it more to highlight the practical aspects, as there are many distractions.

The confidence to engage in a digital course is based on the ease of learning something without the need for prior knowledge. That is why there are learning levels. Tahir [4] argues in his study "Smart Learning and E-Learning recommendations" that to have more confidence in a course, it is better to show from the start everything you will learn and practice. In the engineering field, as in our course, this could be like: seeing and participating in the construction of a robot and then learning the details, from the big to the small, generating a higher level of participation in the course.

If analyzed carefully, this has worked in the present day. In different courses, you see a finished website and then the sales promise of "how to learn to do this". This will give us more confidence because we see the final product. This trend is also affirmed in the work of Voudoukis [5] where he explains that the usual practice is to motivate from the beginning, not along the way. This is a challenge for South American higher education, as the curricula, mainly in engineering, teach in a way that is contrary to this trend. In the experience of Kadirbergenovna [6] the use of Google Classroom is a relevant strategy in socioeconomic levels B and C, as it is present in approximately 76% of the young population. In addition, Google analytics will allow teachers to have access to important data such as: time in class, uploaded files, number of downloads, and even attendance.

While it is understood that it is important for the teacher to have a good performance, this research primarily analyzes the factors on which a student bases their decision to purchase a course, whether visual, perceptual in quality and confidence, as well as the extra benefits it offers. In figure 1, the process of the route maker program is detailed.

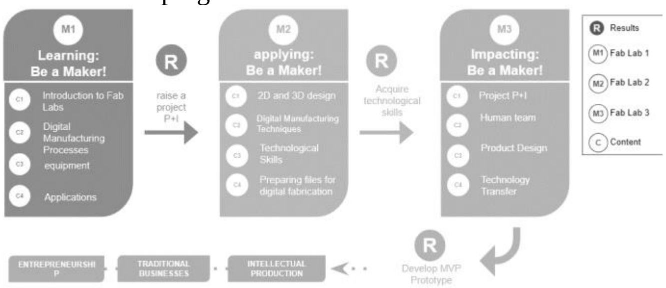

Fig. 1 Maker route program process - own authorship.

The Maker Route program is inspired by the “Maker” methodology [7], which is divided into learning, applying, and impacting with a positive impact project. This diagram was also inspired by the FAB ACADEMY program at MIT (Massachusetts Institute of Technology) to be directed at undergraduate engineering students with manufacturing and modeling. Additionally, it is subdivided into learning modules for file generation and production on 3d printing machines, CNC router, mini CNC, laser cutting and vinyl cutting as proposed by Weller [8].

According to Mourtzis [9], technologies and curricula in the maker environment should be divided into modeling and manufacturing, as this is how they are fulfilled in large companies with maker environments. The files and works must comply with open access to all areas in order to be manufactured in different parts of a company, region, or country. What is developed in one part of the world must be able to be manufactured in another part.

Thanks to Mourtzis, the categorization or levels of "maker" are also used, being:

1) *Fabber Beginner: Certification in skills and knowledge in digital manufacturing.*
2) *Fabber Basic: Certification in basic knowledge Fabrication Laboratory*
3) *Fabber Advanced: Certification in developing DIY projects that positively impact their environment.*
4) *Fabber Expert: Certification in converting positive projects into applied research or ventures through technology transfer*

For the interaction between courses and students, the administration proposed by Mwanje [10] is taken into account. In his research, Mwanje details the correct strategic implementation of positive impact projects for initiatives. He mentions that in higher education institutions, they must be linked to business incubators and seed financing. In this way, the ideas will be taken more seriously, as it will be known that they will lead to a project applied in society. It also mentions that it is necessary to have an administration with stakeholders (companies) to correctly develop the implementation.

From a social perspective, digital learning of the maker or fabrication culture is present in many fields that contribute to the development of a region. In Mapuva's analysis [11], the challenges of universities in online education are presented, where their emphasis on professionalizing family work is detailed. It is useful to have an approach that seeks to professionalize family work with engineering, as it will allow the automation of processes and activities with a social-family approach.

Another study examined the impact of experience on university students on the applications of their activities in communities. This study showed that retention of students in initiatives increased by 85% and academic satisfaction by 95%. It was detailed that these experiences allow students to collaborate with professors and classmates. In addition, each project was positively adapted to its faculty with the generation of a MVP and future entrepreneurship [12].

It is timely to cite Wong et al. [13] "Student satisfaction and attraction in higher education". In this way, it is noted that the more a student sees their knowledge reflected in a product, the better satisfaction they will have. Although this is not precisely a law, it was also shown that there was better follow-up of activities using digital environments, as they allowed students to have more time. Sousa et al. [14] in their study on: “Digital learning is an educational format towards sustainable education” also reaffirm that digital environments are more sustainable not only for students but also for teachers. While the student has to feel comfortable with their courses, the teacher is the one who provides the methodology, and this same teacher is the one who must have more ease and practicality to carry out their subjects. This allows teachers to be more flexible with their schedules. Teachers can teach at any time of the day or night, which allows them to balance their professional and personal obligations. Additionally, they will collect data on their students' performance, helping them to identify areas where students need more help and to effectively adapt their teaching accordingly.

In the analysis of important factors, the attraction for a MOOC course is considered, where Zhou [15] warn that motivation varies according to the scheduling of academic activities, this because psychologically a person will be more attracted when they are more free, their level of commitment will increase possibly by 250% and even more if it is done digitally. A study that also speaks of attraction in courses is that of Leonardi et al [16] in their recent work, which shows that carrying out gamified activities in the middle of courses will provide more interest and motivation, in addition to sharing the course with other colleagues using social networks. These activities should be understood as a "Plus" of the presented content, such as dynamics or interactive forums that allow the work done to be "liberated" in a certain way and attract more students.

Kneifel [17] discuss the relationship between trust in online learning and acquired skills. In this study, which focuses on medicine, they detail that trust is often based on the usability of the platforms, making the workflow simple and the constant optimization of the content. They also extend this to the idea that trust increases when teaching is synchronous, especially if it is to learn practical skills. Although the study takes cases from medicine, it also validates that this can be extended to other sciences, as people after the pandemic have a certain amount of more trust in online education. Another study examined the perceived quality of digital education, where it was specified that the presentation of the teaching staff and the exposure of their achievements is going to positively influence the perception of quality. This is because knowledge will be better received when you have a better image of the person teaching you, that is why it is important to tell the story of the instructor well [18]. It is also examined for the post-pandemic, Martin et al. [19], concluded that a course is more interesting when the "Blended Learning" methodology is used. They propose this strategy as a teaching trend to improve the learning experience in new scenarios in order to increase the purchase intent.

In our previous research on the role of manufacturing labs in the pandemic [20] the work of the maker culture was highlighted in the framework of an international, multi-participant collaboration according to the needs of the environment; forming motivated and empowered students as a specialized human team to support operational processes and technological transfer. In this study, through online education, we analyze the best skills to learn and the fundamental aspects to improve purchase intent in a maker program that follows a path from basic to expert, sharing in an open course for all interested students. Based on the above considerations, the following hypotheses are proposed:

H1: Perceived usefulness is positively related to Behavioral Intention to use.
H2: Job Relevance is positively related to Behavioral Intention to use.
H3: Time Efficiency is positively related to Behavioral Intention to use.
H4: Perceived Ease-of-use is positively related to Behavioral Intention to use.
H5: Job Relevance is positively related to Perceived usefulness.
H6: Perceived usefulness is positively related to Perceived Ease-of-use.
H7: Job Relevance is positively related to Time Efficiency.

II. METHODOLOGY

The sample for the study consisted of 220 university students from the following professional careers: Industrial Engineering, Mechanical Engineering, Civil Engineering, Mechatronics Engineering, and Electrical Engineering at the Universidad Continental in Arequipa, Lima, Huancayo, and Cusco. The students were randomly selected, with 72% men and 28% women, aged 18 to 23. The mean age was 20.5, and the instrument was applied in May and July 2023.

The survey was conducted on a Likert scale of 1 to 7 in order to better correlate the data, as proposed by Batterton [21] 1 indicates complete disagreement, and 7 indicates complete agreement. Data collection was conducted through an online survey.

Statistical reliability tests were performed, resulting in a Cronbach's (α) of 0.971, interpreted as good [22]. Subsequently, an Exploratory Factor Analysis (EFA) was performed [23], and the result for the Kaiser-Meyer-Olkin (KMO) test was 0.897, interpreted as good [24] and Bartlett's test with a p-value of $< .001$.

For the Confirmatory Factor Analysis (CFA) and the necessary subsequent tests, Structural Equation Modeling was chosen, using partial least squares, based on variances (PLS-SEM) [25]. The development of the research followed a systematic and rigorous process of data classification and analysis at all times with the statistical software IBM SPSS Statistics (v. 27), Smart PLS (v. 4.0.1).

III. RESULTS

In the process of determining the evaluation of the measurement model for reflective constructs of factor items, the individual indicator reliability criterion was used and a desired threshold of external loadings equal to or greater than $\lambda \geq 0.707$ was accepted [26]. This indicates that the construct explains more than 50% of the variance of the indicator, thus providing acceptable item reliability. The values obtained are shown in Table 1.

TABLE I
OUTER LOADINGS.

	Behavioral Intention to use	Perceived Ease-of-use	Perceived usefulness	Job Relevance	Time Efficiency
A1		0.942			
A2		0.953			
A3		0.957			
A4		0.897			
CA1				0.931	
CA2				0.956	
CA3				0.926	
CA4				0.966	
CO1			0.925		
CO2			0.952		
CO3			0.799		
CO4			0.872		
IR1	0.845				
IR2	0.832				
IR3	0.805				
IR4	0.823				

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IR5	0.806				
PM1					0.974
PM2					0.825
PM3					0.952
PM4					0.963

The results are high and these are ranged between 0.799 and 0.974

As for the convergent validity criterion, the Average Variance Extracted (AVE) was used. The values must be ≥ 0.5, this indicates that the construct explains at least 50% of the variance of its elements, as shown in Table 2; therefore, the result is quite satisfactory because all its values exceed 0.500 [27]. As for using the (rho_A) coefficient as a construct reliability criterion, it is recommended to verify the reliability of the values obtained in the construction and design of PLS-SEM. The results obtained in (rho_A) must have values of 0.7 or higher to demonstrate composite reliability, the results obtained are satisfactory.

TABLE 2
CONSTRUCT RELIABILITY AND VALIDITY

	Cronbach's Alpha	Composite Reliability (Rho_a)	Composite Reliability (Rho_c)	Average Variance extracted (AVE)
Behavioral Intention to use	0.887	0.918	0.913	0.676
Job relevance	0.960	0.960	0.971	0.893
Perceived Ease-of-use	0.954	0.955	0.967	0.879
Perceived usefulness	0.911	0.932	0.937	0.790
Time Efficiency	0.947	0.958	0.963	0.866

The validity discriminant test of the model, which will allow us to know to what extent the construct is different from other constructs or measures different things. In Table 3, using the Fornell-Larcker criterion, there is discriminant validity [28] in the latent variables that are part of the structural model.

TABLE 3
FORNELL-LARCKER CRITERION

	Behavioral Intention to use	Job relevance	Perceived Ease-of-use	Perceived usefulness	Time Efficiency
Behavioral Intention to use	0.822				
Job relevance	0.728	0.937			
Perceived Ease-of-use	0.534	0.704	0.889		
Perceived usefulness	0.689	0.833	0.807	0.945	
Time Efficiency	0.727	0.683	0.645	0.787	0.931

Another criterion for determining discriminant validity in reflective models is the Heterotrait-Monotrait (HTMT) ratio, which is defined as the mean of the interconstruct item correlations relative to the geometric mean of the average correlations for items that measure the same construct [29]. According to the results obtained, the discriminant validity criterion is also met. See Table 4.

TABLE 4
HETEROTRAIT-MONOTRAIT CRITERION.

	Behavioral Intention to use	Job relevance	Perceived Ease-of-use	Perceived usefulness	Time Efficiency
Behavioral Intention to use					
Job relevance	0.676				
Perceived Ease-of-use	0.738	0.871			
Perceived usefulness	0.529	0.854	0.746		
Time Efficiency	0.736	0.824	0.721	0.708	

Figure 2 is a graphical representation of the reliability and validity analysis of the model, based on R2 (coefficient of determination). In the proposed structural model, the variables that assume a dependent role are different, unlike the variable Course Quality with the Brand, which is exclusively independent. The results obtained through the R2 results show statistically significant effects of influence between the variables in the model.

We obtained:

1) *Perceived usefulness: R2 with an effect of 0.743, which is equivalent to 74% explained by the model.*
2) *Perceived Ease-of-use: R2 with an effect of 0.602, which is equivalent to 62% explained by the model.*
3) *Behavioral Intention to use: R2 with an effect of 0.836, which is equivalent to 83% explained by the model.*
4) *Time Efficiency: R2 with an effect of 0.637, which is equivalent to 63% explained by the model.*

The remaining percentage of each R2 is explained by other variables that are not part of the proposed model. See Figure 2.

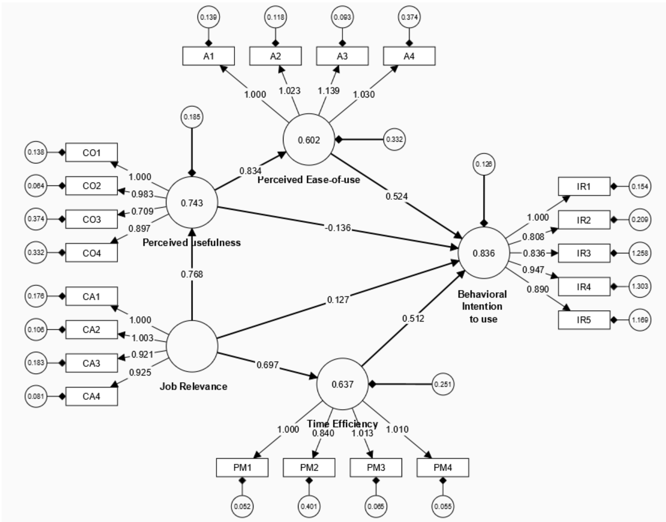

Fig. 2 Model R2 – SmartPLS – CBSEM

Table 5 presents the results of the Bootstrapping test, which allows us to know that the relationships are significantly different from zero. This is done by a process of extracting a large number of bootstrap samples (10,000) with replacement from the original sample and then estimating the parameters of the model for each bootstrap sample. The standard error of an estimate is inferred from the standard deviation of the bootstrap estimates. Considering the significance level for the p-value ($p < 0.05$), we reject hypotheses H1, H5, and H7 and accept hypotheses H2, H3, H4, and H6.

TABLE 5
FORNELL-LARCKER CRITERION

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Value
Job relevance -> Behavioral Intention to use	0.029	-0.039	0.342	0.083	**0.934**
Job relevance -> Perceived usefulness	0.807	0.809	0.077	10.477	0.000
Job relevance -> Time Efficiency	0.787	0.778	0.111	7.085	0.000
Perceived Ease-of-use-> Behavioral Intention to use	0.476	0.439	0.240	1.983	0.047
Perceived usefulness -> Behavioral Intention to use	-0.117	-0.084	0.179	0.652	**0.515**
Perceived usefulness -> Perceived Ease-of-use	0.704	0.701	0.109	6.486	0.000
Time Efficiency -> Behavioral Intention to use	0.454	0.535	0.324	1.400	**0.161**

IV. CONCLUSIONS

The Ruta Maker program offers a valuable opportunity for the development of specialized skills in digital manufacturing for engineering. By being designed as an experiential route on an open platform, it provides users from diverse disciplines the opportunity to improve their employability profiles, focusing on 4.0 technologies, digital manufacturing, and I+P product design. This approach aligns with the current demands of the labor market, where skills in these areas are becoming increasingly essential. See figure 3.

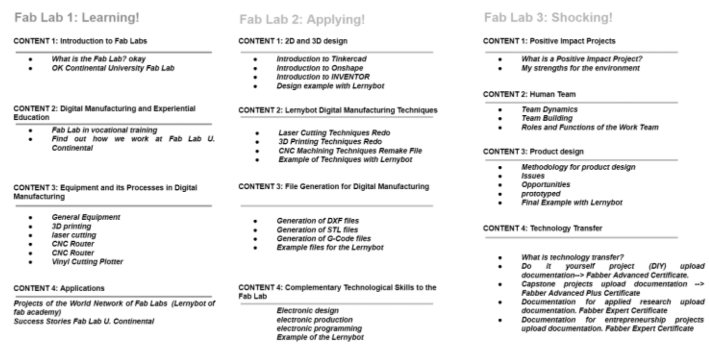

Fig. 3 Contents per module - own authorship

The first module, Fab Lab 1, is presented as an accessible introduction for users with no prior knowledge of digital manufacturing. The goal of providing foundations and understanding of the impact on the development of technological products offers a solid foundation for progression to more advanced levels.

Fab Lab 2 and Fab Lab 3 build on this foundation, offering a deeper and more practical approach for users with different levels of understanding. These modules allow participants to acquire complementary technological skills and advance from basic training to the creation of functional prototypes and field validation.

The virtual distance learning environment facilitates the participation of users from diverse locations, while the support of a competent team from the Fab Lab U. Continental ensures the quality and appropriate guidance throughout the modules. The availability of digital manufacturing laboratories on several campuses for the prototyping and development phase of minimum viable products (MVPs) adds a practical and real-world component to the program. The proposed technology transfer, from the laboratory to the market, underscores the practical and entrepreneurial approach of the program. The inclusion of aspects such as documentation for production and intellectual property, as well as the orientation towards entrepreneurship or traditional businesses according to the interests of the users, demonstrates the versatility and applicability of the program in diverse professional contexts.

The Maker Router program not only offers a comprehensive, free training in digital manufacturing technologies, but it also promotes practical application and entrepreneurship. Its potential to elevate specialized skills in digital manufacturing for engineering positions it as a significant contribution to the development of professionals who are qualified and adaptable to the changing demands of the industry.

V. Discussion

Future improvements to be considered:

Gradual progression of knowledge and skills: The program begins with an accessible introduction for users with no prior knowledge of digital manufacturing. As participants progress, they are presented with more complex concepts and skills. This allows participants to learn at their own pace and adapt to their individual needs.

Practical focus: The program focuses on the practical application of digital manufacturing skills. Participants have the opportunity to develop functional prototypes and validate their designs. This helps them develop problem-solving and innovation skills.

Entrepreneurial focus: The program promotes entrepreneurship and innovation. Participants have the opportunity to develop their own projects based on the skills they have learned. This helps them develop project management and business creation skills.

Add more content on emerging technologies: Digital manufacturing is a rapidly evolving field. It is important for digital manufacturing programs to include content on emerging technologies, such as additive manufacturing, robotic manufacturing, and artificial intelligence.

Offer more opportunities for collaboration: Collaboration is important in the current workforce. Digital manufacturing programs could offer more opportunities for participants to collaborate on projects with each other. This would help them develop teamwork and communication skills.

Integrate sustainability: Sustainability is becoming an increasingly important concern in manufacturing. Digital manufacturing programs could integrate sustainability into their curriculum. This would help participants develop skills for sustainable manufacturing.

Acknowledgment

Thanks to the research, a correct digital distribution of content was carried out in the academic ecosystem of the Continental University, having positive results and progressive certifications of students, mostly engineering students. Even exceeding 8 million interactions/events on the page, highlighting that there is constant activity in the development of maker courses (from basic to expert).

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