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THE EFFECTS OF 3D PLASTIC MODELS OF ANIMALS AND CADAVERIC DISSECTION ON STUDENTS' PERCEPTIONS OF THE INTERNAL ORGANS OF ANIMALS

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Abstract. *The decrease in the method of cadaveric dissection and its replacement with alternative methods has led to discussions about the significance of dissection in biology/anatomy lessons. Certain authors argue that the decline in anatomy knowledge in students is at least partially caused by these factors. An investigation was carried out on the effectiveness of teacher's demonstrations of cadaveric dissection as opposed to a 3D plastic model on pre-service biology teachers' ideas concerning what is inside animals. Students were pre-tested on their ideas as to what is inside animals and randomly divided into four treatments (Dissection + Model, Dissection, Model, Model + Dissection). After the treatment, the post-test scores revealed that treatments where both methods were combined resulted in the highest achievement scores, particularly in the case of anatomy of fish. It has been concluded that the combination of cadaver dissection with modern innovative methods is more effective for obtaining anatomy knowledge than the use of only one method. The use of alternative methods should not be in conflict with traditional methods.*

Key words: *anatomy, animals, biology education, dissection, ideas, student.*

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Introduction

Modern technologies significantly influence student learning and attitudes (Chompu-Inwai & Doolen, 2008; Bangs, MacBeath, & Galton, 2011). Traditional methods are often replaced with modern innovative methods (Patel & Moxham, 2006) which are expected to reduce the number of curriculum hours and produce graduates who are better in creative thinking and problem solving (Felder, Woods, Stice, & Rugarcia, 2000). Virtual reality (Aggarwal et al., 2006), tablet computers (Lewis, Burnett, Tunstall, & Abrahams, 2014) and other achievements of modern times are expected to positively influence academic success, although the majority of them are costly and/or require additional skills and training on the part of teachers (Janssen, Westbroek, & van Driel, 2014). Critical evaluation of their effectiveness is consequently required (Heywood, 2000).

Cadaver dissection was a traditional part of biology education for a long period of time although its status in school lessons has changed (De Villiers & Monk, 2005). Several ethical issues concerning the killing of animals for educational purposes (e.g., Oakley, 2009, 2012) along with the possibilities of modern technology (Torres et al., 2014) have led to a critical re-evaluation of traditional dissection (Texley, 1992; Hug, 2005, 2008; Milano, 2010). As a result, the cadaveric dissection method is decreasing primarily due to time and money constraints (Raftery, 2006; Bergman et al., 2014). Anatomy knowledge on the part of students is continuously decreasing (Yammine, 2014).

The main controversy in the use of cadaveric dissection lies in the mixed results in terms of their effectiveness in recent literature (Bergman et al., 2014). The use of simulations (Predavec, 2001), clay models (Waters et al., 2005; DeHoff, Clark, & Maganathan, 2011), three-dimensional virtual

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models (Nicholson, Chalk, Funnell, & Daniel, 2006) or plastic models (Lombardi, Hicks, Thompson, & Marbach-Ad, 2014) may on the one hand lead to improved anatomy knowledge score as compared with cadaveric dissection. Certain authors found on the other hand that a purely computerized approach leads to a lower level of anatomical knowledge as compared with students who experienced traditional dissection (Biasutto, Caussa, & del Rio, 2006), and/or that the use of both computerized and cadaveric dissection is superior than the use of computerized dissection alone (Kinzie, Strauss, & Foss, 1993; Akpan & Andre, 1999, 2000; Biasutto et al., 2006). Kooloos et al. (2014) in their recent study determined that students who performed clay-modelling exercises showed less improvement in anatomical knowledge than students who experienced live observation.

Proponents of cadaveric dissections additionally demonstrated that those students who experienced traditional dissection have more positive attitudes towards dissection as compared with students who did not experience traditional dissection (Franklin, Peat, & Lewis, 2002; Fančovičová, Prokop, & Lešková, 2013; Lombardi et al., 2014) reinforcing the importance of cadaveric dissection for students.

The Purpose of the Study

The present study investigates the effects of teacher demonstrations of cadaveric dissection as opposed to a 3D plastic model on pre-service teacher conceptions about what is inside animals. The primary motivation of this study lies in the time and money constraints in anatomy courses stressed by certain authors (Raftery, 2006; Bergman et al., 2014). Certain teachers may, in other words, due to time/financial constraints, decide to demonstrate dissection to their students with the traditional method (i.e., a cadaveric dissection) or by using a 3D plastic model or both. Both these possibilities were experimentally examined. Specifically, there was an investigation as to whether the use of cadaveric dissection influences pre-service biology teachers' ideas about what is inside animals more than 3D models, or whether a combination of both methods is superior than the use of only one of these methods alone.

Research Methodology

This study was conducted in the zoology laboratory of Trnava University. A pre-test post-test design was applied to test the effectiveness of the experimental methods and the pre-service teachers' responses were collected with paper-and-pencil tests. The participants were assured that their responses would only be used for research purposes and would not affect their final exam scores.

The Participants

A total of 59 students (95 % of those attending a Vertebrate zoology course) with a mean age of 22 years (range: 21 - 25, SE = 0.07) attending Trnava University participated in the study. The students were in the 3rd year of their studies and all of them actually attended the Vertebrate zoology course where an acquiring dissection skill is required prior to the final exam. The study was not focused on dissection skills, however, but on the effect of teacher demonstrations of animal internal organs which precedes cadaveric dissection in the Vertebrate zoology course. The students were unaware of the hypotheses of this study and their participation was voluntary. Only several students, who were not present in the lectures during the research, did not participate in the study.

The Experimental Procedure

The experiment was carried out in the summer semester in the zoology lab class over two occasions. The dissection of a trout was followed the next week by the dissection of a rat. The students were randomly divided into four experimental groups (Dissection + Model, Dissection, Model, Model + Dissection) on each occasion and received distinct ID numbers in order to ensure anonymity and to allow for pair-wise comparisons. All the students were instructed to draw what is inside the fish (the first occasion) and what is inside the rat (the second occasion) following the instructions of Tunnicliffe and Reiss (1999, 2001) and Prokop, Prokop and Tunnicliffe (2007) at the beginning of each lesson (pre-test data). The participants were specifically asked to draw what they thought was inside each animal specimen when these animals were alive. On the first occasion, the same researcher (PP) demonstrated a cadaveric dissection of a rainbow trout (*Oncorhynchus mykiss*) (approximately 30 cm long, see Appendix, Photograph 1) and described the main body organs and organ systems and their functioning in front of a group of students during a 45 min. lesson (the Dissection treatment). In the Model treatment, a 3D plastic model of a fish (38 cm long, see Appendix, Photograph 2) was presented to the students in the same way, but without a cadaveric dissection. During the Dissection + Model treatment, a model presentation was followed after the cadaveric dissection and in the Model + Dissection treatment, the dissection was preceded by a model presentation. The same procedure was applied to a freshly killed laboratory rat (*Rattus norvegicus*) (approximately 15 cm long, see Appendix, Photograph 3) and a 3D plastic model of a rat (20 cm long, see Appendix, Photograph 4). The specimens used for dissection were commercially available. After the demonstration, the students were once again asked to draw what they think is inside a fish (the first occasion) and a rat (the second occasion) on a separate sheet of A4 paper (post-test data). The number of students in the first (N = 46) and second experiments (N = 59) was different since certain students were absent due to unknown reasons. A detailed report with the sample sizes per each treatment can be found in Figures 1 – 4. Only seven students were males, thus we omitted any comparisons of possible gender differences.

Analyses of the Students' Drawings

The organ systems were analysed following Tunnicliffe and Reiss (1999, 2001) and Prokop et al. (2007) on a 7 level scale, where Level 1 is defined as "no representation of the internal structure" and Level 7 is defined as "comprehensive representation with four or more systems indicated out of skeletal, circulatory, digestive, gaseous exchange, reproductive, excretory and nervous". More details can be found in Tunnicliffe and Reiss (1999, 2001) and Prokop et al. (2007). The drawing method was used to analyse participants' ideas concerning what is inside animals since it is a reliable tool on how data about learners' ideas can be effectively and easily obtained (Tunnicliffe and Reiss, 1999, 2001). The two researchers separately and independently scored the drawings. In the few cases where the scores differed, the drawings were discussed until an agreement regarding the level was awarded.

Statistical Analyses

Data were checked for normality with the Shapiro-Wilk test and then analysed with parametric statistics. The pre-test scores were treated as covariates in the analysis of covariance (ANCOVA) in order to eliminate the potentially confounding effects of prior knowledge concerning animal internal organs. A similar procedure can be found in related works (e.g. Kooloos et al., 2014). Pair-wise comparisons were made with paired t-tests. Partial eta squared was used in order to measure the effect size (0.01 was considered small, 0.04 moderate, and 0.1 large; Huberty, 2002).

Results of the Research

Pre-service teachers revealed a low awareness about what is inside fish and rats, at least when the drawing method used in this study is considered. The following subsections analyse the effects of treatments on drawings of fish and rats separately.

Ideas Concerning Fish

A one-way ANOVA revealed significant differences between the four experimental groups in the pre-test mean scores of drawings of fish ($F_{(3,42)} = 4.77$, $p = 0.006$, eta squared = 0.25). The pre-test score was consequently treated as a covariate in the analysis of covariance (ANCOVA) to control for pre-existing differences between the four groups. An ANCOVA with a fish post-test score as the dependent variable revealed no significant effect of treatment on mean post-test scores of drawings of fish ($F(3,41) = 2.06$, $p = 0.12$, eta squared = 0.13, Figure 1). The effect of the pre-test was also non-significant ($F_{(1,41)} = 1.54$, $p = 0.22$, eta squared =0.04).

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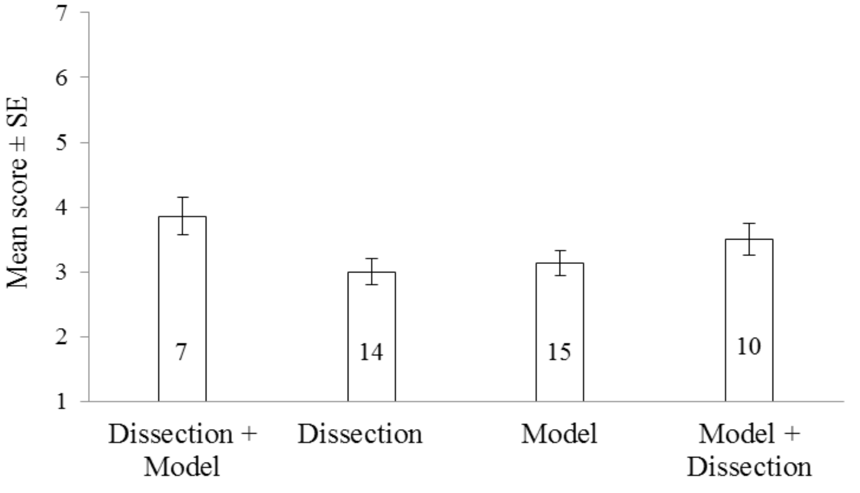

Figure 1: Mean post-test scores for the four experimental groups after controlling for pre-test fish scores. The numbers inside the bars are sample sizes.

In the next analysis, Dissection + Model and Model + Dissection treatments were compared to the Dissection and Model treatment with planned ANOVA comparisons. The difference was significant ($F(1,41) = 6.17$, $p = 0.02$) indicating that students received superior mean scores in Dissection + Model and Model + Dissection treatments than in the remaining Dissection and Model treatment.

There were significant differences in pre-test and post-test scores in all the treatments. As shown in Figure 2, all the post-test scores were significantly higher than the pre-test scores suggesting that the demonstration significantly influenced participants' knowledge about the anatomy of fish.

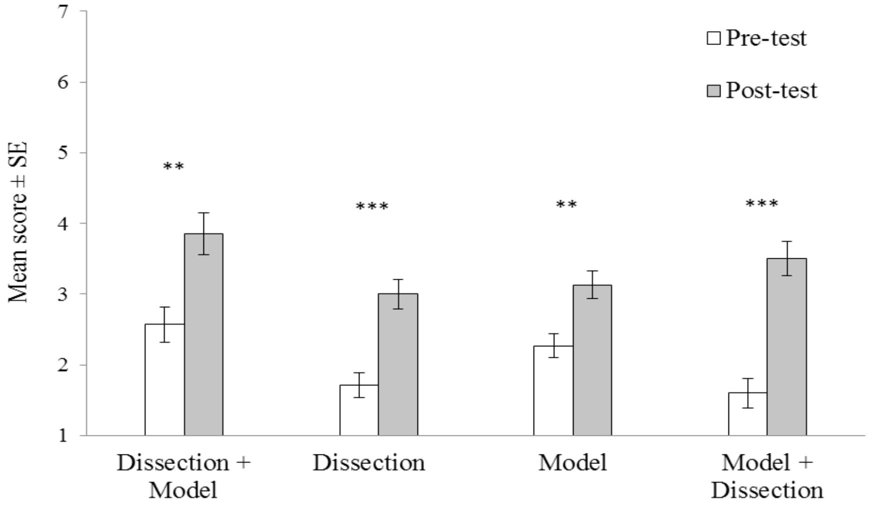

Figure 2: Differences in pre-test and post-test scores when drawing fish in four treatments. The asterisks denote significant differences based on paired t-tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). The sample sizes are identical with Figure 1.

Ideas Concerning Rats

The one-way ANOVA revealed marginally significant differences between the four experimental groups in the pre-test mean scores of the drawings of rats (F (3,55) = 2.30, p = 0.087, eta squared = 0.11). The pre-test score was consequently treated as a covariate in the analysis of covariance (ANCOVA) to control for pre-existing differences between the four groups. An ANCOVA with a rat post-test score as a dependent variable revealed no significant effect of treatment on the mean post-test scores of drawings of rats (F(3,54) = 0.24, p = 0.87, eta squared = 0.01, Figure 3). The effect of the pre-test was significant (F (1,54) = 11.52, p = 0.001, eta squared =0.18).

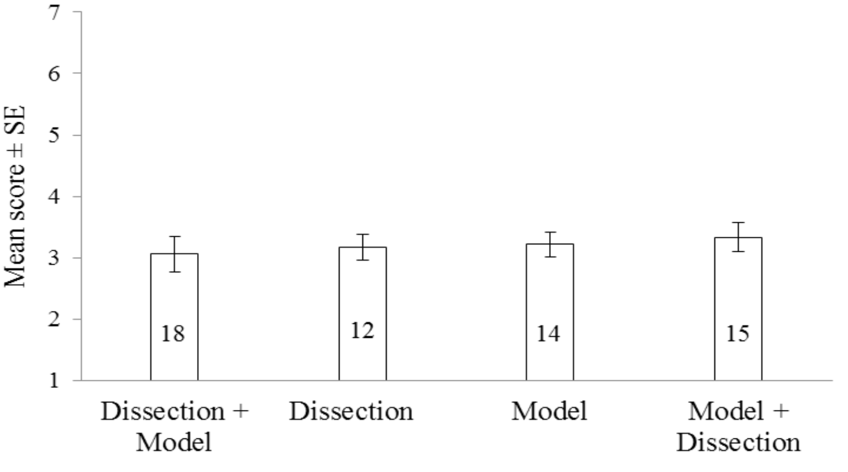

Figure 3: Mean post-test scores for the four experimental groups after controlling the pre-test rat scores. The numbers inside the bars are sample sizes.

In the next analysis, Dissection + Model and Model + Dissection treatments were compared to the Dissection and Model treatment with planned ANOVA comparisons. The difference was not statistically significant (F(1,54) = 0.02, p = 0.88) indicating that students received similar mean scores in Dissection + Model and Model + Dissection treatment as compared with the Dissection and Model treatment.

There were significant differences in the pre-test and post-test scores in all the treatments. As shown in Figure 4, all the post-test scores were significantly higher than the pre-test scores suggesting that the demonstration significantly influenced respondent knowledge about the anatomy of rats.

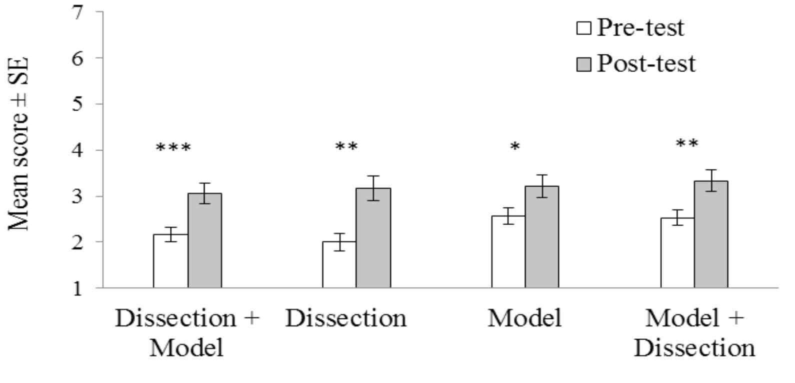

Figure 4: Differences in pre-test and post-test scores when drawing rats in four treatments. The asterisks denote significant differences based on paired t-tests (* p < 0.05, ** p < 0.01, *** p < 0.001). The sample sizes are identical with Figure 3.

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A Comparison of Drawings of Fish and Rats

There were significant differences in the pre-test scores between the drawings of fish (M = 2.0, SE = 0.1) and rats (M = 2.3, SE = 0.09) (t-test, t = 2.28, df = 103, p = 0.02). The post-test scores were, however, not significantly different between fish (M = 3.28, SE = 0.12) and rats (M = 3.19, SE = 0.12) (t-test, t = 0.57, df = 103, p = 0.57).

Discussion

This study investigated the effects of teacher demonstrations of cadaveric dissection as opposed to a 3D plastic model on pre-service biology teachers' ideas concerning what is inside animals. Trout and rats were used as examples since these animals are both easily accessible and frequently used in biological settings as model organisms (Fančovičová et al., 2013; Randler, Hummel, & Wurst-Ackermann, 2013).

The use of cadaveric dissection or 3D plastic models alone was less effective than the use of a combination of these two methods. These results are in agreement with Kinzie et al. (1993) and Akpan and Andre (1999, 2000) and Biasutto et al. (2006) who found that a combination of dissections with video-based or computerized simulations resulted in better achievement scores on the part of participants. These findings were extended in the field of teacher demonstration, a viable part of science education lessons (Kirschner, 1992; Sever, Yurumezoglu, & Oguz-Unver, 2010).

Two key questions emerge from the results of this study. Why did the combination of the dissection and the model have a stronger effect on pre-service teachers' ideas about animals than the use of a single method? Why was a combination of these methods only effective in the case of fish, but not in the case of rats? The use of cadaveric dissection has various benefits, particularly that the possibility of direct contact with tissues and anatomical elements cannot yet be replaced with plastic models (e.g., Offner, 1993; Biasutto et al., 2006; Bergman et al., 2014). An actual cadaver may be more motivational for students and can enhance learning as compared with other alternative since it provides a new, potentially exciting experience while models may be perceived as less suggestive (Randler et al., 2013; Lombardi et al., 2014). Plastic 3D models, are, in contrast, extremely simplistic in terms of manipulation, and have clearly differentiated internal organs by various colours, which may promote learning and retention (Waters et al., 2005; Lombardi et al., 2014). This may be why the combination of both dissections and plastic models has yielded superior results.

The second question is why different, non-significant patterns were observed in rats as compared with fish. Two explanations for this phenomenon, which are not mutually exclusive, have been proposed. Firstly, the samples of students who were involved in this experiment were not independent. This is because the participants in the lesson with rats were influenced by previous experiences with the lesson with trout. This suggests that with the lesson with rats (Experiment 2), students were able to transfer their knowledge of fish to rats. This claim can be supported by the significantly higher pre-test scores of rats as compared with fish. Alternatively, the internal organs of fish might be less understood since they are less familiar with humans and students at this age should be much more experienced with human anatomy than with zoology (considering the fact that all our students completed a Human biology course in their first year of studies) (Tunnicliffe & Reiss, 1999, 2001; Prokop et al., 2007). We consequently believe that the results of our first experiment with trout are more significant, because participants were unaffected by immediate experience with vertebrate dissection. Fish, unlike rats, is not influenced by anatomic familiarity with humans.

Conclusions

This study addresses important implications for teaching biology. First, while 3D plastic models are cheaper than regular investment into cadaveric dissection, their value is limited when their use is not combined with actual cadavers. Biology/anatomy lessons, on the other hand, should be supplied with (plastic) alternatives which prepare students for more complex activities with cadavers. Second, the post-test scores were consistently higher after the demonstration of anatomy by the teacher. This suggests that receiving teacher instruction in the preparatory phase prior to cadaveric dissection makes sense as it enhances the student achievement score. Third, the overall mean scores of the drawings were low and comparable to secondary school children (Prokop et al., 2007, 2008). This suggests that anatomy knowledge on the part of pre-service biology teachers is poor and requires deeper attention. In summary, cadaveric dissections should still play an important role in biology courses and needs to be *supplied* rather than *replaced* with modern innovative teaching methods.

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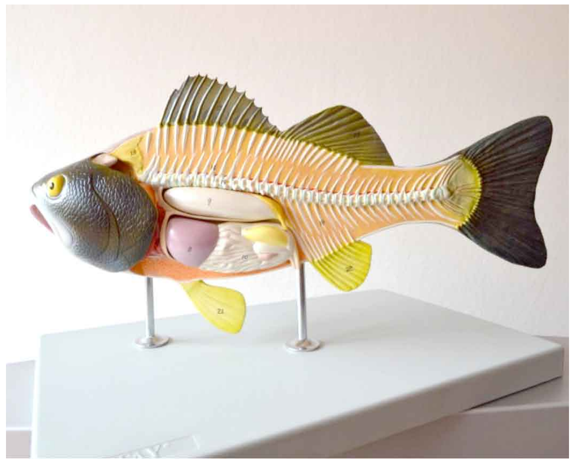
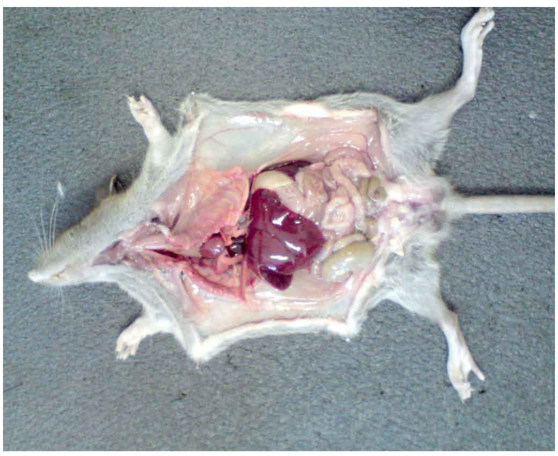
Appendix: Photographs of cadaveric dissection and 3D plastic models

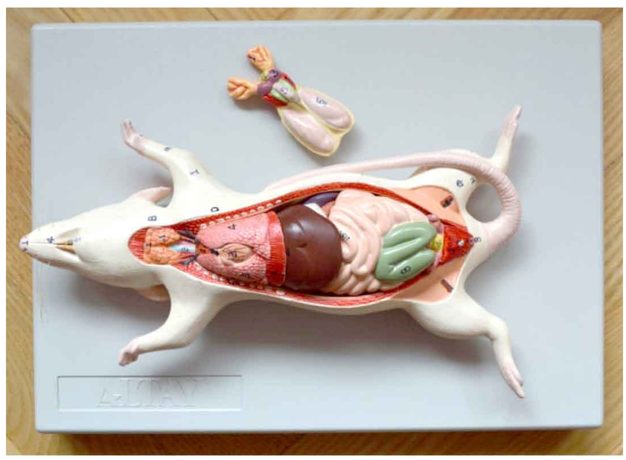
Photograph 1. Demonstration of a trout dissection.



Photograph 2. A 3D plastic model of a fish.



Photograph 3. Demonstration of a rat dissection.



Photograph 4. A 3D plastic model of a rat.

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