Digital Transformation in Education during COVID–19: a Case Study

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***Abstract*—Digital transformation is slow process in education which became an urgent topic in the spring of 2020 due to COVID-19. In mid March, the Hungarian Government closed the schools and universities and the classes were held in online form. This faced both students and teachers with unexpected challenges. Survey was conducted among the Computer Science and Information Technologist students of the Eszterhazy Karoly University at the end of the semester. Our survey was focused on the experience, feelings and overall expression of the students regarding to digital education and recent changes. Moreover, the survey contains questions about technical preparation and infrastructure. The responses are processed by well-known statistical data analysis tools. Based on the results, the students enjoyed the digital education and half of them are willing to continue it in the future. In addition, students would prefer to use their own devices during on tutorials which allow some changes in the labor environments. Unfortunately, some students had technical issues which may be caused by the heterogeneous software environment and can be solved with support material. Digital transformation was considered successful and the feedback will be integrated into our online classes.**

I. Introduction

Digital Transformation is an important process to integrate digital solutions to our everyday lives. It affects different sectors, for example businesses [1], [2], industry [3] or health care [4]. However, the digital transformation not just enhances traditional solutions, it can lead to innovative approaches. There was also a demand to integrate digital solutions into education [5], [6], [7].

Cognitive Infocommunication [8], [9] technologies focuses on inter-cognitive and intra-cognitive communications. Cognitive infocommunication technology development allowed the remote work and asynchronous collaboration in the last decades. "Cognitive infocommunication investigates the link between the research areas of infocommunications and cognitive sciences, as well as the various engineering applications which have emerged as a synergic combination of these sciences" [8]. The augmented reality is an emerging technology to be used for multiple purposes [10], [11], [12], [13], [14]. It also have a huge impact on education [15], [16], [17], [18], [19] Digital education and remote work rely on infocommunication technologies to facilitate collaboration and may include intelligent tools.

The digital solutions in the classroom [20], [21], [22] can be hardware-based or software-based. Hardware-based solutions mean using devices like tablets, smart phones or interactive SMART boards to enhance the learning process. Software-based solutions can promote collaboration among the students, or speed up the learning process. There are different strategies how to carry out digital transformation in education [23], [24], [25]. The teachers' ability to adapt to the digital education is examined [26], [27]. Moreover, novice teachers could adapt to the digital solutions more rapidly [27].

Learning Management Systems and Online Courses are well known phenomena and used in private education but they are seldom used in Hungarian public schools and universities. However, it require the possession of capable devices [28], which limit the accessibility of these solutions. These solutions in the higher education had been examined previously [29], [30], [31].

COVID-19 forced the Digital Transformation in Education in Hungary in early 2020. Remote education and work are not a novel solution but it is not quite common in Hungary therefore it faced both students and teachers with new challenges. Eszterhazy Karoly University among other institutions was closed in mid March due to the pandemic and education was changed from classical face–to–face to online classes.

Our goal is to perform an exploratory analysis in order to get a better insight into the performance of the recent digital transformation and identify student groups. Survey among students of computer science was conducted about their feeling, challenges, experiments about the digital courses and recent changes.

II. Methods

The goal of the research is to explore the experience, the feelings and the overall expression of the students regarding digital education and recent changes. A survey had been created using Google Forms to reach the students and to reveal their thoughts about the topic. The target group is the Computer Science, and Business Informatics Engineer students of Eszterhazy Karoly University. The participation in the research was voluntary.

A. Survey

The survey consisted of 27 questions, where besides the two identification fields, 5 groups can be established, and each group contains 5 questions.

Questions about the student's information is presented to ensure that no duplicates can be found in the results. A student can attend multiple subjects, and the subjects are held using various methods and require different environments. Thus, besides the identifier of the student called `Neptun-code`, the subject is asked in the survey. A text entry and a multiple choice question types are used to receive these information.

In the survey, five question groups could be established, focusing on adaptation in different viewpoints of the digital transformation. The question groups are presented in different pages in order to not decrease the willingness of the contribution. Every question is selected to be rating scale typed using 1 to 5 as values. For most of the questions, the 1 means *Not at all*, while the 5 is *Fully*. However, there are cases when different explanation is added to the question, and it will be included in the list.

1) Technical Conditions: The technical conditions are crucial to the digital education, because if these are not met, the student is severely disadvantaged in terms of learning. The student is unable to learn the curriculum despite sufficient mental ability or motivation. The questions about this topic are:

1) How challenging was the technical preparation during the transition to online education?
2) How difficult was to participate in online classes and assignments?
3) How appropriate was the curriculum sharing platform used by the instructor?
4) How well did the the technological background suit online tutoring during the semester?
5) To what extent did you consider the received information of the proper use of infrastructure to be helpful?

2) Preferred Hardware: The hardware requirements of information technology subjects can vary, and for some subjects, the students' will to use their own device already surfaced in normal education. However, the inaccessibility of institutional devices can be serious problems for students without usable hardware. The questions about this topic are:

6) If you had had the opportunity to use the labs of the institution instead of your own computer, how likely would you have taken the opportunity?
7) Did the tools provided by yourself, or the institution help you to learn the curriculum better? *(Own tool- Institutional tool)*
8) To what extent did the own tools meet the system requirements of the given subject?
9) How difficult was it to build the software environment?
10) In the future, would you prefer to use your own resources or those provided by the institution? *(Own tool- Institutional tool)*

3) Student Relationships: The student relationships are an important part of higher education, as it can help build social skills and improve the behaviour in future workplaces. Digital education can effect human relationships negatively, and it hinders the opportunity for a face-to-face meeting. The questions about this topic are:

11) How has online education affected contact with your fellow students? *(Extremely badly- Extremely well)*
12) How often did you ask your fellow student for help during online education? *Never- Very often*
13) How typical was it to seek help from other students only for study purposes?
14) How regular were online student gatherings NOT for study purposes?
15) How much do you looking forward to meeting your fellow students in person?

4) Personal Contact: "Personal Contact means an encounter in which two or more persons are in visual or physical proximity to each other". More information and better understanding can be accessed through teacher and other students' body language and voice. Moreover, the student can focus more on the curriculum, because there are less distractions. The questions about this topic are:

16) How important is to you that the instructor use webcam during lessons?
17) In your opinion, can you better learn the lesson material in case of personal presence or online participation? *(Personal presence- Online participation)*
18) How important is to you the weekly verbal contact with the instructor?
19) How much does it help you to understand the subject material if you can ask questions during class?
20) Would you prefer online lessons in the future?

5) Emotions: Emotion and learning are deeply connected and the relationship between them affects academic performance. Emotion biases our attention, memories, and capacity for rational thought. However, traditional face to face classes can improve student's mental health. Measuring the amount of emotional support students require during virtual classes is challenging. The questions about this topic are:

21) How challenging was it for you to adapt to the situation?
22) How challenging was it to adapt to working online?
23) How much did you require interactivity during the online lessons?
24) How effective did you find online education?
25) How much did you enjoy online education?

B. Data Set

The survey had been sent to the target group on multiple platforms, and the number of responding students is 60. The responses had been saved from the survey system in `csv` file format. Then the responses had been handled in Python using the pandas library. The structure of the data had been modified to be used in knowledge extraction. First, the data set is checked make sure it does not contain duplicates, then the identifier of the student and the subject are eliminated. Moreover, the survey system automatically added a timestamp to each response, which is also not significant to be presented in the data set. Then the questions are replaced with the previously used numbering using the Qi notation. The inspection of missing values can be omitted because every question had been required during the surveying process. Thus an element in the data set contains the selected value of the rating scale for each question.

C. Data Analysis

The correlations between the questions are calculated to examine the relationships between them. The data set is analysed to determine the groups of responders, and to investigate the deciding factors. The high dimensionality of the data set is reduced to be suitable for clustering purposes. Then a decision tree is constructed from the labelled data set. Machine learning models have been used to transform data into dimensional representation and clustering using Scikit-Learn library.

1) Correlation: Pearsons Correlation computes the linear dependence between two features. The correlation coefficients between X and Y features are calculated as shown in Equation 1, where σ is the standard deviation, μ is the mean, and E is the expectation.

$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \tag{1}$$

The Pearsons correlation coefficient is ranged between $[-1,1]$, where 1 means positive linear correlation, 0 means no correlation and -1 means negative linear correlation, also called as anti-correlation.

2) Dimension reduction: To improve the visualization and to avoid the curse of dimensionality, the data set is transformed into a low-dimensional representation. Principal component analysis (PCA) is a feature projection method that uses linear transformation. It transforms the data to a new coordinate system, with the principal components as dimensions. It uses eigenvectors and eigenvalues to rank the principal components, and selects the first k with the highest eigenvalues. With this method, the variance of the original data is preserved in the transformed data.

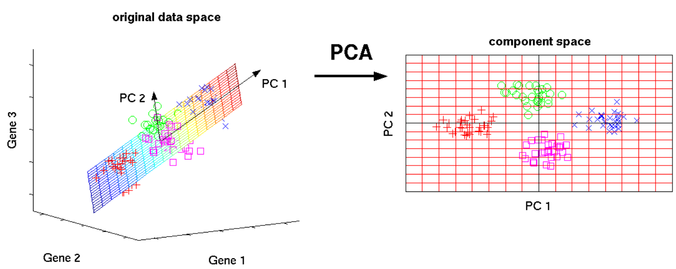

Fig. 1. Principal Component Analysis [32]

3) Clustering: Clustering is an unsupervised learning method to discover large groups of objects in a data set, called clusters. The elements of the clusters are similar to each other, while they differ from the elements of other clusters. Clustering process consists of three steps, namely the feature selection and extraction, interpattern similarity and grouping. The feature selection process identifies the most effective subset for clustering. The feature extraction makes transformations of available features to create new important features. The interpattern similarity is measured by a distance function defined between two patterns, and most commonly the Euclidean distance is used. The grouping methods can be categorized based on the output to hard, or fuzzy. In hard clustering, each pattern belongs to only one cluster, while the soft clustering results in degree of membership for each cluster.

a) k-means: The k-means clustering method is intended to partition the data set into k number of clusters. The algorithm works iteratively to assign each data point to one of K groups based on the objects. The representation of each cluster is called mean or centroid, and the algorithm estimates the means initially. This estimation can be done by random generation, or random selection of the objects. Then the following two steps are executed until the terminating condition is not fulfilled. Firstly, each object is assigned to its nearest centroid using squared Euclidean distance. Secondly, the centroid of each cluster is recalculated by taking the mean of all objects assigned to that cluster. The algorithm stops when no objects change cluster, the sum of the distances is minimised or some maximum number of iterations is reached.

4) Decision Tree: The decision tree is a decision support tool, with the advantage to visualize the decision-making process. The internal nodes test attributes and each branch represents a decision, while the leaves denote categories. For each unused attribute it calculates an Attribute Selection Measure(ASM) of the subset, then selects the attribute with the best value, and splits the subset based on it. It repeats the previous step on every subset until one of the following exit criteria is fulfilled: there are no more attributes to select, the subset belongs to the same class or no examples are left in the subset. It uses a greedy approach by selecting the best variation in every step, which can lead to local optima.

a) Gini Impurity: Gini Impurity is the probability of incorrectly classifying a randomly chosen element in the dataset if it were randomly labeled according to the class distribution in the dataset.

$$G = \sum_{i=1}^{C} p(i) * (1 - p(i)) \tag{2}$$

Equation 2 shows the formula of Gini Impurity, where C is the total number of classes, and $p(i)$ denotes the probability of picking an object with class i. To select the attribute to be the split based on, the Gini Gain is maximized. The Gini Gain is calculated by subtracting the weighted gini impurities of the branches from the impurity of the node.

b) Information Gain: Information gain measures how much information a feature gives us about the class. Information gain is calculated as the difference between entropy before split and average entropy after split of the dataset based on given attribute values.

$$IG(T,a) = H(T) - H(T|a) \tag{3}$$

Equation 3 shows the formula of information gain, where T is the training set, a is the feature and H denotes the entropy. To select the attribute on which the split can be split based on, the information gain is maximized.

III. Results

A. Response

Figure 2 visualizes the absolute value of the correlation matrix of the questions. Most of the questions have moderate correlation and there are a few strong correlations. Question

23 does not correlate on any other questions. In other words, it seems to be random whether a student needed or not the interactivity during the classes.

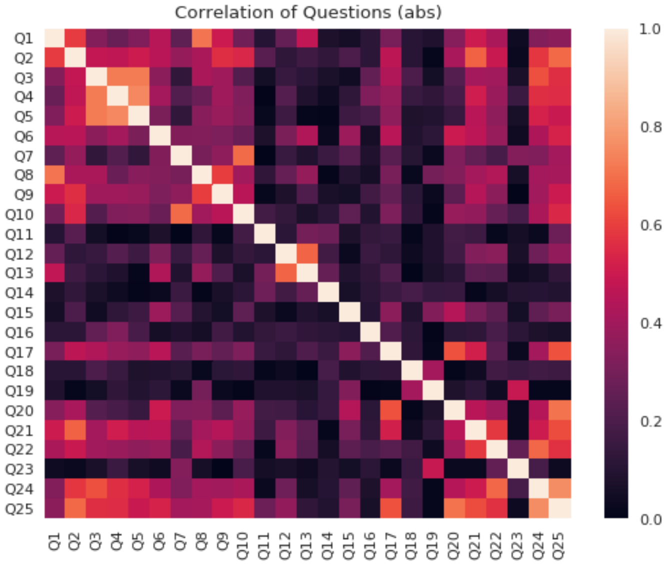

Fig. 2. Correlation Matrix

Analyzing the correlation coefficients three highly correlating question groups can be identified. Firstly, Question 1 and 8 has a -0.71 correlation which can be interpreted as if someone has problem with change to the digital education form then their own devices were not satisfactory for the course requirements. Secondly, Question 3, 4 and 5 are also highly correlating. These questions were focused on the platform, technology and support. Finally Question 25 correlated with Question 20 and 24 although the later two questions had no significant correlation. If a student enjoyed the online classes then he found them efficient and he would likely prefer them in the future.

B. Student Clusters

Clustering of the responses was used to identify groups of students. Three different clusters were identified during our analysis however the experiments were performed with different cluster numbers. Although using more clusters would give a detailed insight into the students, it would have required more responses.

Figure 3 shows the yielded clusters using k–means clustering algorithm. The cluster sizes are $(18, 17, 25)$ so these clusters represent roughly the half and two quarter of the entire data set. These clusters could represent some common behavior of the responses therefore the responses were labeled with the cluster identifier. Then a decision tree classifier were built to explain which questions split the responses. Hence, the decision tree gives insight into the key differences between the responses.

Figure 4 shows the built decision tree for three clusters. The first decision is made by Question 20 so it decides whether the students would prefer the online classes or not. It shows that about half of the students would prefer the online courses

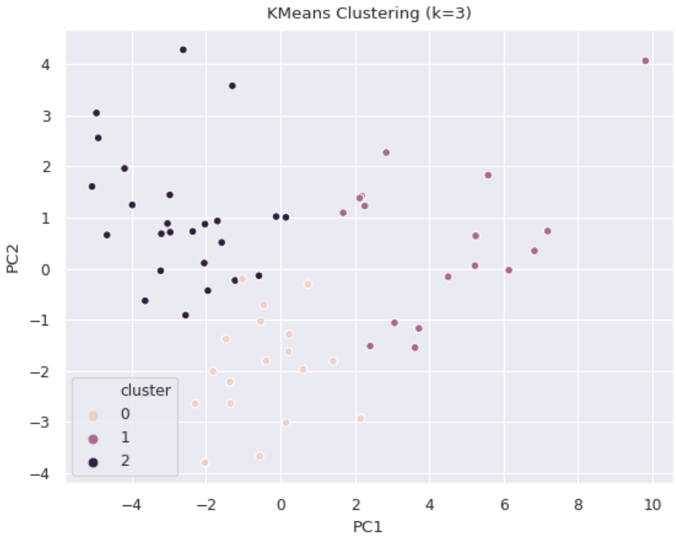

Fig. 3. PCA Mapping with 3 Clusters

if they are held weekly. The other half of the students who would not prefer the online courses were split whether they had problem with the recent situation. Although Figure 4 presents only three levels of the decision tree further analysis showed that about one cluster was in lack of infrastructure (Question 8 ≥ 3.5) and the other cluster just simple did not liked (Question 25 $\leq$ 3.5) the online classes. In addition, the students who would prefer the online course they would like to use their own devices.

IV. Discussion

Survey shows that the digital transformation due to the COVID-19 was not smooth and without challenges but half of the students liked it and they would prefer it in the future. Our analysis allows to draw a few remarks and conclusions. Firstly, half of the students preferred online education and they are willing to continue it. Secondly, the students who had no technical issues would prefer to use their own devices during the tutorials. Finally, the students who will not prefer online education are divided by technical issues ans other concerns.

Online education was considered successful because about half ot he students would prefer it in the future. Almost all of these responses agreed upon that weekly classes are necessary. Hence, they would like to learn from home with the well established schedule of semesters. Acceptance of rescheduled training like intensive courses would require further investigation because there were no specific questions about it. Current results shows that the students think that weekly classes are indispensable. These students did not mention technical issues and had the necessary infrastructure.

The survey showed that many students are willing to use their own configuration in the future instead of the laboratories if it is possible. This observation suggests a change in the laboratories where tutorials were held. Currently, the students work on the local computers during the tutorials but they can work on their own computers too. Based on our prior experience, some of the students use their devices regardless the labor environment. The current results confirmed this

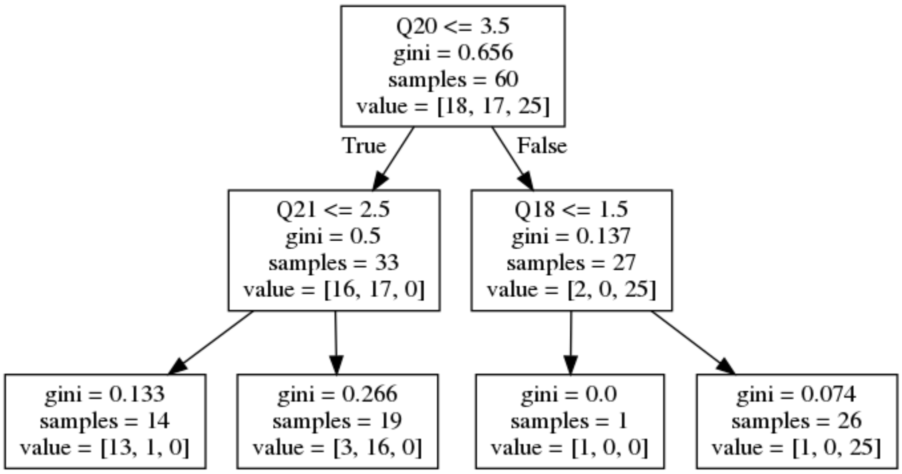

Fig. 4. Decision Tree

observation and it suggests some changes in our laboratories. Based on these results, the installation of workplaces without computers was suggested where the students can dock their own computers. This transformation may improve the students' performance in the tutorials.

Students, who do not prefer to continue the online education, are divided into two categories. Half of them had some sort of technical issues and the other simply did not like the online education. These technical issues may be related to hardware or software. Hardware related problem should be solved by the students. Software related issues may be caused by the huge variety of platforms and tools that are used in different courses. Step–by–step tutorials or configured virtual environments could be used to improve the students' online learning experience.

V. CONCLUSION

The paper examines digital education with participated students of Eszterhazy Karoly University. The target group of the survey is computer science and Business Informatics Engineer students. The survey consisted of question groups, namely technical conditions, preferred hardware, student relationships, personal contact, and emotions. A data set is constructed using the students' responses, which is analysed using well-known methods.

The presented experimental results and exploratory analysis gives some insight into online education experience and may set further directions. Based on the results, the digital education can be considered successful. The students enjoyed the digital education and half of them are willing to continue it in the future. Students would prefer to use their own devices during on tutorials which allow some changes in the labor environments. Unfortunately, some students had technical issues which may be caused by the heterogeneous software environment and can be solved with support material. Therefore, the successful utilization of the digital education can be achieved in the near future.

ACKNOWLEDGMENT

This research was supported by the grant EFOP-3.6.1-16-2016-00001 (Complex improvement of research capacities and services at Eszterhazy Karoly University).

REFERENCES

[1] A. Andal-Ancion, P. A. Cartwright, and G. S. Yip, "The digital transformation of traditional business," *MIT Sloan Management Review*, vol. 44, no. 4, p. 34, 2003.

[2] D. L. Rogers, *The digital transformation playbook: Rethink your business for the digital age*. Columbia University Press, 2016.

[3] A. Ustundag and E. Cevikcan, *Industry 4.0: managing the digital transformation*. Springer, 2017.

[4] R. Agarwal, G. Gao, C. DesRoches, and A. K. Jha, "Research commentarythe digital transformation of healthcare: Current status and the road ahead," *Information Systems Research*, vol. 21, no. 4, pp. 796–809, 2010.

[5] M. Warschauer, "The paradoxical future of digital learning," *Learning Inquiry*, vol. 1, no. 1, pp. 41–49, 2007.

[6] C. Dede, "Emerging technologies, ubiquitous learning, and educational transformation," in *European Conference on Technology Enhanced Learning*. Springer, 2011, pp. 1–8.

[7] N. Cuellar, "The transition from classroom to online teaching," in *Nursing Forum*, vol. 37, no. 3. Blackwell Publishing Ltd., 2002, p. 5.

[8] P. Baranyi and Á. Csapó, "Definition and synergies of cognitive infocommunications," *Acta Polytechnica Hungarica*, vol. 9, no. 1, pp. 67–83, 2012.

[9] P. Baranyi, A. Csapo, and G. Sallai, *Cognitive Infocommunications (CogInfoCom)*. Springer, 2015.

[10] B. K. Wiederhold and M. D. Wiederhold, *Virtual reality therapy for anxiety disorders: Advances in evaluation and treatment.* American Psychological Association, 2005.

[11] B. Berki, "Desktop vr and the use of supplementary visual information," in *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2018, pp. 000 333–000 336.

[12] B. Berki, "2d advertising in 3d virtual spaces," *Acta Polytechnica Hungarica*, vol. 15, no. 3, pp. 175–190, 2018.

[13] ——, "Desktop vr as a virtual workspace: a cognitive aspect," *Acta Polytechnica Hungarica*, vol. 16, no. 2, pp. 219–231, 2019.

[14] A. Gallagher, N. McClure, J. McGuigan, I. Crothers, and J. Browning, "Virtual reality training in laparoscopic surgery: a preliminary assessment of minimally invasive surgical trainer virtual reality (mist vr)," *Endoscopy*, vol. 31, no. 04, pp. 310–313, 1999.

[15] K. Bir, G. Molnr, D. Pap, and Z. Szts, "The effects of virtual and augmented learning environments on the learning process in secondary school," in *2017 8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2017, pp. 000 371–000 376.

[16] I. Horvath, "Innovative engineering education in the cooperative vr environment," in *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*. IEEE, 2016, pp. 000 359–000 364.

[17] V. Kövecses-Gősi, "Cooperative learning in vr environment," *Acta Polytechnica Hungarica*, vol. 15, no. 3, pp. 205–224, 2018.

[18] C. Moro, Z. Štromberga, and A. Stirling, "Virtualisation devices for student learning: Comparison between desktop-based (oculus rift) and mobile-based (gear vr) virtual reality in medical and health science education," *Australasian Journal of Educational Technology*, vol. 33, no. 6, 2017.

[19] G. Molnár, Z. Szűts, and K. Biró, "Use of augmented reality in learning," *Acta Polytechnica Hungarica*, vol. 15, no. 5, pp. 209–222, 2018.

[20] R. M. Palloff and K. Pratt, "Making the transition: Helping teachers to teach online." ERIC, 2000.

[21] S. Simmons, W. Jones Jr, and S. Silver, "Making the transition from face-to-face to cyberspace," *TechTrends*, vol. 48, no. 5, p. 48, 2004.

[22] A. Kirkwood, "Elearning: you don't always get what you hope for," *Technology, Pedagogy and Education*, vol. 18, no. 2, pp. 107–121, 2009. [Online]. Available: https://doi.org/10.1080/14759390902992576

[23] H. Zsohar and J. A. Smith, "Transition from the classroom to the web: Successful strategies for teaching online," *Nursing Education Perspectives*, vol. 29, no. 1, pp. 23–28, 2008.

[24] J. Borrego, "Roadmap for a successful transition to an online environment." *Contemporary Issues in Education Research*, vol. 3, no. 5, pp. 59–66, 2010.

[25] J. VanSickle, "Making the transition to teaching online: Strategies and methods for the first-time, online instructor." 2003.

[26] I. Horvth, "Digital life gap between students and lecturers," in *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016, pp. 000 353–000 358.

[27] C. Englund, A. D. Olofsson, and L. Price, "Teaching with technology in higher education: understanding conceptual change and development in practice," *Higher Education Research & Development*, vol. 36, no. 1, pp. 73–87, 2017. [Online]. Available: https://doi.org/10.1080/07294360.2016.1171300

[28] J. Battle, Paul Attewell, "Home computers and school performance," *The information society*, vol. 15, no. 1, pp. 1–10, 1999.

[29] P. Cowan, P. Neil, and E. Winter, "A connectivist perspective of the transition from face-to-face to online teaching in higher education." *International Journal of Emerging Technologies in Learning*, vol. 8, no. 1, 2013.

[30] N. C. Burbules and T. A. Callister, "Universities in transition: The promise and the challenge of new technologies," *Teachers College Record*, vol. 102, no. 2, pp. 271–93, 2000.

[31] M. Bond, V. I. Marín, C. Dolch, S. Bedenlier, and O. Zawacki-Richter, "Digital transformation in german higher education: student and teacher perceptions and usage of digital media," *International Journal of Educational Technology in Higher Education*, vol. 15, no. 1, p. 48, 2018.

[32] M. Scholz, "Approaches to analyse and interpret biological profile data," 2006.