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TESTING THE HYPOTHESIS THAT THE DEEP APPROACH GENERATES BETTER ACADEMIC PERFORMANCE

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ABSTRACT

Students' Approaches to Learning (SAL) theory assumes that the deep approach generates better academic performance when compared to the surface approach. This study tests this hypothesis, using a randomized experimental design of pre- and post-test case-control. Students in a discipline of a biology course were randomly allocated to the experimental and control groups. The experimental group carried out a pedagogical activity which aimed to mobilize the deep approach, while the control group performed a mobilizing activity with a surface approach. Student performance was analyzed by valid and reliable educational tests designed for this purpose, using statistical Rasch Models. Results indicated that both groups showed substantial gains in two of the three learning tasks. The experimental group did not show a higher gain than the control group. From the present study, it can be seen that, in order to actually test the SAL principle, it is necessary to monitor in detail the student's cognitive process. In addition, it can be concluded that it is important that the research area on SAL increases its efforts in quantitative studies of learning processes.

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INTRODUCTION

Several areas of scientific study, like education and psychology, consider learning and understanding school content as challenging topics (Gomes & Borges, 2009a; Gomes, 2010a, Gomes, 2011a; Fontes, 2019). Studies argue about the inadequacy of the transmissive model in teaching to promote better quality learning (Gomes & Borges, 2009a; Gomes, 2010a, 2010c; Gomes, 2011a) and lead to the need to promote teaching that stimulates a more active and autonomous posture of the student (Gomes, 2007; Gomes & Borges, 2009a; Gomes, 2010a; Gomes, 2010c; Gomes, 2011a). It is essential that research on learning in an educational context is based on well-grounded theories, which enable resolutions to issues related to the success and quality of learning (Costa, Pfeuti & Nova, 2014). SAL (Students' Approaches to Learning) theory studies the interaction of the subject with a learning task and its effects for the acquisition of knowledge and learning (Fontes & Duarte, 2019). According to this theory, there are two forms of interaction between students and the learning task, the surface approach and the deep approach (Fontes & Duarte, 2019, Gomes & Golino, 2012b).

These approaches present an interlaced relationship between motivations and learning strategies. In the surface approach, the affective factor is directed to a motivation extrinsic to the task. In turn, the deep approach involves an active posture of the subject in the learning process, and the affective factor is supported by intrinsic interest in what is learned and in the development of skills (Gomes, 2010a; Gomes, Golino, Pinheiro, Miranda & Soares, 2011; Gomes & Golino, 2012b; Gomes, 2013). Considering strategies, the deep approach is characterized by cognitive processes that involve the construction of meaning and understanding, while the surface approach emphasizes memorization and repetition. Researchers indicate that the differences in the quality of learning are related to the approaches used (Fontes, 2019). SAL theory assumes that the surface approach negatively influences quality of learning, meaning that it makes it more limited, while the deep approach tends to positively influence quality of learning, making it more expanded (Fontes, 2019; Gomes, 2011a). However, it is necessary to highlight that the evidence of many studies show that other variables seem to be more important to predict academic achievement than students' approaches to learning. Socioeconomic variables (Gomes, Amantes & Jelihovschi, 2020; Gomes & Jelihovschi, 2019; Gomes, Lemos, & Jelihovschi, 2020; Pazeto, Dias, Gomes & Seabra, 2019), executive functions (Cardoso, Seabra, Gomes, & Fonseca, 2019; Dias et al., 2015; Gomes, Golino, Santos, & Ferreira, 2014; Pereira, Golino, M. T. S., & Gomes, 2019; Reppold et al., 2015), metacognition (Gomes & Golino, 2014; Gomes, Golino, & Menezes, 2014) and intelligence (Alves, Gomes, Martins, & Almeida, 2016, 2017, 2018; Golino & Gomes, 2019; Golino, Gomes & Andrade, 2014; Gomes, 2010a, 2010b, 2011b, 2012; Gomes & Borges, 2007, 2008b, 2009b, 2009c; Gomes, de Araújo, Ferreira & Golino, 2014; Gomes & Golino, 2012a, 2012b, 2015; Gomes et al., 2014; Muniz, Gomes, & Pasian, 2016; Valentini et al., 2015) have a prominent role, while motivational and self-reference variables have a secondary role, such as students' approaches to learning (Gomes, 2010c, 2011a; Gomes et al., 2011; Gomes & Golino, 2012b; Gomes, 2013), students' belifs about the teaching-learning processes (Alves, Flores, Gomes & Golino, 2012; Gomes & Borges, 2008a), motivation for learning (Gomes & Gjikuria, 2018), academic self-reference (Costa, Gomes, & Fleith, 2017) and learning styles (Gomes, Marques, & Golino, 2014; Gomes & Marques, 2016).

An important principle of the Students' Approaches to Learning theory states that the deep approach generates a higher quality of learning, since it involves the active participation of the student in the selection, interpretation and enforcement of knowledge (Gomes, 2011a). Testing this principle is an important aim and one way to evaluate this aspect of theory involves evaluating intentionally designed forms of teaching to increase students' deep approach. Assuming that the deep approach provides better learning and greater academic performance, thus it is expected that an education that promotes the deep approach will generate an increase in student understanding and learning of school content. Presently, the portfolio stands out among innovative methodologies of teaching, learning and assessment (Cotta, Costa, & Mendonça, 2015), being a pedagogical tool widely used as a teaching resource at different levels of education (Vieira, 2002). This methodology has been the object of study over the last few decades, and there is consensus today that the portfolio enhances self-regulated learning (Dias & Santos, 2016). The portfolio is defined as a collection of evidence and replications that students use to demonstrate results of a specific learning (Costa et al., 2018). It is a carefully selected documentation, significantly remarked and systematically organized and contextualized over time (Alarcão, 2010). The use of portfolio supports the access of the student in relation to the learning task, allowing them to give meaning to the content learned, obtaining a more significant learning during production (Prado & Simas, 2012). The portfolio is an effective instrument in the teaching of any curricular component that intends to be able to develop its contents in a meaningful and logical manner for the student (Nascimento & Roças, 2015).

Some examples of the relevance of the portfolio could be mentioned. Dias and Santos (2016) carried out a case study with three high school students, seeking to understand to what extent the portfolio contributes to the learning of 1st year students in Mathematics. Aspects of mathematical learning in situations mediated by the portfolio were analyzed as a regulatory assessment device for learning. Results indicate that the portfolio is an effective method to exercise pedagogical differentiation and provides, in a continuous and systematic way, the development of metacognitive processes conducive to the development of a self-regulated and better learning (Dias & Santos, 2016). Gobbo, Beber and Bonfiglio (2016) applied portfolio activities to a class in the first period of the Business course. The evaluation of the use of the portfolio as an active methodology was made by self-assessment of the academics revisiting their work. Results showed that students realized the importance of the portfolio in the learning process, as they could see its evolution throughout the elaboration of the activity and the authors conclude that the portfolio is an active methodology that must be recovered in higher education (Gobbo et al., 2016). Fuente-Rojas applied the portfolio to 120 students enrolled in two health disciplines. It was found that the portfolio was an instrument that enabled reflection, conception of the entire process developed during elaboration of the activity, helped to develop organizational skills, attention to details, associate theory to professional practice, as well as use contents as a resource to support work. In addition, this methodology enabled students to evaluate the entire learning process, allowing students to build their own knowledge, surpassing imitation of theory (Fuentes-Rojas, 2017). In medical education, Maia and Struchiner (2016) analyzed the portfolio role as a facilitator of the construction of student learning, based on a reflective practice. Qualitative and quantitative research-intervention was used as a research method, whose sample consisted of 10 students enrolled in Anesthesiology. According to the results, all students demonstrated some degree of recursive process when preparing the portfolio. This suggests that this methodology represented an opportunity for students to reflect, apply and articulate theoretical concepts in different practical situations, in order to broaden their knowledge of the topic and understand it at deeper levels of complexity, contributing to a greater tendency to build meaningful learning (Maia & Struchiner, 2016). In this research, 60% of the students presented significant learning in their portfolios and indicated as a positive aspect the accomplishment of the portfolio as a support in learning; 20% of students declared that the portfolio helped in the learning organization and 10% reported that the activity allowed them to demonstrate learning, contributing to the development of autonomy, providing meaningful, active and deep learning.

Considering the above, to test the principle of the SAL theory which stands that the deep approach generates higher quality of learning and knowledge acquisition of the learning task, this work uses the random experimental design of case and control and applies the portfolio methodology in certain classes of Invertebrates Zoology of the course of Biology of a Brazilian university. The study tests the hypothesis that the use of portfolio, as an activity that aims to promote the deep approach, generates greater knowledge acquisition of Zoology, in the topics Plathelminths, Annelids and Arthropods, in comparison with an activity based on methodologies that enhance, in theory, the surface approach.

METHODS

Participants

The research was carried out with students enrolled in the discipline of Invertebrates Zoology, in the 4th period of the degree course in Biology of a Brazilian public university. The sample number was of 57 students, with an average age of 23.7 years (SD = 6.7), being 41 (72%) female students.

MATERIAL

Three tests were designed for this research, each one related to a phylum of specific animals (Phylum Platyhelminthes, Phylum Annelida and Phylum Arthropoda), which are part of the content of the subject Invertebrates Zoology. Each test contains three short answer questions, each question consisting of a specific number of items, detailed below. Question 01 addresses aspects of the animal's external anatomy and consists of 20 items. In this question, the student is asked to draw five important structures present in the animal's body, describing, naming and providing the function of each of these structures. The second question addresses aspects of the animal's internal anatomy and consists of 16 items. It is requested that the student draw the structures present in the system, describe it, name it and provide the function of the structures of each functional system present in the group of the animal mentioned (digestive system, circulatory system, nervous system and excretory system). The third question is related to taxonomy and ecology and it is composed of 15 items. Images of 3 specimens of animals are shown and, for each specimen, students must identify the animal, citing its popular name, classify it taxonomically, provide characteristics related to eating habits, habitat and life habits. Therefore, each test consists of 51 items, with variable levels.

Procedure

Study intervention

Zoology Portfolio (ZP): The Zoology Portfolio (ZP) used as an intervention in this research is a study guide pre-established and prepared by the teacher of the discipline Invertebrates Zoology of the Biology degree course of a Brazilian public University, following the content provided in the Lesson Plan of the discipline, and used with the intention to promote a deep learning in students. The preparation of the ZP is an activity composed of several stages, listed and described below.

Name the Phylum and give meaning to the Phylum's name

Animal Phyla are generally named in Latin, which hinders students' memorization. However, these names are usually defined according to an important characteristic of the group (for example: Phylum Arthropoda, which means articulated feet, is composed of animals that have this peculiar characteristic). When researching the meaning of the name given to the group of animals studied, the concern reflects on the underlying meanings, the main ideas and the student associates the name with the important characteristics of the group. The behavior used in this type of strategy is to seek to understand and critically analyze the meaning of what is being learned. Accordingly, a deep strategy is used, since attention is mainly focused on the meaning of the content in question, in addition to the literal aspects (Fontes, 2019), which helps in memorization and learning.

Name specimens of animals belonging to the Phylum

Student should think about animals that he knows, that are part of his daily life, to relate the animal to the Phylum. Consequently, he associates knowledge in different contexts, including in daily life and his previous experience, which helps in the process of deep learning.

Draw a specimen of the Phylum, detailing aspects of the animal's external and internal anatomy, indicating its main components and coloring the structures of each system in a specific color

In this task the student must choose an animal that represents a Phylum and make a survey of images that contain structures of the external and internal anatomy of the chosen animal. This survey can be made in books, handouts or internet sites and must be done carefully, selecting scientifically correct images as complete as possible. After choosing the images, the student must create his own drawings, in order to reproduce, with the greatest possible detail, the important structures of the internal and external anatomy of this animal. Structures must be identified and named in the drawing. In the external anatomy drawing, the animal must be colored according to its natural color, thus the student associates the drawing made with the animal in nature. For the internal anatomy drawing, a pre-established color legend must be followed, where each color represents a system (for example, yellow represents the digestive system, red represents the circulatory system, and so on). Consequently, when observing the drawing, it would be possible to identify the structures of each system by color, which can assist in learning. Elaborating your own drawing can be considered an active strategy, important for deep learning, once the student needs to search for images related to the specimen chose to draw, check if the images are suitable and reproduce its drawing. Frequently, student uses more than one image to elaborate his drawing, in order to complement the missing information in the researched images. Drawing demands a complex cognitive skill of synthesis, in which he gathers the information to create something new, involving the production of a unique communication. When drawing, the student pays close attention to the details of the structures, which helps memorization and learning.

Characterize life habits, habitat, feeding habit, embryonic development and the functional systems of the animals of the Phylum

To develop this task, student must do a survey in scientific books in the area of Zoology and Biology and on internet sites. Through the performance of the survey, student makes a critical analysis of the contents read, verifying which information is relevant and scientifically correct. Based on the information collected and on their previous knowledge, students should prepare summaries, in order to synthetically characterize the animals of the studied Phyla, under various aspects (morphological, physiological, ecological and embryonic). Therefore, for each of these aspects, students write texts, in their own words, seeking to understand and critically analyze the meaning of what is being learned and giving meaning to the content studied. This task can also be considered a deep strategy, once the student actively confronts academic tasks through the elaboration of information, according to the opinion and previous experience and relating to other knowledge (Lourenço & Paiva, 2015; Sources, 2019). In other words, the student elaborates new representations about subjects learned through constant updates of the personal conceptualization system (Monteiro, Almeida & Vasconcelos, 2012; Parpala, Lindblom-Ylänne, Komulainen & Entwistle, 2013).

Taxonomically classify the Phylum, naming and describing the main Classes belonging to that Phylum

Animal taxonomy is an important area in Zoology, as it helps to systematize groups for identification and study. However, due to the use of Latin to name groups and the excessive number of names used to designate taxonomic groups, students find it very difficult to understand and memorize the most complex taxonomic classifications. Understanding the meaning of group names and recognizing the main characteristics that are observed by scientists to group animals into taxonomic categories can help students to better understand this aspect of Zoology. This portfolio task was designed to help students learn. For its development, students need to search in Zoology and Biology scientific books and on internet sites about the main Classes belonging to the Phylum in question. The gathered information should be related to the meaning of the Class names and the main characteristics that determine the grouping of animals in a certain Class (for example: the Oligochaeta Class is a class of animals belonging to the Phylum Annelida. Oligochaeta is a Latin name that means few bristles, that is, the annelids belonging to this Class are animals that have few bristles on their bodies). Students should make a critical analysis regarding the collected content, in order to select the most pertinent information that will help to relate the group's name to the characteristics of the animals. After this selection, they must prepare a summary, in their own words, describing the most striking characteristics that are considered by scientists to determine this classification. In this task, the student is induced to take a deep approach, based on the elaboration of information, according to the opinion and previous experience and by trying to understand and critically analyze the meaning of what is being learned.

Draw a specimen of each Class

In this task, student must research which animals are part of the Classes listed in the previous task and choose an animal to represent the Class. The chosen animal must be draw by the student to illustrate the portfolio. This activity helps the student to make an association between an animal known to him (previous knowledge) and the Class to which it belongs (new knowledge), assisting in learning about the taxonomic classification of animals. In this manner, this activity induces the deep strategy, seeing that it involves not only the retention of information by understanding (Monteiro et al., 2012), but also the ability to integrate previous knowledge with new information, implying the use of cognitive and metacognitive learning strategies (Paiva, 2007). The ZP activity is performed in classroom, as a guided study, under the supervision and guidance of the teacher; consultations selected by the students should be carried out on didactic and technical materials on the subject. To do the ZP, students organize themselves in small groups for discussion and solution of doubts. Dallimore, Hertenstein, and Platt (2010) argue that it is important to encourage student participation and confrontation, especially using the small group discussion strategy, to improve learning. In addition, classes with open activities that provide an environment of curiosity and autonomy, teaching methods that encourage the sociability of the learning procedure, providing that students help each other, argue and explain their positions, are related to a deep approach (Fontes, 2019). Performing the ZP activity in small groups of students in the classroom is intended to make students feel motivated to engage in the pursuit of discussions with the teacher and other colleagues, demonstrating an involvement with the learning task and a constant and in-depth search in sources of information beyond to those offered by teachers in the classroom (Fontes, 2019). This type of motivation is related to a deep learning approach.

Accordingly, ZP is constructed in an active and reflective way by students, with the aim of systematizing the content learned in the classroom, creating a study routine, discussing and solving doubts, selecting reliable sources of reading. During the entire activity of ZP, an active interaction of the student with the learning task is required (Gomes, 2011a), therefore enabling a profound learning in the students.

Control task: An intervention activity given to the control group was developed to induce surface learning in students. In this class, held in the Zoology laboratory, students had contact with some specimens representing the Phylum of invertebrates studied, corresponding to the portfolio activity carried out by the experimental group, simultaneously. With the purpose of providing a surface learning, tests with questions that demanded simple memorization and repetition of information by the students were elaborated, such as the animal's name, Class to which it belongs, identification of external parts and structures of the animal's body. For example, in the control activity class referring to the Phylum Annelida, an earthworm was presented to the students and they had to taxonomically classify the worm (from Kingdom to Class) and identify some structures of its body, such as clitelum, metameres, prostomium, pigid, etc. In order to perform these activities, it is not necessary to elaborate information according to previous opinions or experiences, nor to relate it to other knowledge, to contest, reflect or criticize, which encourages a passive strategy and surface learning by students. The surface strategy involves the behavior of capturing and accumulating the information transmitted and subsequently reproducing it nearly *ipsis litteris*, with little or no intervention or elaboration of the information, and could therefore be considered a type of passive strategy (Fontes, 2019). This activity was intentionally designed to give students little autonomy, recruiting low complexity cognitive skills, once students only needed to accurately reproduce information received during theoretical class, focusing on specific details of the content, and thus boosting the surface approach (Fontes & Duarte, 2019).

Research design, data collection and analysis: Prior to data collection, the study was approved by the UFMG Ethics Committee through process number (to be informed if the article is accepted for publication) and only those students who signed an informed consent form were part of the research. All ethical precautions were preserved, such as confidentiality and anonymity and the freedom to withdraw from participating in the study at any time. Before starting data collection, students were trained to perform the portfolio intervention activity. A script detailing the stages of execution of the portfolio was created and explained to students. Like training, students performed the portfolio activity on three zoology content that would not be tested. For this training, 9 hours/classes (3 hours/classes for each content) were allocated during which students in a group performed the portfolio activity under the supervision of the teacher and with consultation of didactic and technical materials related to the subject, exactly as it would be done during the experiments. During training, students were able to ask questions about the activity and after completing it, portfolios were presented to the teacher, consequently there was confidence that students understood the task well. The experiment was only started after this training. The research employed the experimental design of random case-control of pre and post-test. The study followed these steps: (1) lecture on a particular Phylum of Zoology with the presence of all students (experimental and control group); (2) pre-test, application of the educational test in all students, seeking to measure the level of student knowledge about the Philo presented in the lecture; (3) portfolio activity for the experimental group and laboratory activity for the control group; both activities were carried out in 100 minutes; (4) post-test, application of the same educational test applied in the pre-test. Students were instructed to carry out the tests without consulting any type of material and respecting a time limit of 1 hour. This sequence of lecture, pre-test, intervention and post-test was made for the three contents selected as learning tasks for this research. In each of the contents, students were randomly allocated to the experimental and control groups, so that a student could participate in the control group in one content and participate in the experimental group in the other two contents, for example. The chi-square test and the t-test were performed with the purpose of examining whether the control group (CG) and the experimental group (EG) are statistically equal in relation to sex and age in the three contents of the study. Tests were corrected according to the correction criteria and response patterns stipulated during their elaboration. For each item, answers considered correct were scored as one (1) and wrong answers with zero (0).

The three educational tests were evaluated in terms of the validity of their measurement. The validity of the one-dimensional Rasch measure for each educational test was verified by means of the Martin-Löf statistical test (Verguts & Boeck, 2000) and by the infit index of the items, which indicates an acceptable value of adjustment of the items to the model between 0.5 and 1.5 (Linacre, 2009). The reliability of the scores was calculated using the person separation index, values equal or greater than 0.7 being indicators of acceptable reliability (Mair, 2018). The Binary Logistic Regression, a type of extended Rasch model, has a series of properties that justify its use in the analysis of this research. The Binary Logistic Regression does not depend on the normality of the data, it can be used for analysis of binary data, small samples and repeated measures (Golino, Gomes, Amantes & Coelho, 2015). The Conditional maximum likelihood (cML) of the Binary Logistic Regression was used to calculate the measurement parameters (items level and people's ability). This estimator allows to estimate parameters of the items and people separately (Mair & Hatzinger, 2007).

In addition, it allows estimating the parameters of the testing effect and the intervention effect. The test effect parameter allows to evaluate whether there was an improvement in the students' performance due to the fact that they performed the test twice. Verifying this parameter is important because it makes it possible to know if there has been an improvement in students' knowledge about the tested content, regardless of the applied intervention. The intervention effect parameter allows to assess whether the gain (post-test versus pre-test) of the experimental group was greater than the gain of the control group. This parameter allows to infer if the portfolio intervention, focused on the deep approach, generated in the students a better knowledge acquisition in Zoology in comparison to the control activity, focused on the surface approach. For the analyzes, we used the eRm package (v. 1.0-0), developed by Mair, Hatzinger and Maier (2019), and version 3.6.1 of the R software (R Development Core Team, 2019).

RESULTS

Results of random allocation: In this section, it is first presented results regarding the random allocation of students to experimental and control groups. The results below indicate that the random allocation proved to be successful, generating groups with similar characteristics, therefore the inferences of causality become more robust. As stated, 57 students participated in this study, with a mean age of 23.7 years (SD = 6.7), 41 (72%) of whom were female and 16 (28%) were male. The sample referring to the Platyhelminthes content includes 46 participants, of which 20 (43%) students were part of the control group and 26 (57%) of the experimental group. The mean age of students in this sample was 23.6 years (SD = 6.7), comprising 33 (72%) female participants and 13 (28%) male participants. The sample referring to Annelids content included 41 participants, 22 (54%) students belonging to the control group and 19 (46%) to the experimental group. The mean age of students was 24.6 years (SD = 7.5), being 29 (71%) female participants and 12 (29%) male participants. Finally, the sample related to the Arthropod content included 42 participants, of which 22 (52%) formed the control group and 20 (48%) the experimental group. The mean age of the students was 24 years (SD = 7), being 27 (64%) female participants and 15 (36%) male participants. For the Platyhelminthes content, results of the chi-square test in relation to the sex of participants in the experimental and control groups were X^2 (DF) = 0 (1) and p = 1.00 and the results of the t-test in relation to age group participants were t (DF) = -1.36 (42) and p = 0.18. Regarding Annelids content, results of the chi-square test in relation to sex of the participants in the experimental and control group were X^2 (DF) = 0.002 (1) and p = 0.97. The t-test for the age of participants in the groups resulted in t (DF) = 0.47 (38) and p = 0.64. For the sample related to the content about Arthropods, results of the chi-square test in relation to sex of the participants of the two groups were X^2 (DF) = 2.31 (1) and p = 0.13 and the results of the t-test in relation to age of participants in the groups were t (DF) = 1.58 (38) and p = 0.12. These results indicate that the participants in the experimental and control groups do not present a statistically significant difference in relation to sex and age and that random allocation of students in the EG and CG groups was successful.

Validity of the measure of the educational tests developed

Platyhelminthes test: Of the 51 items prepared for the Platyhelminthes test, 3 were removed once there was no variation in scores considering results in the pre and post-test. Hence, the Platyhelminthes test was composed of 48 items. The model tested in this analysis was that of a latent dimension (knowledge of students on the subject Platyhelminthes) explaining the 48 items of the test, in 2 moments (pre and post-test). The Martin-Löf test was performed to verify whether the data fit the model. The null hypothesis is that the data fit the model (Mair, 2018). The result of the Martin-Löf test (LR = 335.276 and p-value = 1.00) indicated that the null hypothesis should not be rejected. The items had a mean infit of 1.0 (SD = 0.27), indicating a good mean fit to the model and corroborating the results of the Martin-Löf test (Mair, 2018). Analysis of the reliability of the person separation (0.92) indicated that the test scores showed excellent consistency (Mair, 2018). Students' ability on the test was scaling (Figure 1) and results showed that the test was able to distinguish students' abilities, seeing that scores were well distributed over the measure [minimum = -2.85 logits (raw score = 16 out of 96 points), mean = - 1.12 logits (SD = 0.96), (raw score = 40.4 out of 96 points, SD = 15.2), maximum = 1.15 logits (raw score = 72 96 points)]. Consequently, the Platyhelminthes test presented evidence of validity and reliability of the measure.

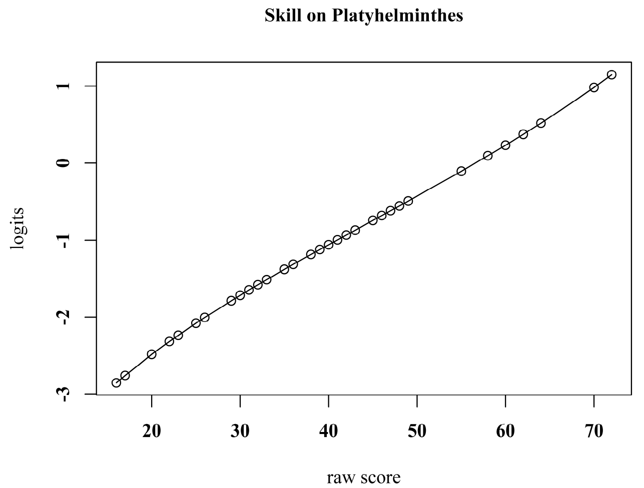

Figure 1. ***Scaling of students' ability on the Platyhelminthes test***

Annelids Test: Of the 51 items elaborated for the Annelids test, 4 were removed because they did not present any variation, leaving 47 items to compose this test. Accordingly, the model tested in this analysis was that of a latent dimension (students' knowledge of the subject of Annelids) explaining the 47 test items in 2 stages (pre and post-test). The result of the Martin-Löf test (LR = 226.747 and p-value = 1.00) indicated that the null hypothesis should not be rejected, in other words, the data fit the model. The items had a mean infit of 1.0 (SD = 0.17), indicating a good mean fit to the model and corroborating the results of the Martin-Löf test (Mair, 2018). Analysis of the reliability of the person separation (0.92) indicated that the test scores showed excellent reliability (Mair, 2018). Students' ability in the test was scaling (Figure 2) and results showed that it was able to distinguish the students' abilities, as the scores were well distributed over the measure [minimum = -3.60 logits (raw score = 6 of 94 points), mean = - 0.54, logits (SD = 0.91), (raw score = 40 of 94 points, SD = 14.3), maximum = 0.98 logits (raw score = 65 of 94 points)]. Therefore, the Annelids test also presented evidence of validity and reliability of the measurement.

Arthropods test: Of the 51 items elaborated for the Arthropods test, 4 were removed because they did not present any variation, leaving 47 items to compose this test. Accordingly, the model tested in this analysis was that of a latent dimension (students' knowledge of the subject of Arthropods) explaining the 47 test items in 2 stages (pre and post-test). The result of the Martin-Löf test (LR = 232.471 and p-value = 1.00) indicated that the null hypothesis should not be rejected and that, therefore, the data fit the model. Items had a mean infit of 0.98 (SD = 0.27), indicating a good fit to the model and corroborating the results of the Martin-Löf test (Mair, 2018). Analysis of the reliability of the person separation (0.93) indicated that the test scores showed excellent reliability (Mair, 2018).

Figure 2. ***Scaling of students' ability on the Annelids test***

Students' ability in the Arthropod test was scaling (Figure 3) and results showed that the test was able to distinguish the students' skills, seeing that scores were well distributed over the measure [minimum = -2.87 logits (raw score = 15 out of 94 points), mean = - 0.18, logits (SD = 1.01), (raw score = 49.3 out of 94 points, SD = 15.8), maximum = 1.67 logits (raw score = 73 out of 94 points)]. Consequently, the Arthropod test also presented evidence of validity and reliability of the measure.

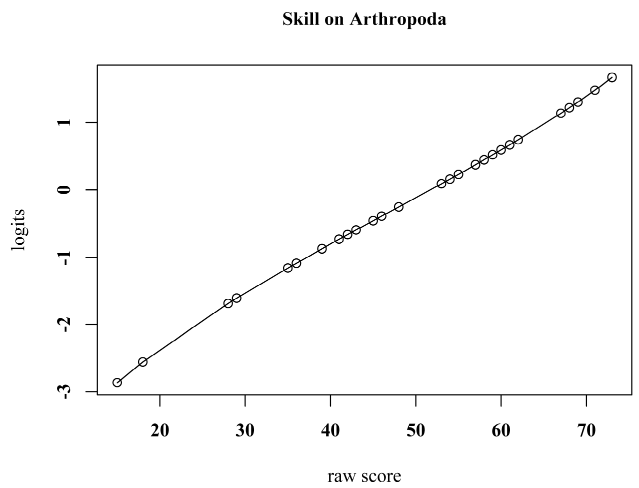

Figure 3. ***Scaling of students' ability on the Arthropods test***

Estimation of tests and intervention effects

Platyhelminthes test: The test effect parameter, which allows assessing whether there was an improvement in student performance over time, indicated an increase of 1.12 logits (95% CI [0.89 / 1.36]) in student knowledge, comparing the second test in relation to the first. This increase was statistically significant and had a strong size effect (Cohen, 1988). The intervention effect showed 0.25 logits in favor of the control group. However, this difference was not statistically significant [95% CI (-0.562 / 0.056)].

Annelids test: The testing effect parameter showed a gain of 0.17 logits [95% CI (-0.037 / 0.386)], when comparing student knowledge about Annelids between the second and the first test. This result does not allow us to reject the null hypothesis (Mair, 2018), therefore it cannot be said that there was an improvement in the participants' knowledge over time. The intervention effect showed an estimate of 0.20 logits in favor of the experimental group. However, there was no statistically significant difference between the experimental and control groups [95% CI (-0.104 / 0.520)].

Arthropods test: The test effect parameter for the Arthropod test indicated a gain of 0.63 logits [95% CI (0.406 / 0.863)]. This result allows us to reject the null hypothesis (Mair, 2018) and suggests that knowledge in arthropods grew moderately between the first and the second test (Cohen, 1988). The intervention effect showed an estimate of 0.15 logits in favor of the control group. However, there was no statistically significant difference between the experimental and control groups [95% CI (-0.49 / 0.17)].

DISCUSSION

The Zoology Portfolio activity was developed with the intention of being an activity that promotes active learning, considering the quality of the elaborated script, which aimed to awaken higher-order cognitive operations, promoting a deep approach. Students were trained to carry out the portfolio and precaution was taken to ensure that the activity was performed adequately. Based on this, it was expected a greater gain of knowledge in students submitted to the portfolio activity, when compared to students submitted to the control activity, which was highly promoter of a surface approach. However, surprisingly, no statistically significant or relevant differences were found in favor of the experimental group. A reasonable hypothesis for this result is the manner in which students may have carried out the portfolio activity. The script was designed for students to develop an interactive process of knowledge, relating information, performing analysis, studies, individual and collective decision-making, which should therefore recruit deep cognitive operations. However, as the activity was performed with free consultation of materials, students could copy information available in the material consulted, performing lower and superficial cognitive operations, not reaching the intervention aim. When trying to facilitate student learning, teacher may provide tasks that allow lower cognitive processing. Therefore, teacher must be very cautious when designing and applying didactic activities wherefore they can effectively be profound activities. In order to truly test the SAL principle, where the deep approach generates better quality of learning, it is necessary to monitor in detail the student's cognitive process, during the execution of the proposed tasks.

Traditionally, studies in learning approaches have empirically investigated the procedural aspects of deep and surface approaches through the phenomenological method (Soler-Contreras, Cárdenas-Salgado, Fernández-Pina, & Monroy-Hernández, 2017). Although relevant, qualitative research method may present biases, once the students' performance is categorized as the deep and surface approach according to the researcher's previous expectation (Quadros, 2020). Providing that the learning theory of approaches gradually incorporated the quantitative methodology, through elaboration and application of self-report instruments (Soler-Contreras et al., 2017), the study on procedural aspects remained focused on the use of qualitative methodology. Summing up, the absence of valid and reliable quantitative instruments that assess the students' learning process at the time they are learning is an important gap in the field of research on the effect of teaching interventions on student learning approaches. Analysis of the instruments for measuring school performance used in our educational environment reveals several levels of technical quality. Along with some which actually demonstrate measuring what they propose, there is, unfortunately, a large number of instruments that have a complete lack of technical requirements (Vianna, 1998). Thanks to principles provided by Statistics and Psychology, teachers are now able to develop school evaluation procedures with broad scientific support (Gil, 2015).

In order to develop instruments for valuable educational measures and to avoid mistakes commonly made by teachers when preparing school exams, it is important that the teacher observe some essential technical procedures (Pires & Gomes, 2017, 2018). In the present study, three educational tests were carefully designed to measure students' knowledge of specific Zoology content. Tests were analyzed for their validity and reliability indicating that they are good instruments for verifying students' knowledge of the learning tasks. It is expected that the practice achieved in this study motivates and encourages other teachers to create school tests with relevant theoretical support and methodology capable of verifying the validity and reliability of the exams. Many studies have indicated that the deep approach correlates positively with academic performance, while the surface approach correlates negatively with student performance (Entwistle, 2018; Haarala-Muhonen, Ruohoniemi, Parpala, Komulainen, & Lindblom-Ylänne, 2017; Herrmann, McCune, & Bager-Elsborg, 2017; Richardson, Abraham & Bond, 2012; Watkins, 2001). These studies also indicate that correlations are consistently weak. A possible explanation for the uncertain points of association between learning approaches and exam scores has been that, although the deep approach is recognized as capable of raising quality of learning, assessment systems may not always reflect highly complex learning outcomes (Asikainen, Parpala, Virtanen & Lindblom-Ylänne, 2013; Herrmann et al., 2017), due to the lack of technical quality of the evaluations. Working in a Dutch university context, Asikainen et al. (2013) discuss how assessments in education may not fully measure the qualitative products of student learning and do not always reward a deep approach.

Vermunt (2005) concluded that aspects of students' learning strategies, such as criticism, analytics and abstract thinking, seemed to be rewarded to a lesser extent in school exams. According to Herrman et al. (2017), a deep approach could result in complex and subtle understandings, with which students may have difficulty expressing themselves well under exam or test conditions (Herrmann et al., 2017). In addition, school grades, which characterize academic performance, are frequently composed of a mixture of several factors, for example, student participation in classes and activities. However, none of these elements explains why the students in experimental group in our study did not have greater knowledge acquisition compared to students in control group. As already mentioned, the three tests developed were carefully designed and analyzed, in terms of their validity and reliability. Certainly, they assess the target knowledge, hence that students' scores reflect their knowledge about teaching contents. As mentioned earlier, the great challenge of studying whether certain forms of teaching mobilize the deep approach and, in turn, improve academic performance, involves the pressing need for the development and validation of quantitative instruments on learning processes, at the moment or soon after the student performs some learning activity. Analysis of the testing effect performed in the present study showed interesting results. In two tested contents, Platyhelminthes and Arthropods, students showed an important improvement in their performance in the second test (post-test). This possibly indicates that students were motivated to perform activities and research, once there was a considerable gain in knowledge after performing both activities, either from experimental group or from control group. The absence of a control group without intervention prevents us from saying that the improvement in time was due to the interventions, but this is a conceivable hypothesis. This result suggests that, in some cases, having superficial activities can also be productive in the learning process. Using only superficial activities in the classroom has a limiting effect, but these activities can contribute, when associated with activities of a more constructive character. In other words, the surface approach may not necessarily be antagonistic to the deep approach.

The absence of temporal improvement in student performance related to the content of Annelids may be related to the context in which students performed the activities of this content. Activities related to the Annelids were applied at a time during the semester where they concentrated assessments from other disciplines, which may have compromised students' involvement in execution of activities of the discipline of Zoology. Thereat, it is suggested to consider the schedule of activities of other subjects and disciplines when research is carried out in the school context, as this factor can interfere with the students' performance. An initial analysis of the results made the first author of this article believe that students were not motivated to perform the activities, due to the absence of difference in performance in the post-tests, between the students of the control and experimental groups. As a teacher, it was hoped that students who performed the portfolio would perform better on tests after interventions. Despite not having found this expected result, empirical results of time effect showed that students improved their performance, contradicting the initial belief about student demotivation. This shows the importance of the teacher himself conducting empirical research on the classroom, in order to test their beliefs, expectations and values.

This study happened in the context of a Brazilian public university, with a limited number of classes and students. Although studies carried out in specific contexts are valuable, as it allows a more detailed analysis of a relevant configuration, it would be important to repeat the analyzes with other, more diverse and larger samples. It would have been ideal for the study given that the sample was expanded, carried out the research in other universities, in different contexts. Moreover, the portfolio activity is a punctual activity regarding the students who participated in this research, regarding that this activity is not used in other subjects, and is therefore not common and recurrent in the course. Due to this, students were not used to performing the portfolio, which may have interfered with the quality of its execution and disappointing regarding its objective of promoting a deep approach. A possible direction for future research would therefore be, in addition to increasing and diversifying the sample, providing training and detailed monitoring of the students' cognitive process when carrying out the proposed activities, in order to test the principle of the Students' Approaches to Learning theory where the deep approach generates better quality of learning. The aim of the present study was to test the principle of the Students' Approaches to Learning (SAL) theory that the deep approach generates higher quality of learning and acquisition of knowledge about the learning task. Although it was not possible to test this principle, this study brought some important contributions to the area of research on approaches to learning. Testing a theory principle, using empirical and quantitative methods, is an important objective as it helps to consolidate the theory in question. However, from the present study, it can be seen that, in order to actually test the SAL principle, it is necessary to monitor in detail the student's cognitive process. In addition, it can be concluded that it is important that the research area on SAL increases its efforts in quantitative studies of learning processes. Moreover, it is necessary to encourage higher education teachers to perform empirical research in the classroom context, as well as to prepare educational exams aimed at assessing the acquisition of deep knowledge and verifying its reliability and validity. Analyzing student performance through the creation of valid and reliable educational tests, using a statistical model such as the Rasch Models, was also a contribution of this study.

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