Applying a Project-Based Learning Approach in a Programming Course

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Abstract

The ever-changing digital society we are living in nowadays requires people to quickly adapt to the rise of new technologies faster and faster. In order to cope with it, the concepts of digital competence and digital literacy are key points to be able to deal with such changes and take the best out of them. Therefore, there is a need for students to learn the basics of new technologies in order for them to get by in a digitalized society, and that is why active learning strategies are really interesting when it comes to getting students used to take the initiative in their learning process. In this paper, a project-based learning approach is applied to a programming course, where students need to design its own project, which in turn they have to present in front of their classmates in a pitch presentation of just a few minutes long. The academic evaluation of each presentation is done on a peer review basis though a specific construct, whereas the engagement level is also rated through a determined construct. This approach reduces the risk of cheating because students need to be able to explain what, why, and how they did it during the pitch presentation.

Keywords: active learning, construct, level of engagement, peer-review evaluation, project-based learning

1. Introduction

Digital competence is defined in different ways in the literature. For instance, it is usually seen as an indicator of quality education environment as society is ever moving towards digitalization [1]. Likewise, it is also considered as the knowledge, skills, and attitudes having a critical role in technology integration [2]. Hence, it could be defined according to a bunch of parameters, such as technical competence, ability to apply digital technologies in a meaningful way, ability to evaluate digital technologies in a critical manner, and motivation to take part and perform in the digital culture [3]. This way, a citizen with digital competence is considered to be able to get by online when it comes to managing information, communicating, creating content, staying safe, and solving problems [4].

Digital literacy is deeply related to digital competence, and it is one of the main priorities in government' educational policies in order to get citizens adapted to the use of digital technologies [5]. This acquisition of those capacities is considered to be crucial, as its confident use is ever necessary to not only work or learn in a digitalized society live, but also to be able to develop any sort of regular activity related to digital technologies [6]. Those capacities should be acquired at younger ages, where the development of digital culture is geared by teachers, such that training scenarios could be set up where technologies are naturally included [7].

This way, competence-oriented education may play a key role by changing the focus from what is taught towards what is learnt, thus shifting from the transmission of knowledge to designing learning experiences [8]. A convenient way to carry out this approach is the establishment of active learning strategies, which are basically associated to student-centered learning, which usually involves activity, critical thinking, participation, and engagement [9].

There are different methods to implement an active learning paradigm, such as problem-based learning, challenge-based learning, or team-based learning [10]. However, in this paper the focus is set on project-based learning, where students are faced with a project they have to get through while they play the key role in its development and testing [11]. Furthermore, it has been reported that project-based learning methodologies also promote the acquisition and development of generic transversal competences [12], which complements the core competences obtained throughout the regular course instruction.

Focusing on project-based learning, it relates to problem-oriented student-centered learning which is set up around projects, such that new skills and contents are learned during the make up of the project [13]. These project could be undertaken either on an individual basis or on a group basis, where the former focuses more on technical skills, whereas the latter also works soft skills, such as collaboration and communication [14].

It is considered that project-based learning develops a high degree of involvement and participation of pupils along the learning process, such that teachers must promote cooperation among students so as to research, decision-making and response to challenge [15]. Furthermore, the role of project-based learning has been cited in the literature as one of the best ways to acquire a significant learning in order to efficiently respond to the development of the necessary knowledge and skills to get by in the 21st century [16].

Looking at project-based learning from a pedagogical view, it has been reported that the best results have been obtained for small group sizes, namely, not having more than 4-5 components per group [17]. The main reason for this is because there is a significant relation between this active learning method and collaborative learning, which eventually produces a rise in academic results [18].

Furthermore, working in projects develops the spirit of investigation, as well as the other features such as innovation, creativity, productive thoughts and motivation to solve problems [19]. Additionally, project-based learning has been reported to help develop general competences, such as analyze, synthetize, and manage information, as well as solving individual problems, apart from the specific competences acquired during hands-on work [20].

Finally, many research experiments have been exposed in the literature by comparing the outcome obtained out of project-based learning against a control group geared by traditional verbal-visual teaching, where many times the former offers better results than the latter [21], even though in some cases the outcome achieved may be worse, such as a non-collaborative group, a lack of effective leadership, or an inconsistent communication [22].

Hence, this paper applies the project-based learning approach for the evaluation of a STEM course, specifically to a computer science course, such that a coding project in Python needs to be developed, and in turn, presented to the rest of students in order for them to evaluate it on a peer review basis with a specific construct. In addition to it, the level of engagement when dealing with the project is also measured with another construct [23].

The organization of the rest of the paper follows the following structure: Section 2 introduces the method used, Section 3 presents the results, Section 4 exposes the discussion about those results, and Section 5 draws the final conclusions.

2. Method

We run a course on programming fundamentals at college with 50 students aged 18 to 24. The curriculum of that course was based on Python language, such that its target was to learn its basics so as to develop fluency in writing Python code in order to be able to build up a final project.

Hence, by the end of the course, each student had to come up with a particular project in Python, whose evaluation was made through a 2-minute presentation to be held in a specific session where all students were attending in-person. In order to avoid cheating and to make sure that each student coded its own project, each presentation had to expose how the programming was made and a brief code execution.

It is to be taken into account that this course is focused on learning the basics of programming, so the majority of projects presented are not overly complicated, but just projects taking advantage of simple functionalities of Python. This fact helps students summarize their codes in just two minutes each, which will be dedicated to expose their code structures and algorithms, as well as running a small prove of concept of what their codes do.

After each presentation, it had to be assessed on a peer-review basis by means of a hand-made construct specifically prepared for this purpose, and further validated by a panel of experts. Such an instrument had six Likert-type questions, where half of them were devoted to programming skills and the other half were dedicated to presenting skills. Additionally, at the end of the session dedicated to carry on all presentations, a further construct was also presented to all students in order for them to evaluate their level of engagement with the course.

Focusing deeper on the workflow of this project, the outcome to be measured are two-fold. On the one hand, the presentations made by students involve a previous work in order to design an program in Python, where each student will have to design the algorithms and the data structures needed to implement a certain functionality. As the type of projects to be presented was up to each student, then each one could apply their knowledge and skills related to coding in order to freely choose the type of project to be designed.

Before the presentation day arrives, students also have to prepare the presentation, considering not only the type of code they develop, but also they have to consider how to explain it to their classmates, and how to present a short prove of concept about the capabilities of such a code. Once in the presentation day, they have to move swiftly through the code, as the amount of time allowed is limited, and they also have to allow some time to the small prove of concept, so some planning beforehand is needed to face the presentation adequately.

On the other hand, apart from the academic outcome obtained by the programs exposed, the level of engagement experienced by the students when carrying out this project is also going to be measured. This way, the results obtained are going to be compared with those quoted in the literature, where there is usually a link between a rise in academic results when implementing active learning methodologies and a high level of engagement. Hence, such a relationship is going to be either corroborated, or otherwise, refuted according to the outcome achieved in this project.

Therefore, the outcome of this project is to be measured considering not only the academic results, but also the level of engagement experienced. In order to do so, three different constructs were used in relation to the assessments for the presentation session. First of all, a construct for a panel of experts to validate the items composing the peer-review assessment which students will use in the session devoted to presentations. Afterwards, the construct with the items validated for students to undertake the peer-review assessment, which is the one previously validated by the panel of experts. Finally, the construct for students to evaluate their level of engagement with the course at the end of the session dedicated to carry out the presentations.

3. Results

The results obtained with the three constructs exposed above are going to be exposed in separate subsections for clarity purposes.

3.1. Item validation construct

A panel of 5 experts in the field were consulted in order for them to validate some proposed items for the peer-review assessment. Six items were proposed, such that three of them were geared to programming skills and the other four were somehow related to communication skills.

Each of those items had to be evaluated according to 2 dimensions, such as construction of the item and clarity of the item, with a 4-point Likert type scale. In such a scale, a value of 1 meant fully disagree, 2 meant disagree, 3 meant agree, and 4 meant fully agree. Table 1 exhibits those six items.

Table 1. Items for the peer-review assessment

Category	**Identifier**	**Item**
Programming	I1	Coding skills
	I2	Code clarity
	I3	Code explanation
Presenting	I4	Functionality
	I5	Execution
	I6	Communication skills

The average values obtained for each item in each dimension were found out, which in turn led to calculate the average per dimension, and eventually, the average of the whole construct [24]. This result, along with the upper and lower bounds of the Likert-type scale employed, was then used to determine the value of the Aiken's V test, as shown in Table 2.

Table 2. Aiken's V test

	Construction	**Clarity**
Average I1	3.8	3.8
Average I2	3.8	3.4
Average I3	4.0	3.6
Average I4	3.4	3.8
Average I5	3.6	3.4
Average I6	4.0	4.0
Average for each dimension	3.767	3.667
Average for the whole construct	3.717	
Aiken's V test	0.906	

The value obtained in the Aiken's V test is higher than the usual benchmarks shown in the literature, such as 0.87 established by Aiken [25], 0.70 proposed by Charter [26], or 0.50 set by Cicchetti [27]. Hence, it means that the construct is validated and its items are fit to be presented for the students to carry on the peer-review assessment of the projects, even if the highest benchmark is selected, which happens to be the most restrictive one.

3.2. Peer review construct

After each of the 2-minute presentations exposed by the corresponding student, they all had to rank such a presentation by means of a construct composed of the items shown in Table 1, where each item had to be evaluated in a 5-point Likert-type scale. In such a scale, a value of 1 meant fully disagree, 2 meant disagree, 3 meant neither agree nor disagree, 4 meant agree, and 5 meant fully agree. Table 3 exhibits some descriptive statistics applied to the grades obtained [28], organized by dimensions and overall.

Table 3. Descriptive statistics for the peer-review

Statistics	**Programming**	**Presenting**	**Overall**
Average	4.78	4.75	4.76
Mode	5	5	5
25^{th} Perc	5	5	5
Median	5	5	5
75^{th} Perc	5	5	5
Variance	0.18	0.19	0.18
Std Dev	0.42	0.43	0.42
Coef Var	0.09	0.09	0.09

Furthermore, the reliability of those results obtained was found out by means of Cronbach's Alpha, as it measures internal consistency of data [29]. Table 4 displays the values calculated for each dimension and overall.

Correlation of the data obtained in both dimensions are inferred from the Cronbach's Alpha value [30], although Pearson's correlation coefficient and Spearman's rank correlation coefficient could also be used to corroborate this purpose, as shown in Table 5.

Table 4. Cronbach's Alpha for the peer-review

Programming	**Presenting**	**Overall**
0.74	0.72	0.78

Table 5. Correlation coefficients for the peer-review

Pearson's correlation coefficient	0.52
Spearman's rank correlation coefficient	0.53

3.3. Level of engagement construct

After all 2-minute presentations were done, a final construct had to be completed in order to measure the level of engagement. For this purpose, the ISA engagement scale was used [31], which is composed of 9 standard questions, grouped in 3 dimensions, as seen in Table 6. It was originally designed for working environments, even though it was later adopted in other fields, such as in education [32].

Table 6. The ISA engagement scale

Dimensions	**Items**
Intellectual Engagement	I focus hard on my work.
	I concentrate on my work.
	I pay a lot of attention to my work.
Social Engagement	I share the same work values as my colleagues.
	I share the same work goals as my colleagues.
	I share the same work attitudes as my colleagues.
Affective Engagement	I feel positive about my work.
	I feel energetic about my work.
	I am enthusiastic in my work.

Each item in the ISA engagement scale is ranked in a 7-point Likert-type scale, where a value of 1 meant fully disagree, 2 meant disagree, 3 meant partially disagree, 4 meant neither agree nor disagree, 5 meant partially agree, 6 meant agree, and 7 meant fully agree. The expected score is above 6 in all dimensions and overall, as it stands for a high level of engagement, because 6 is the agree value [33]. Table 7 displays some descriptive statistics applied to the scores obtained, grouped by dimensions and overall.

Table 7. Descriptive statistics for engagement level

Statistics	**Intell**	**Soc**	**Affect**	**Overall**
Average	6.49	6.69	6.79	6.66
Mode	7	7	7	7
25^{th} Perc	6	6	7	6
Median	7	7	7	7
75^{th} Perc	7	7	7	7
Variance	0.53	0.23	0.17	0.32
Std Dev	0.73	0.48	0.41	0.57
Coef Var	0.11	0.07	0.06	0.08

Reliability of these results related to the engagement level is not really relevant, as scores are meant to be consistently high, as opposed to those related to the peer review assessment, where some scores might be consistently high, whilst others might be consistently low. Anyway, Table 8 shows the values of Cronbach's Alpha for each dimension and overall regarding the outcome referred to the level of engagement, which stands for the internal consistency of data and hints about correlation level.

Table 10 Cronbach's Alpha for engagement level

Intellectual	**Social**	**Affective**	**Overall**
0.89	0.86	0.74	0.76

4. Discussion

Regarding the first construct, it was meant to validate the items contained in the peer-review tool for students. Six items were presented to a panel of 5 experts, who rated each of those items in 4-point Likert-type scales according to 2 dimensions, namely construction and clarity. In turn, the average of all ratings was found out, which accounted for 3.717, and this figure was used to calculate the Aiken's V test, which yielded 0.906.

There is different cutoff marks proposed in the literature for the Aiken's V test. For instance, the benchmark proposed by Aiken is 0.87, which is considered as a more conservative cutoff mark, the one proposed by Cicchetti is 0.50, which is considered as loose cutoff mark, or the one proposed by Charter is 0.70, which is considered as an balanced option between them both. Anyway, the value obtained herein, namely 0.906, is higher than all the benchmarks exposed, so the items could be considered as validated by the panel of experts.

With respect to the second construct, it was intended for students to assess each 2-minute presentation exposed on a peer-review basis. It is to be noted that this type of presentation requires short and clear messages to get the points across. In this context, students are supposed to briefly expose the general structure of the code developed, its functionality and a quick execution of an instance.

The analysis of the descriptive statistics related to the peer-review grades show similar values for the 2 dimensions considered, where items were measured with 5-point Likert-type scales. It is to be noted that the dimensions considered in this construct are programming and presenting, which happen to be the categories where the six items of the first construct were grouped into.

Specifically, programming had an average of 4.78, whereas presentation had an average of 4.75, with an overall average of 4.76. Likewise, the quartiles and the mode are all 5, which reveals that most students fully agreed with the projects exposed. At the same time, the variance, the standard deviation, and the coefficients of variation are also pretty similar, where the latter had a value of 0.09 in both dimensions and overall, which means of low variability in the data obtained.

It is to be remarked that the values obtained for both dimensions were basically the same, as only slight differences were appreciated. This fact indicates that students were as good in programming their codes as in presenting their results to their peers, which demonstrates that students took the presenting part as seriously as they did the programming part.

The value obtained for the overall Cronbach's Alpha is 0.78, which is over the acceptable cutoff mark of 0.7 and it is quite close to the good cutoff mark of 0.8, although the excellent cutoff mark of 0.9 is far away. Likewise, the Cronbach's Alpha corresponding to the dimensions proposed are 0.74 for the programming one and 0.72 for the presenting one, which are both over 0.7.

Those values represent internal consistency of data in both dimensions and overall, as well as a high correlation between data belonging to both dimensions. Nonetheless, the latter has also been corroborated by means of both Pearson's and Spearman's rank correlation coefficients. Both offer similar values in this case, as the former yields 0.52, and the latter yields 0.53. Those values are higher than 0.5, which accounts for high correlation.

With regards to the third construct, which took place at the end of the presentation session, the average of the scores belonging to each dimension are all higher than 6, where items were measured with 7-point Likert-type scales. Specifically, the intellectual dimension had an average of 6.49, the social dimension had an average of 6.69, and the affective dimension had an average of 6.79, accounting for an overall average of 6.66. Hence, as all figures were higher than 6, which is the 'agree' value in a 7-point Likert-type scale, then it indicates that the level of engagement was high in all dimensions and overall.

It is to be noted that the values obtained for all three dimensions were really high, which was pretty above of the benchmark result of 6. However, delving deeper in those results, it seems clear that the result of the intellectual dimension is a bit below their other counterparts, which appears to indicate that students get a bit less engaged by the intellectual part compared to the other parts. On the other hand, by comparing the result of the social dimension with that of the affective dimension, it occurs that the social part is a bit below than the affective part, which appears to indicate that the sense of being integrated in a group is not as powerful as the way they feel about taking part in the competition.

Furthermore, the rest of centralization statistics considered for the level of engagement shows values between 6 and 7, which corroborates the high level of engagement experimented by the students. Also, the values for the coefficients of variation are pretty low, ranging from 0.11 to 0.06, with an overall value of 0.08, which accounts for low variability of the data obtained, as all those values are lower than 0.15.

In addition to it, the Cronbach's Alpha values related to each dimension and overall are all higher than 0.7, which represents acceptable values, even though those figures are not really relevant because the values for the level of engagement are supposed to be consistently high, which is appreciated in the centralization measurements. Furthermore, the lack of relevance of internal consistency, with respect to the engagement values led to skip the calculation of correlation coefficient. However, it can be stated that there is indeed internal consistency and high correlation among data obtained for all dimensions and overall, as the values of the Cronbach's Alpha are higher than 0.7 in all cases.

5. Conclusions

In this paper, the preparation and evaluation of a project-based learning activity has been exposed for a programming fundamentals course run at college and based on Python coding language. The scope of this course is to go from the basics of Python all the way to develop fluency in writing Python code, thus leading students to create useful coding projects.

The evaluation of this course was done in a specific session through the exposition of each student's projects with a 2-minute presentation, where students had to explain the general structure of the code developed, its functionality and a small execution of an instance. This way, the possibility of cheating by getting the code from an AI-generated application, or anywhere else on the internet, gets minimized because students must explain the what they did, why they did it, and how they did it.

Three constructs have been used in order to undertake the evaluation of the project-based learning activity proposed to the students. The first construct was for a panel of experts to validate the six items intended for the peer-review construct. Each item had to be ranked with a 4-point Likert-type scale according to two dimensions, namely its construction and its clarity. Then, the average of all scores was calculated, and in turn, it was used to find out the value of the Aiken's V test. The value obtained was 0.906, which was higher than the usual cutoff marks established in the literature. Hence, the six items proposed were validated and they were all included in the peer-review construct for students.

Therefore, the second construct was composed of those six items, and students had to fill it in after each 2-minute presentation was performed in order to evaluate them on a peer-review basis. Each of those items had to be ranked with a 5-point Likert-type scale, where half of the items were related to the programming dimension and the other half were referred to presenting one. The ranks obtained were aggregated by these two dimensions and a statistical analysis was performed, resulting in similar values for each dimension and overall. In fact, the overall average was 4.76 out of 5, which accounts for a quite high value, whereas the coefficient of variation was 0.09, which stands for a low variability of data.

Furthermore, Cronbach's Alpha was also calculated for each dimension, yielding 0.74 for the programming one and 0.72 for the presenting one. Furthermore, the overall of Cronbach's Alpha overall was 0.78, which is an acceptable value for being higher than 0.7. This implies an internal consistency of the data collected, as well as a high correlation between dimensions, which was further corroborated by the value of the Pearson's correlation coefficient, which was 0.52, and the value of the Spearman's rank correlation coefficient, which was 0.53. Hence, as both coefficients were higher than 0.5, it is assumed to have a high correlation between both dimensions.

Additionally, the third construct was proposed to measure the level of engagement by means of the ISA engagement scale. It is composed of 9 standard questions, which are grouped into 3 dimensions, such as intellectual, social, and effective, where each item has to be ranked with a 7-point Likert-type scale. The average values for each dimension were 6.49 for the intellectual one, 6.69 for the social one, and 6.79 for the affective one, which accounts for an overall average of 6.66. Taking into consideration that 6 is the value of agree and 7 is the value of fully agree, then it is clear that all values are above 6 and close to 7, meaning that the engagement level was quite high. Also, the coefficients of variation were all lower than 0.15, which implies a low variability of the scores. Additionally, the average value for the intellectual dimension is lower than the rest, which might indicate that students get more motivated by the social dimension and even more by the affective one.

6. References

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