STUDENTS' PERCEPTIONS ABOUT THE USE OF FLIPPED CLASSROOM IN THE FIELD OF ELECTRONIC ELECTRICAL ENGINEERING

PERCEPCIONES DE LOS ESTUDIANTES SOBRE EL USO DEL AULA INVERTIDA EN EL CAMPO DE LA INGENIERÍA ELÉCTRICA ELECTRÓNICA

Ricardo-Adán Salas-Rueda
Universidad Nacional Autónoma de México, UNAM
Cidade do México, México
ricardo.salas@icat.unam.mx

Jesús Ramírez-Ortega
Universidad Nacional Autónoma de México, UNAM
Cidade do México, México
jesus.ramirez@icat.unam.mx

Abstract. The objective of this mixed research is to analyze the impact of flipped classroom in the educational process on the Combinational Circuits through data science and machine learning. Flipped classroom facilitates the organization of active activities before, during and after the class. The participants are 17 students of Electronic Electrical Engineering who took the Digital Design course in the National Autonomous University of Mexico during the 2019 school year. The results of machine learning indicate that the consultation of the videos before the class, resolution of the exercises during the class through the Quartus software and realization of the laboratory practices after the class positively influence the development of skills on circuit design. Data science identifies 3 predictive models of the use of flipped classroom through the decision tree technique. Finally, teachers can improve the learning process, develop the skills of students, build new educational spaces and carry out creative activities through flipped classroom.

Keywords: flipped classroom; higher education; technology; data Science; machine learning.

Resumen. El objetivo de esta investigación mixta es analizar el impacto del aula invertida en el proceso educativo sobre los Circuitos Combinacionales por medio de la ciencia de datos y el aprendizaje automático. El aula invertida facilita la organización de actividades activas antes, durante y después de la clase. Los participantes son 17 estudiantes de la Ingeniería Eléctrica Electrónica que cursaron la asignatura Diseño Digital en la Universidad Nacional Autónoma de México durante el ciclo escolar 2019. Los resultados del aprendizaje automático indican que la consulta de videos antes de la clase, la resolución de ejercicios durante la clase por medio del software Quartus II y la realización de prácticas de laboratorio después de la clase por medio del software Quartus II influyen positivamente el desarrollo de habilidades sobre el diseño de circuitos. La ciencia de datos identifica 3 modelos predictivos sobre el uso del aula invertida por medio de la técnica árbol de decisión. Por último, los docentes pueden mejorar el proceso de aprendizaje, desarrollar las habilidades de los estudiantes, construir nuevos espacios educativos y realizar creativas actividades por medio del aula invertida.

Palabras clave: aula invertida; enseñanza superior; tecnología; ciencia de datos; aprendizaje automático.

INTRODUCTION

Flipped classroom is a pedagogical model that proposes the realization of school activities inside and outside the classroom (Desai, Jabeen, Abdul, & Rao, 2018; Oncel & Kara, 2019; Salas-Rueda, 2020). Information and Communication Technology (ICT) plays a fundamental role during the planning and organization of the courses (Galimullina, Ljubimova, & Ibatullin, 2020; McGowan, 2020; Padilla-Rodriguez, Armellini, & Rodriguez-Nieto, 2020). In fact, teachers create new activities before, during and after the face-to-face sessions through technological tools, educational platforms and web applications (Green & Schlairet, 2017; Rezaei & Latifi, 2020; Salas-Rueda, 2019).

Flipped classroom consists of organizing and carrying out various activities before, during and after the class (Lin, 2019). For example, students can take exams online and consult digital resources such as videos and digital presentations at home (Lin, 2019; Webel, Sheffel, & Conner, 2018). In the classroom, students carry out various activities that facilitate the active participation such as group discussions, collaborative work and problem solving (Oncel & Kara, 2019).

The incorporation of flipped classroom in universities is causing that students actively participate during the learning process (Bingen, Steindal, Krumsvik, & Tveit, 2019). For example, students of medicine viewed the anatomy videos, solved the online exams and held the discussion forums outside of the classroom (Bingen, Steindal, Krumsvik, & Tveit, 2019). Furthermore, the students worked collaboratively in the face-to-face sessions (Bingen, Steindal, Krumsvik, & Tveit, 2019).

In the field of Electronic Electrical Engineering, students have problems developing their skills and assimilating knowledge about logic gates because these topics are difficult to understand and use in the business field. Technological advances are transforming the learning process because students actively participate inside and outside the classroom through the use of digital tools and web applications in school activities.

This mixed research proposes the transformation of the teaching-learning process on the Combinational Circuits through flipped classroom. The students of Electronic Electrical Engineering took the Digital Design course with the aim of understanding the use of logic gates in the productive context. Consequently, the teacher of this course seeks to improve the teaching-learning process on the Combinational Circuits through the consultation of videos before the class, resolution of exercises with the support of the Quartus software during the class and realization of the laboratory practices after the class. The Combinational Circuits unit contains the topics about Truth tables, Karnaugh Maps and use of Combinational Circuits. Therefore, the research questions are:

- What is the impact of flipped classroom during the educational process on the Combinational Circuits?
- What are the predictive models on the use of flipped classroom and development of skills on circuit design?
- What are the students' perceptions about the realization of the activities before, during and after the class?

FLIPPED CLASSROOM IN THE EDUCATIONAL FIELD

Flipped classroom facilitates the active role of students during the teaching-learning process because this pedagogical model promotes the performance of collaborative activities in the face-to-face sessions and participation of students at home through the consultation of videos and digital presentations (Desai, Jabeen, Abdul, & Rao, 2018). In the software engineering course, flipped classroom improved the academic performance, increased the motivation of students and facilitated the resolution of problems through videos, online exams and collaborative work (Lin, 2019).

The students of chemical engineering mention that flipped classroom facilitated the use of theoretical concepts in the productive field and increased the motivation during the learning process (Valero, Martinez, Pozo, & Planas, 2019). In fact, the consultation of videos at home and realization of the collaborative activities in the classroom facilitated the assimilation of knowledge on the topics of chemistry (Valero, Martinez, Pozo, & Planas, 2019).

Various authors (e.g., Oncel & Kara, 2019) have used flipped classroom to build new educational spaces and improve the teaching-learning process on electrical engineering and electronics. During the electrical engineering course, students consulted the digital readings with voice and took the online exams on communication systems at home (Oncel & Kara, 2019). Also, the class time was used for the realization of discussion forums and problem solving (Oncel & Kara, 2019).

The benefits of flipped classroom are the increase of academic performance and creation of new educational spaces that facilitate the learning process (Oncel & Kara, 2019). Finally, flipped classroom is a pedagogical model that improves the teaching-learning conditions through the realization of creative activities outside and inside the classroom (Dehghanzadeh & Jafaraghaee, 2018; Kim, Yoon, Hong, & Min, 2019; Webel, Sheffel, & Conner, 2018).

METHODOLOGY

The objective of this mixed research is to analyze the impact of flipped classroom in the educational process on the Combinational Circuits through data science and machine learning.

Participants

The participants are 17 students of Electronic Electrical Engineering (11 men and 6 women) who took the Digital Design course during the 2019 school year. The average age is 21.41 years.

Procedure

The teacher of the Digital Design course used the techno-pedagogical model proposed by Gamboa-Rodríguez (2015) to transform the learning process through the incorporation of technology and use of flipped classroom in school activities (See Figure 1).

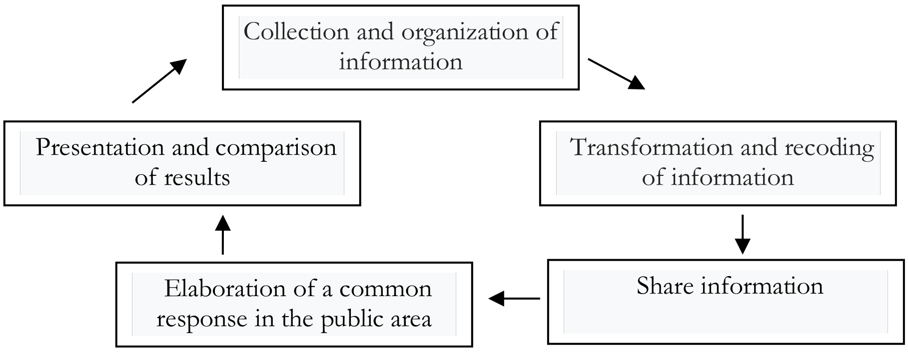

Figure 1. Techno-pedagogical model proposed by Gamboa-Rodríguez (2015).

The teacher of the Digital Design course selects the YouTube videos on the truth tables (session 1), Karnaugh Maps (session 2 and 3) and use of combinational circuits (session 4 and 5) to facilitate the consultation of the information at any place and time. Also, the Quartus software allows the design and analysis of digital circuits, therefore, the organization of exercises and laboratory practices considers the use of this software (See Table 1).

Table 1. Use of flipped classroom in the Combinational Circuits unit.

Session	Objective	Before the class	During the class	After the class
1	Understand the use of truth tables	The students consult the videos on the truth tables: And, Or, Not, Nand and Nor	In a collaborative way, the students solve the exercises on the truth tables: And, Or, Not, Nand and Nor through the Quartus software	The students do the laboratory practices on the truth tables: And, Or, Not, Nand and Nor through the Quartus software
2	Understand the use of Karnaugh Maps for 2 and 3 variables	The students consult the videos on the use of Karnaugh Maps for 2 and 3 variables	In a collaborative way, the students solve the exercises on the use of Karnaugh Maps for 2 and 3 variables through the Quartus software	The students do the laboratory practices on the use of Karnaugh Maps for 2 and 3 variables through the Quartus software
3	Understand the use of Karnaugh Maps for 4 variables	The students consult the videos on the use of Karnaugh Maps for 4 variables	In a collaborative way, the students solve the exercises on the use of Karnaugh Maps for 4 variables through the Quartus software	The students do the laboratory practices on the use of Karnaugh Maps for 4 variables through the Quartus software
4	Understand the decoders and multiplexers	The students consult the videos on the decoders and multiplexers	In a collaborative way, the students solve the exercises on the decoders and multiplexers through the Quartus software	The students do the laboratory practices on the decoders and multiplexers through the Quartus software
5	Understand the comparators and adders	The students consult the videos on the comparators and adders	In a collaborative way, the students solve the exercises on the comparators and adders through the Quartus software	The students do the laboratory practices on the comparators and adders through the Quartus software

Table 2 shows an example of the activities performed during and after the class through the Quartus software.

Table 2. Example of activities during and after the class.

No.	Topic	Objective	During the class	After the class
1	Karnaugh Maps for 2 variables	Understand the use of Karnaugh Maps for 2 variables	Collaboratively (2 or 3 people), reduce the following function. A | B | Z 0 | 0 | 1 0 | 1 | 1 1 | 0 | 1 1 | 1 | 0 Subsequently, design the digital circuit through the Quartus software	Reduces the following function. A | B | Z 0 | 0 | 0 0 | 1 | 1 1 | 0 | 1 1 | 1 | 1 Subsequently, designs the digital circuit through the Quartus software
2	Karnaugh Maps for 3 variables	Understand the use of Karnaugh Maps for 3 variables	Collaboratively (2 or 3 people), reduce the following function. A | B | C | Z 0 | 0 | 0 | 0 0 | 0 | 1 | 0 0 | 1 | 0 | 1 0 | 1 | 1 | 1 1 | 0 | 0 | 1 1 | 0 | 1 | 1 1 | 1 | 0 | 0 1 | 1 | 1 | 0 Subsequently, design the digital circuit through the Quartus software	Reduces the following function. A | B | C | Z 0 | 0 | 0 | 0 0 | 0 | 1 | 0 0 | 1 | 0 | 0 0 | 1 | 1 | 0 1 | 0 | 0 | 1 1 | 0 | 1 | 1 1 | 1 | 0 | 1 1 | 1 | 1 | 1 Subsequently, designs the digital circuit through the Quartus software

The research hypotheses on the use of flipped classroom in the teaching-learning process are:

- Hypothesis 1 (H1): The consultation of the videos before the class positively influences the development of skills on circuit design
- Hypothesis 2 (H2): The resolution of the exercises during the class through the Quartus software positively influences the development of skills on circuit design
- Hypothesis 3 (H3): The realization of the laboratory practices after the class through the Quartus software positively influences the development of skills on circuit design

Data science allows identifying the following predictive models on the use of flipped classroom:

- Predictive Model 1 (PM1) on the consultation of the videos before the class and development of skills on circuit design
- Predictive Model 2 (PM2) on the resolution of the exercises during the class through the Quartus software and development of skills on circuit design
- Predictive Model 3 (PM3) on the realization of the laboratory practices after the class through the Quartus software and development of skills on circuit design

Data analysis

The Rapidminer tool allows calculating machine learning to evaluate the research hypotheses about the use of flipped classroom and build the predictive models through the decision tree technique. Machine learning uses the training section (60%, 70% and 80% of the sample) to calculate the linear regressions and evaluation section (40%, 30% and 20% of the sample) to identify the accuracy of these linear regressions. On the other hand, data science allows building the predictive models on the use of flipped classroom.

Data collection

Table 3 shows the questionnaire on the use of flipped classroom in the teaching-learning process. Data collection was performed at a Mexican university during the 2019 school year.

Table 3. Questionnaire on the use of flipped classroom.

Variable	Dimension	Question	Answer	n	%
Profile of students	Sex	1. Indicate your sex	Man	11	64.71%
			Woman	6	35.29%
	Age	2. Indicate your age	19 years	0	0.00%
			20 years	0	0.00%
			21 years	11	64.71%
			22 years	5	29.41%
			> 22 years	1	5.88%
Flipped classroom	Before the class	3. The consultation of the videos before the class improves the learning process	Too much (1)	11	64.71%
			Much (2)	6	35.29%
			Little (3)	0	0.00%
			Too little (4)	0	0.00%
		4. The activities before the class improve the development of skills on circuit design	Too much (1)	6	35.29%
			Much (2)	10	58.82%
			Little (3)	1	5.88%
			Too little (4)	0	0.00%
	During the class	5. The resolution of the exercises during the class through the Quartus software improves the learning process	Too much (1)	6	35.29%
			Much (2)	9	52.94%
			Little (3)	2	11.76%
			Too little (4)	0	0.00%
		6. The activities during the class improve the development of skills on circuit design	Too much (1)	6	35.29%
			Much (2)	11	64.71%
			Little (3)	0	0.00%
			Too little (4)	0	0.00%
	After the class	7. The realization of the laboratory practices after the class through the Quartus software improves the learning process	Too much (1)	5	29.41%
			Much (2)	10	58.82%
			Little (3)	2	11.76%
			Too little (4)	0	0.00%
		8. The activities after the class improve the development of skills on circuit design	Too much (1)	2	11.76%
			Much (2)	15	88.24%
			Little (3)	0	0.00%
			Too little (4)	0	0.00%
Perception of students	Activities before the class	9. What do you think about the realization of the activities before the class?	Open	-	-
	Activities during the class	10. What do you think about the realization of the activities during the class?	Open	-	-
	Activities after the class	11. What do you think about the realization of the activities after the class?	Open	-	-

The values of Load Factor (> 0.500), Cronbach's Alpha (> 0.700) and Composite Reliability (> 0.700) allow the validation of the questionnaire (See Table 4).

Table 4. Validation of the questionnaire.

No.	Variable	Dimension	Load factor	Cronbach's alpha	Average Variance Extracted	Composite Reliability
1	Flipped classroom	Consultation of the videos	0.575	0.751	0.475	0.843
		Activities before the class	0.669			
		Resolution of the exercises	0.724			
		Activities during the class	0.747			
		Realization of the laboratory practices	0.772			
		Activities after the class	0.628			

RESULTS

The results of machine learning indicate that the consultation of the videos before the class, resolution of the exercises during the class through the Quartus software and realization of the laboratory practices after the class positively influence the development of skills on circuit design (See Table 5).

Table 5. Results of machine learning.

Hypothesis	Training	Linear Regression	Conclusion	Squared error
H1: Consultation of the videos → development of skills on circuit design	60%	y = 0.499x + 1.000	Accepted: 0.499	0.178
	70%	y = 0.571x + 0.857	Accepted: 0.571	0.232
	80%	y = 0.555x + 0.888	Accepted: 0.555	0.206
H2: Resolution of the exercises → development of skills on circuit design	60%	y = 0.416x + 0.833	Accepted: 0.416	0.139
	70%	y = 0.499x + 0.750	Accepted: 0.499	0.162
	80%	y = 0.442x + 0.852	Accepted: 0.442	0.205
H3: Realization of the laboratory practices → development of skills on circuit design	60%	y = 0.367x + 1.102	Accepted: 0.367	0.099
	70%	y = 0.372x + 1.118	Accepted: 0.372	0.114
	80%	y = 0.299x + 1.300	Accepted: 0.299	0.060

Table 6 shows the predictive models on the use of flipped classroom. Data science identifies 3 conditions for PM1, 5 conditions for PM2, and 4 conditions for PM3 through the decision tree technique.

Table 6. Predictive models on the use of flipped classroom.

Predictive models	Consultation of the videos → learning	Resolution of the exercises → learning	Realization of the laboratory practices → learning	Sex	Age	Activities → development of skills
1	Too much	-	-	Man	≤ 22.5 years	Too much
	Much	-	-	Man	≤ 22.5 years and > 21.5 years	Too much
	Much	-	-	Man	≤ 21.5 years	Much
2	-	Too much	-	-	> 22.5 years	Much
	-	Too much	-	Man	≤ 22.5 years	Too much
	-	Too much	-	Woman	≤ 22.5 years	Much
	-	Much	-	-	-	Much
	-	Little	-	-	-	Much
3	-	-	Too much	Man	-	Much
	-	-	Too much	Woman	-	Too much
	-	-	Much	-	-	Much
	-	-	Little	-	-	Much

Before the class

The consultation of the videos before the class improves too much (n = 11, 64.71%) and much (n = 6, 35.29%) the learning process (See Table 3). Likewise, the activities before the class improve too much (n = 6, 35.29%), much (n = 10, 58.82%) and little (n = 1, 5.88%) the development of skills on circuit design. The results of machine learning with 60% (0.499), 70% (0.571) and 80% (0.555) of training indicate that H1 is accepted (See Table 5). Therefore, the consultation of the videos before the class positively influences the development of skills on circuit design.

The PM1 presents 3 predictive conditions about the activities before the class with the accuracy of 70.59% (See Table 6). For example, if the student considers that the consultation of the videos before the class improves too much the learning process, is a man and has an age ≤ 22.5 years then the activities before the class improve too much the development of skills on circuit design.

The students of Electronic Electrical Engineering mention that the consultation of the videos before the class facilitates the learning process:

> "It helps to understand" (Student 4, man, 23 years old).
> "It helps to understand the design of circuits" (Student 9, woman, 21 years old).

In addition, the activities before the class allow that students acquire the knowledge at home:

> "It gives us information before the class" (Student 10, man, 21 years old).
> "We know concepts previously" (Student 14, woman, 21 years old).

During the class

The resolution of the exercises during the class through the Quartus software improves too much (n = 6, 35.29%), much (n = 9, 52.94%) and little (n = 2, 11.76%) the learning process (See Table 3). Also, the activities during the class improve too much (n = 6, 35.29%) and much (n = 11, 64.71%) the development of skills on circuit design. The results of machine learning with 60% (0.416), 70% (0.499) and 80% (0.442) of training indicate that H2 is accepted (See Table 5). Therefore, the resolution of the exercises during the class through the Quartus software positively influences the development of skills on circuit design.

The PM2 presents 5 predictive conditions about the activities during the class with the accuracy of 82.35% (See Table 6). For example, if the student considers that the resolution of the exercises during the class through the Quartus software improves too much the learning process, is a woman and has an age ≤ 22.5 years then the activities during the class improve much the development of skills on circuit design.

The students of Electronic Electrical Engineering mention that the resolution of the exercises during the class through the Quartus software facilitates participation during the learning process:

> "It fosters the participation and collaboration" (Student 8, man, 21 years old).
> "We share the experiences and knowledge" (Student 14, woman, 21 years old).

The activities during the class allow solving the doubts:

> "It allows resolving the doubts" (Student 1, man, 21 years old).
> "It helps to clarify the doubts" (Student 4, man, 23 years old).

After the class

The realization of the laboratory practices after the class through the Quartus software improves too much (n = 5, 29.41%), much (n = 10, 58.82%) and little (n = 2, 11.76%) the learning process (See Table 3). Also, the activities after the class improve too much (n = 2, 11.76%) and much (n = 15, 88.24%) the development of skills on circuit design. The results of machine learning with 60% (0.367), 70% (0.372) and 80% (0.299) of training indicate that H3 is accepted (See Table 5). Therefore, the realization of the laboratory practices after the class through the Quartus software positively influences the development of skills on circuit design.

The PM3 presents 4 predictive conditions about the activities after the class with the accuracy of 94.12% (See Table 6). For example, if the student considers that the realization of the laboratory practices after the class through the Quartus software improves too much the learning process and is a woman then the activities after the class improve too much the development of skills on circuit design.

The students of Electronic Electrical Engineering mention that the realization of the laboratory practices after the class through the Quartus software facilitates the review of topics:

> "It allows the review" (Student 10, man, 21 years old).
> "It helps to review the information" (Student 11, man, 21 years old).

Also, the activities after the class facilitate the assimilation of knowledge and learning process:

> "It allows understanding the topics" (Student 7, man, 21 years old).
> "It facilitates the learning process at home" (Student 12, man, 22 years old).

DISCUSSION

Flipped classroom facilitates the construction of new educational spaces and improves the teaching-learning process on the Combinational Circuits. In particular, most of the students (n = 10, 58.82%) think that the activities before the class improve much the development of skills on circuit design.

The use of the Quartus software allows the creation of new educational scenarios that facilitate the active role of the student during the learning process. In fact, most of the students think that the activities during (n = 11, 64.71%) and after (n = 15, 88.24%) the class improve much the development of skills on circuit design.

Before the class

The use of technology before the class allows that students take an active role during the learning process (Lin, 2019; Salas-Rueda, De-La-Cruz-Martínez, Alvarado-Zamorano, & Gamboa-Rodríguez, 2020). Most of the students (n = 11, 64.71%) think that the consultation of the videos before the class improves too much the learning process. In addition, the results of machine learning on H1 are higher than 0.490, therefore, the consultation of the videos before the class positively influences the development of skills on circuit design.

During the class

Various authors (e.g., Lin, 2019; Oncel & Kara, 2019; Salas-Rueda, Salas-Rueda, & Salas-Rueda, 2020) mention that the use of technological tools in the classroom improves the academic performance of students. Most of the students (n = 9, 52.94%) think the resolution of the exercises during the class through the Quartus software improves much the learning process. The results of machine learning on H2 are greater than 0.410, therefore, the resolution of the exercises during the class through the Quartus software positively influences the development of skills on circuit design.

After the class

Teachers can build new learning spaces through the use of ICTs (Oncel & Kara, 2019; Webel, Sheffel, & Conner, 2018). Most of the students (n = 10, 58.82%) think that the realization of the laboratory practices after the class through the Quartus software improves much the learning process. The results of machine learning on the H3 are greater than 0.290, therefore, the realization of the laboratory practices after the class through the Quartus software positively influences the development of skills on circuit design.

CONCLUSION

Flipped classroom improves the teaching-learning process on the Combinational Circuits through the use of technology. The results of machine learning indicate that the consultation of the videos before the class, resolution of the exercises during the class through the Quartus software and realization of the laboratory practices after the class positively influence the development of skills on circuit design. On the other hand, data science identifies 3 predictive models on the use of flipped classroom.

This research recommends the use of flipped classroom in the educational field because students acquire an active role during the realization of the activities before, during and after the class. In fact, the implications of this study are the importance of flipped classroom for the construction of new educational spaces and organization of creative activities supported by the use of technology.

The limitations of this research are the sample size and consultation of videos and use of the Quartus software during the teaching-learning process. Therefore, future research can analyze the impact on the review of digital readings, realization online exams and use of web 2.0 tools, educational platforms and mobile applications inside and outside the classroom. In addition, teachers can implement flipped classroom considering distance education.

Finally, teachers and educational institutions have the opportunity to improve the teaching-learning conditions through flipped classroom because this pedagogical model facilitates the organization and realization of new activities before, during and after the class.

ACKNOWLEDGMENTS

This research is supported by the "Aula del Futuro" project.

REFERENCES

Bingen, H. N., Steindal, S. A., Krumsvik, R., & Tveit, B. (2019). Nursing students studying physiology within a flipped classroom, self-regulation and off-campus activities. *Nurse Education in Practice*, 35, 55-62. https://doi.org/10.1016/j.nepr.2019.01.004

Dehghanzadeh, S. & Jafaraghaee, F. (2018). Comparing the effects of traditional lecture and flipped classroom on nursing students' critical thinking disposition: A quasi-experimental study. *Nurse Education Today*, 71, 151-156 https://doi.org/10.1016/j.nedt.2018.09.027

Desai, S. V., Jabeen, S. S., Abdul, W. K. & Rao, S. A. (2018). Teaching cross-cultural management: A flipped classroom approach using films. *The International Journal of Management Education*, 16(3), 405-431.

Galimullina, E., Ljubimova, E., & Ibatullin, R. (2020). SMART education technologies in mathematics teacher education - ways to integrate and progress that follows integration. *Open Learning: The Journal of Open, Distance and e-Learning*, 35(1), 4-23. https://doi.org/10.1080/02680513.2019.1674137

Gamboa-Rodríguez, F. (2015). Diseño de Espacios Colaborativos Interactivos para el aprendizaje. In J. Zubieta-García & C. Rama-Vitale, *La Educación a Distancia en México: Una nueva realidad universitaria* (pp. 201-212). Mexico City: UNAM.

Green, R. D. & Schlairet, M. C. (2017). Moving toward heutagogical learning: Illuminating undergraduate nursing students' experiences in a flipped classroom. *Nurse Education Today*, 49, 122-128. https://doi.org/10.1016/j.nedt.2016.11.016

Kim, Y. M., Yoon, Y. S., Hong, H. C., & Min, A. (2019). Effects of a patient safety course using a flipped classroom approach among undergraduate nursing students: A quasi-experimental study. *Nurse Education Today*, 79, 180-187. https://doi.org/10.1016/j.nedt.2019.05.033

Lin, Y. T. (2019). Impacts of a flipped classroom with a smart learning diagnosis system on students' learning performance, perception, and problem solving ability in a software engineering course. *Computers in Human Behavior*, 95, 187-196. https://doi.org/10.1016/j.chb.2018.11.036

Oncel, A. F. & Kara, A. (2019). A flipped classroom in communication systems: Student perception and performance assessments. *International Journal of Electrical Engineering & Education*, 56(3) 208-221.

McGowan, V. (2020). Institution initiatives and support related to faculty development of open educational resources and alternative textbooks. *Open Learning: The Journal of Open, Distance and e-Learning*, 35(1), 24-45. https://doi.org/10.1080/02680513.2018.1562328

Padilla-Rodriguez, B. C., Armellini, A., & Rodriguez-Nieto, M. C. (2020). Learner engagement, retention and success: why size matters in massive open online courses (MOOCs). *Open Learning: The Journal of Open, Distance and e-Learning*, 35(1), 46-62. https://doi.org/10.1080/02680513.2019.1665503

Rezaei, S. & Latifi, A. (2020). Iranian EFL learners' identity construction in a critical reflective course: a case of an online course. *Open Learning: The Journal of Open, Distance and e-Learning*, 35(1), 63-81. https://doi.org/10.1080/02680513.2019.1632700

Salas-Rueda, R. A. (2020). Use of the flipped classroom to design creative and active activities in the field of computer science. *Creativity studies*, 13(1), 136–151. https://doi.org/10.3846/cs.2020.10336

Salas-Rueda, R. A. (2019). Construction and evaluation of a web application for the educational process on Normal Distribution considering the science of data and machine learning. *Research in Learning Technology*, 27, 1-24. https://doi.org/10.25304/rlt.v27.2085

Salas-Rueda, R. A., De-La-Cruz-Martínez, G., Alvarado-Zamorano, C., & Gamboa-Rodríguez, F. (2020). Mobile devices and Collaborative wall: Media to innovate the teaching learning process on social sciences? *Meta: Avaliacao*, 12(36), 601-624.

Salas-Rueda, R. A., Salas-Rueda, E. P., & Salas-Rueda, R. D. (2020). Analysis and design of the web game on descriptive statistics through the ADDIE model, data science and machine learning. *International Journal of Education in Mathematics, Science and Technology*, 8(3), 245-260. https://doi.org/10.46328/ijemst.v8i3.759

Valero, M. M., Martinez, M., Pozo, F., & Planas, E. (2019). A successful experience with the flipped classroom in the Transport Phenomena course. *Education for Chemical Engineers*, 26, 67-79.

Webel, C., Sheffel, C., & Conner, K. A. (2018). Flipping instruction in a fifth grade class: A case of an elementary mathematics specialist. *Teaching and Teacher Education*, 71, 271-282. https://doi.org/10.1016/j.tate.2018.01.007