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Can Virtual Dissection Replace Traditional Hands-on Dissection in School Biology Laboratory Work?

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ABSTRACT

With the advent of computers virtual dissection was recognized as a plausible option for the replacement of hands-on dissection. Based on survey data collected from 489 Czech Biology teachers it was revealed that teachers value positively both variants of dissection, even more, differences are small or even negligible. Differences on motivation scale toward both variants are small or negligible too. From the answers based on motivation scale, we can construct a ghost teacher as someone who recognizes both alternatives of dissections as interesting, and even pleasant and fun activities. However, dissection should be performed as mostly as self-regulated activities with perceived benefits for the students as the dominant incentive, while not recognizing activity as important. The differences exist both between the acceptability of different kind of organisms for hands-on and virtual dissection, and in the actual school practice. In the long term perspective is cohabitation of both variants most probable.

Keywords: attitudes to hands-on and virtual dissection, biology teachers, general biology education, prospective biology teachers, school experimental activity

INTRODUCTION

There is no other direct way than dissection to get insight into what the inside of an animal or human bodies is; likewise *"all instructional methods used in anatomy teaching, except dissection itself, have in common that they can be recognized as derivatives of dissection, because there is no alternative to obtaining primary insight inside the bodies of members of the animal kingdom"* (Špernjak, & Šorgo, 2017a). However, especially with possibilities opened by new computer-based technologies in education a vivid debate has arisen if the hands-on dissection is a relic from the past or a necessary component of contemporary Biology and human anatomy education (De Villiers, & Monk, 2005; Hug, 2005; Hug, 2008), leading to a question if virtual dissection is plausible alternative for replacement of traditional hands-on dissection in school Biology laboratory work.

For the purpose of clarity we define hands-on dissection as dissection of whole organisms of non-human animals or their parts. The dissection of human cadavers or parts of a human body is out of the scope below university levels, so it is excluded as reliable primary or secondary school experience from our study. Microscopy or exposition of preserved animal and human tissues or organs is not recognized as hands-on dissection. Virtual dissection is an interactive computer simulation modeling the inner animal and human anatomy (these are not static pictures, movies or animations that do not allow the user to interact) without a real interaction with genuine organisms or tissues. Both hands-on and virtual dissection can be performed as individual or group activity by students and performed as a demonstration by a teacher.

At this point, we should be aware about reasons for inclusion of dissection in schools. They are: a) dissection for acquisition of core knowledge about inner anatomy, and b) acquisition of skills such as "observation and comparison, discovering the shared and unique structures of specific organisms, and development of a greater appreciation for the complexity of life" (NSTA, 2008, p.2). Allchin (2005, p. 370) wrote, "*Demonstrating the gap between idealized textbook diagrams and reality is one extraordinary value of looking inside real organisms*," a task that must

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Contribution of this paper to the literature

- The study aims on evaluating the attitude of Czech teachers and prospective teachers of Biology towards hands-on and virtual dissection. Their experiences and preferences for future implementation of these educational activities is analysed. Results of our research show that it is not possible to unequivocally determine which dissection variation is the most suitable for teaching Biology as a universally educational subject. These results lead to preferentially placing their sensible combinations accordingly to the educational targets. Methodology of the research and partially its results exceed the borders of the Czech Republic and can be beneficial for teachers and researchers abroad as well.

be accompanied by the use of proper dissection strategies (e.g. trace clearly visible structures) to allow recognition of a body as a network of interconnected structures.

At last, when considering professional programmes, we should not forget about the development of hands-on skills as professional and craft skills. The incomplete list of such skills includes e.g. fine manipulation with dissection instruments, recognition of real magnitude and a position of organs and tissues, feeling of their physical properties and strength of connections between them; all these skills are necessary for work in professions such as surgery (Pawlina, & Lachman, 2004), veterinary (Theoret, Carmel, & Bernier, 2007) and meat processing.

Controversies on Application of Hands-on and Virtual Dissections in Schools

The most vivid and for some controversial part of debate is at the level of emotions and ethics of hands-on dissection (Balcombe, 1997; Oakley, 2012). It is common for such debates that ethical issues dominate but learning outcomes of different variants of dissection (e.g. real, virtual, 3D models) used in teaching anatomy are usually not considered. If someone considers only core anatomical knowledge, then according to the recent studies, differences between hands-on and virtual variants of dissection, are minimal or are even in favour of the virtual alternative (Havlíčková, & Bílek, 2015; Patel, & Moxham, 2008; Predavec, 2001), so for that reasons both variants are of equal value. However, when accounting for multiple benefits of hands-on dissection for learners (NSTA, 2008) it can be recognized that hands-on dissection should be preferred method in medical education (Böckers, Jerg-Bretzke, Lamp, Brinkmann, Traue, & Böckers, 2010; Patel, & Moxham, 2008; Winkelmann, 2007) and general Biological education (Havlíčková, & Bílek, 2015; NSTA, 2008; Oakley, 2012). It is proposed that society opinions and associated students' attitudes to a substitute of hands-on dissection will slowly change (Balcombe, 2000; Fančovičová, & Prokop, 2014), resulting in reduction of frequency of hands-on dissection and replacement with various kind of dissection alternatives such as figurines, models, images, animations, virtual dissection, etc. However, it seems that such reduction, if happens, would not follow preferences of a majority of students in some countries. As an example, dissection of mammalian organs during the courses on Human Anatomy would be a preferred activity for the majority of Slovenian elementary and secondary school students and only a minority of students would prefer to opt out (Špernjak, & Šorgo, 2017a). As Moore (2001) realises, hands-on dissection is suitable educational activity; however, the use of hands-on dissection should be justified morally and educationally. Therefore, animals should not to be hands-on dissected only for fun or for satisfying one's curiosity.

Alternatives that have currently the greatest potential to replace traditional hands-on dissection in schools are virtual ones in a range from multimedia presentations to interactive simulations. Virtual dissection allows the study of inner animal (human) anatomy by virtual manipulations and provides significant advantages for schools such as repeatability, immediate feedback, independence of time and place, price, etc. (Havlíčková, & Bílek, 2015). However, mixed learning outcomes and preferences of teachers and students are reported in studies. The main critique in using virtual worlds goes toward levels of details and accuracy of representation of real specimens (Lewis, Burnett, Tunstall, & Abrahams, 2014). Students often perceived the virtual dissection as a suitable teaching complement. Students who used the virtual dissection achieved the same or better study results because they better understand the theoretical nature relation (Singh, Singh, Kumari, & Kumar, 2012) and they were not forced to memorize their knowledge (Tan, & Waugh, 2013). Strauss and Kinzie (1994) report that the students prefer practices that they had the opportunity to test. Fančovičová and Prokop (2014) arrive at different conclusions. Their finding was that teaching anatomy using only electronical (virtual) support of dissection activities leads to lower levels of knowledge than using a combination of virtual (electronic) and hands-on dissection. The same finding is reported in the study of Akpan and Andre (2000). The finding that a combination of virtual and hands-on activities is supreme when comparing to each other separately is argued in the context of ecology in a study of Puhek, Perše, and Šorgo (2012).

Attitudes towards Hands-on and Virtual Dissection and Influence on its Implementation

Teachers are the key gatekeepers for introduction of instructional practices in a classroom. Results of studies on teachers' preferences toward hands-on and alternative methods of dissection are mixed, and reflects their personal attitudes, worldview, motivation, opinions of their students, school culture, syllabi, and available technology. There exists different definitions of attitudes and its dimensions (e.g. affective, cognitive and behavioural), and it is out of the scope of the paper to review them. Attitudes can be explicitly and implicitly evaluated, e. g. by assessment of actual behaviour and expressed opinions (e.g. Gawronski, 2007). One of the plausible approach is by assessment and evaluation of responses provided by researchers by use of scales (e.g. Thurstone, 1928; Crites, Fabrigar, & Petty, 1994), applied in uncountable number of studies (Gawrovski, 2007, and references within).

By some studies teachers favour hands-on dissection over other methods (Balcombe, 2000; Oakley, 2012) and non-invasive use of animals (e.g. observation in aquaria) during the lessons (Balcombe, 2000; Lock, & Alderman, 1996). However, regardless of recognition of importance of animal use in a classroom, Lock and Alderman (1996) reveal that less than a half of the surveyed teachers include hands-on dissection into their lessons. Most of the surveyed teachers understand students' objection toward hands-on dissection, but they will still try to convince their student to take part in hands-on dissection as something important. Lock (2007) states that the dissection alternatives have to be provided only to students who has legitimate objection, but he does not count as objection nausea and sensitivity to odours and blood. Holstermann, Grube and Bögeholz (2009) suggest that the teacher should try to eliminate factors (such as blood, odour, select dissecting material, etc.), that could lead to negative feelings. Even more, "*feelings of disgust at the beginning of the class negatively predicted students' interest during the dissection* « (Holstermann, Ainley, Grube, Roick, & Bögeholz, 2012, p. 185). Another factor that can cause a repulsion in students when they dissect an animal is, that even the outer anatomy of dissected animal, e.g. amphibians, produces feeling of disgust (Tomažič, 2011 a,b; Tomažič, & Šorgo, 2017). Students often evaluated hands-on dissection as difficult to be accepted, however, good for their education. Simultaneously, they described hands-on dissection of macroscopic invertebrates as very disgusting (Randler, Hummel, & Würst-Ackermann, 2013). Students are against the breeding and killing of animals in order for hands-on dissection to be performed, whereas women held higher negative attitudes (Fančovičová, & Prokop, 2014; Millett, & Lock, 1992). The practice of many teachers to overcome problems associated with hands-on dissection is that students are entitled to choose between hands-on and dissection alternatives without any disciplinary action or sanction (Balcombe, 2000). At the same time, students themselves most often are not aware of their right to opt out (Oakley, 2012). One of the possible obstacles in introduction of virtual dissections can be hidden in broader context of acceptability and attitudes toward technology (for a review of different theories see Šumak & Šorgo, 2016). Under volitional conditions and assumption that they have access to the equippment they recognized three categories of non-users: a) them who do not use technology, and do not have plans to use it; b) them who do not use it, but are planning to use it in a future; c) them who had allready used it, but have abandoned it. By analogy the same can be true for introduction of virtual dissections in school practice.

AIMS AND PURPOSES OF THE RESEARCH

Active and engaging learning experiences are regarded as a keystone in raising not only interest but motivation toward Biology (Abrahams, & Millar, 2008; Michael, 2006; Prokop, Prokop, & Tunnicliffe, 2007; Tranter, 2004). With greater computer power and their availability in schools as stationary and mobile technology new applications can complement or replace existing laboratory practices (Akpan, & Andre, 2000; Lewis, Burnett, Tunstall, & Abrahams, 2014; Sugand, Abrahams, & Khurana, 2010; Šorgo, Hajdinjak, & Briški, 2008; Špernjak & Šorgo, 2017b). This exploratory research was focused on the position of hands-on and virtual dissection among Biology teachers in Czech Republic, and to find differences among both practices. The impetus was to recognize possible obstacles in introduction of active learning practices into schools to make Biology for students more attractive and engaging, but not at the cost of lower learning outcomes. Dissection as a part of professional programmes of medicine, nursery, and food processing is not an issue of this paper.

Research Questions

Because of the exploratory nature of the research, no prior hypotheses were provided. Research questions were as follows:

1. Are there differences in opinions toward suitability of hands-on and virtual dissection?
2. Are there differences in motivation toward actual and prospective engagement in hands-on and virtual dissections?
3. Are there differences in opinions on acceptability of different organisms for hands-on and virtual dissections at school?

Table 1. Sample characteristics of the Czech teachers (N=489)

ID	Sample characteristics of the Czech teachers	Frequency	%
1	*Affiliations of teachers and prospective teachers*		
	Elementary school teacher (lower secondary school – "2. stupeň základní školy")	247	50.5
	Secondary school teacher (general upper secondary school – "Gymnasium")	240	49.1
	Missing	2	0.4
2	*A teacher of a subject where dissection is applicable*		
	Yes	435	89
	No	52	10.6
	Missing	2	0.4
4	*Qualification of teaching Biology*		
	Yes	429	87.7
	No	59	12.1
	Missing	1	0.2
5	*Second teaching subject*		
	Experimental subjects (e.g. Chemistry, Physics)	155	31.7
	Non experimental subjects (e.g. Languages, Social sciences)	299	61.1
	Missing	35	7.2
14	Male	117	23.9
	Female	372	76.1

MATERIAL AND METHODS

Sample and Sampling

There were 489 respondents to the survey from a total of 1450 addressed Biology teachers and prospective Biology teachers as general-education subject in the Czech Republic.

The questionnaire was distributed by use of the paper and pencil form and an online form as Web-based Google form. The completion of the questionnaire was voluntary and utterly anonymous. The anonymity was ensured by restricted access of the research team to primary data. The data that could lead to the identification the respondents were coded. Analytical evaluation was made by SPSS® 21.0 software.

Structure of the Questionnaire

The questionnaire was divided to the three main parts. The first part was focused on demographic data, the second part dealt with the hands-on dissections and the third part dealt with virtual dissections. In total, there were 117 questions.

Demographics

Personal data, such as educational level, school subject taught, approbation, own experience with hands-on and virtual dissection, and length of practice, were collected. Sample characteristics are given in **Table 1**.

Opinions on Acceptability of Hands-on and Virtual Dissection Scales

Opinions were applied as a measure of attitudes (e.g. Thurstone, 1928; Crites, Fabrigar, & Petty, 1994). Opinions on acceptability of hands-on and virtual dissection among teachers were examined by two separated 16-items scales (**Table 2**) with response format on a scale strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). Two items (*OHD* 9, *OHD* 10) were reverse coded and are denoted with (R). Cronbach's *alpha* of the initial instrument on hands-on dissection was 0.72. Procedure "*alpha* if item deleted" was used to improve it. After deletion of six items (**Appendix 1**) the Cronbach's *alpha* reached level of good 0.81, where deletion of another item would not add to the reliability. Cronbach's *alpha* of the initial instrument on virtual dissection was 0.62. After deletion of seven items the Cronbach's *alpha* reached level of 0.72, where deletion of another item will not add to the reliability. However, to allow readers to get wider information on opinions statistics on excluded items is provided in **Appendix 1**.

Table 2. Opinions about hands-on and virtual dissection sorted by decreased values of loadings of unidimensional factor extracted from initial pool of 16 statements. *(N = 489)*

		Hands-on dissection				Virtual dissection				
Code	**Statement**	**M SD**	**Mode %**	**Med**	**PC_{hd}**	**M SD**	**Mode %**	**Med**	**PC_{vd}**	***d***
OHD5 OVD5	Hands-on (virtual) dissections needs a lot of precious time which can be used more beneficial for other types of instructions.	2.26 1.05	(2) 238 48.7	2.0	0.76	2.39 0.93	(2) 213 43.6	2.0	0.70	0.13
OHD3 OVD3	Hands-on (virtual) dissection is a loss of time; because I must explain everything what was done once again in direct instructions.	1.98 0.94	(2) 221 45.2	2.0	0.73	2.14 0.91	(2) 210 42.9	2.0	0.68	0.17
OHD12 OVD12	Money spent on materials used in hands-on (virtual) dissection, should be used better for other purposes.	2.5 0.98	(2) 198 40.5	2.0	0.71	2.61 0.98	(3) 187 38.2	3.0	0.54	0.11
OHD7 OVD7	I do not prefer hands-on dissection because of fear of possible injuries. / I do not prefer virtual dissection because of fear of computer crashes.	2.49 1.15	(2) 209 42.7	2.0	0.70	1.79 0.95	(1) 237 48.6	2.0	0.56	-0.66
OHD16 OVD16	If I have to decide, I prefer demonstration of dissection over student's hands-on (virtual) work.	2.82 1.07	(2) 165 33.7	3.0	0.61	2.61 1.09	(3) 153 31.3	3.0	0.44	-0.19
OHD1 OVD1ex	All goals to be achieved through hands-on (virtual) dissections is possible to be achieved with other instructional methods.	2.74 1.09	(2) 195 39.9	3.0	0.59	2.87 1.06	(2) 158 32.3	3.0		0.12
OHD6 OVD6	During hands-on (virtual) dissection it is hard to control the students' work.	2.81 1.1	(2) 196 40.1	3.0	0.55	2.51 1.02	(2) 193 39.5	2.0	0.55	-0.28
OHD4 OVD4	Hands-on (Virtual) dissection should be only a supplement to the instructions.	3.46 1.11	(4) 223 45.6	4.0	0.47	3.43 1.05	(4) 215 44	4.0	0.47	-0.03
OHD9R OVD9R	Knowledge achieved during hands-on (virtual) dissection of one organism can be later used for understanding of other organisms.	1.92 0.87	(2) 277 56	2.0	0.44	1.98 0.89	(2) 269 55	2.0	0.52	0.07
OHD10R OVD10R	Knowledge gained through hands-on (virtual) dissections is systematic.	2.52 0.89	(2) 210 42.9	2.0	0.43	2.46 0.86	(2) 216 44.2	2.0	0.48	-0.07
	Cronbach's *alpha*				0.81				0.72	
	Explained variance				25.8				24.5	
	Eigenvalue				4.13				2.7	

Note. OHD = opinions on hands-on dissection. OVD = opinions on virtual dissection. Ex = excluded from PCA. PC_{hd} = principal component – single factor extraction – hands-on dissection. PC_{vd} = principal component – single factor extraction – virtual dissection. *d* = Cohen's *d*

Motivation for Actual and Prospective Engagement in Hands-on and Virtual Dissection Scales

Motivation for actual and prospective engagement in hands-on and virtual dissections (**Table 3**) was examined by use of two separated 16-items scales, one in a context of hands-on and the other of virtual dissection. Applied was The Situational Motivation Scale (SIMS) (Guay, Vallerand, & Blanchard, 2000). The SIMS scale assess constructs of intrinsic motivation, identified regulation, external regulation, and amotivation as defined by Ryan and Deci (Deci, & Ryan, 1985; Ryan, & Deci, 2000). Response format was: not at all (1), corresponds a very little (2), corresponds a little (3), corresponds moderately (4), corresponds enough (5), corresponds a lot (6) and corresponds exactly (7). Cronbach's *alpha* of this instrument on hands-on dissection was 0.80. To preserve the original SIMS scale and due to *alpha* in a good range no item was deleted from the pool, even if with deletion of one of the two items it will be possible to raise scale reliability (*Alpha if item deleted* = *OHE* 4 = 0.82; *OHE* 12 = 0.83). Cronbach's *alpha* of this instrument on virtual dissection was good 0.87, and as in the case of hands-on dissection to preserve original scale no item was deleted, even if raising similar two items (*Alpha if item deleted OVE* 4 = 0.88; *OVE* 12 = 0.88) was a possible choice.

Table 3. Motivation for actual and prospective engagement in hands-on and virtual dissections (N=489)

			Hands-on dissection						Virtual dissection						
Code	**Mot**	**Statement**	**M SD**	**Mode %**	**Med**	**PC1**	**PC2**	**PC3**	**M SD**	**Mode %**	**Med**	**PC1**	**PC2**	**PC3**	***d***
OHE6 OVE6	IR	Because I think that this activity is good for me	3.16 1.76	(1) 110 22.5	3.0	0.88			3.44 1.78	(4) 97 19.8	4.0	0.81			0.16
OHE2 OVE2	IR	Because I am doing it for my own good	2.46 1.57	(1) 179 36.6	2.0	0.83			2.86 1.76	(1) 148 30.3	2.0	0.69			0.24
OHE13 OVE13	IM	Because I feel good when doing this activity	2.75 1.69	(1) 158 32.3	2.0	0.83			2.99 1.79	(1) 143 29.2	3.0	0.85			0.14
OHE5 OVE5	IM	Because I think that this activity is pleasant	3.47 1.78	(4) 101 20.7	4.0	0.79			3.80 1.86	(5) 93 19	4.0	0.88			0.18
OHE14 OVE14	IR	Because I believe that this activity is important for me	3.30 1.83	(1) 114 23.3	3.0	0.69			3.40 1.85	(1) 111 22.7	3.0	0.72			0.05
OHE3 OVE3	ER	Because I am supposed to do it	3.65 1.81	(4) 109 22.3	4.0	0.63			3.50 1.88	(1) 98 20	4.0	0.69			-0.08
OHE9 OVE9	IM	Because this activity is fun	3.95 1.87	(5) 114 23.3	4.0	0.63			4.06 1.91	(5) 91 18.6	4.0	0.86			0.06
OHE10 OVE10	IR	By personal decision	4.13 1.93	(5) 92 18.8	4.0	0.60			3.94 1.96	(4) 94 19.2	4.0	0.68			-0.10
OHE1 OVE1	IM	Because I think that this activity is interesting	5.13 1.62	(5) 115 23.5	5.0				4.83 1.78	(6) 105 21.5	5.0	0.66			-0.18
OHE15 OVE15	ER	Because I feel that I have to do it	2.36 1.59	(1) 215 44	2.0		0.83		2.32 1.58	(1) 216 44.2	2.0			-0.80	-0.03
OHE7 OVE7	ER	Because it is something that I have to do	2.21 1.49	(1) 213 43.6	2.0		0.78		2.23 1.47	(1) 214 43.8	2.0			-0.78	0.01
OHE16 OVE16	AM	I do this activity, but I am not sure it is a good thing to pursue it	2.15 1.41	(1) 213 43.6	2.0		0.71		2.13 1.42	(1) 223 45.6	2.0		0.51		-0.01
OHE11 OVE11	ER	Because I do not have any choice	1.70 1.22	(1) 301 61.6	1.0		0.67		1.86 1.27	(1) 260 53.2	1.0			-0.68	0.13
OHE8 OVE8	AM	I do this activity, but I am not sure if it is worth it	1.74 1.17	(1) 288 58.9	1.0		0.60		1.95 1.29	(1) 245 50.1	1.0		0.53	-0.45	0.17
OHE4 OVE4	AM	There may be good reasons to do this activity, but personally I do not see any	2.68 1.72	(1) 157 32.1	2.0			0.74	2.77 1.64	(1) 135 27.6	2.0		0.81		0.05
OHE12 OVE12	AM	I do not know; I do not see what this activity brings me	2.06 1.61	(1) 269 55	1.0			0.69	2.13 1.50	(1) 235 48.1	2.0		0.72		0.05
		Cronbach's *alpha*				0.88	0.78	0.64				0.92	0.73	0.78	
		Explained variance				33.2	21	7.3				367	20.9	6.6	
		Eigenvalue				5.31	3.36	1.16				5.91	3.34	1.06	

Note: IM = intrinstic motivation; IR = identified regulation; ER = external regulation; AM = amotivation

Opinion on Acceptability of Different Organisms for Hands-on and Virtual Dissections in a School Scales

This part of the survey instrument consisted of nine items (**Table 4**) with response format from completely unacceptable (1) to completely acceptable (5). Cronbach's *alpha* for hands-on dissection was good 0.85, so no item was deleted from the pool. Cronbach's *alpha* for acceptability of virtual organisms was excellent 0.94, so no item was deleted from the pool.

Table 4. Opinion on acceptability of different organisms for hands-on and virtual dissections in a school (N=489)

		Hands-on dissection					Virtual dissection					
CODE	**Organism**	**M SD**	**Mode %**	**Med**	**PC1**	**PC2**	**M SD**	**Mode %**	**Med**	**PC1**	**PC2**	***d***
ACH3 AVD3	Whole birds	2.79 1.43	(1) 134 27.4	3.0	0.87		4.05 1.32	(5) 270 55.2	5.0	0.95		0.92
ACH 2 AVD2	Whole mammals	2.60 1.38	(1) 154 31.5	3.0	0.84		3.99 1.35	(5) 260 53.2	5.0	0.98		1.02
ACH4 AVD4	Whole reptiles and amphibians	2.82 1.43	(1) 133 27.2	3.0	0.78		4.15 1.29	(5) 293 59.9	5.0	0.91		0.98
ACH1 AVD1	Human tissues	1.92 1.24	(1) 271 55.4	1.0	0.59		3.76 1.43	(5) 222 45.4	4.0	0.87		1.38
ACH5 AVD5	Whole fish	3.90 1.33	(5) 227 46.4	4.0	0.52	0.49	4.37 1.11	(5) 328 67.1	5.0	0.66		0.38
ACH7 AVD7	Arthropods (e.g. insects and crabs)	4.41 0.95	(5) 314 64.2	5.0		0.87	4.61 0.85	(5) 372 76.10	5.0		0.81	0.22
ACH8 AVD8	Lower invertebrates (e.g. snails, worms)	4.33 1.02	(5) 297 60.7	5.0		0.85	4.58 0.90	(5) 369 75.5	5.0		0.76	0.26
ACH9 AVD9	Plants	4.89 0.49	(5) 455 93	5.0		0.68	4.76 0.73	(5) 420 85.9	5.0		0.97	-0.21
ACH6* AVD6*	Animal organs	4.29 1.18	(5) 308 63	5.0		0.64	4.46 1.04	(5) 348 71.2	5.0	0.5	0.5	0.15
Cronbach's *alpha*					0.84	0.80				0.94	0.90	
Explained variance					47.6	18				68.1	14.9	
Eigenvalue					4.29	1.62				6.13	1.34	

Note. *ACH6 and AVD6. Animal organs what can be bought in supermarkets or get in slaughterhouses for human consumption (e. g. pig kidneys; ox eyes)

Table 5. Frequency of actual and perspective dissection as hands-on and virtual activity using different kind of animal in a school (N=489)

		Hands-on dissection					Virtual dissection				
CODE	**Organism**	**M SD**	**Mode %**	**Med**	**PC1**	**PC2**	**M SD**	**Mode %**	**Med**	**PC1**	***d***
FHD7 FVD7	Arthropods (e.g. insects and crabs)	3.13 1.40	(3) 133 27.2	3.0	0.88		2.02 1.46	(1) 298 60.9	1.0	0.92	-0.78
FHD9* FVD9	Plants	4.06 1.26	(5) 260 53.2	5.0	0.86		2.29 1.68	(1) 283 57.90	1.0	0.8	-1.19
FHD8 FVD8	Lower invertebrates (e.g. snails, worms)	2.85 1.42	(3) 129 26.4	3.0	0.84		2.04 1.46	(1) 292 59.7	1.0	0.92	-0.56
FHD6* FVD6*	Animal organs	2.60 1.43	(1) 162 33.1	3.0	0.63		1.9 1.4	(1) 315 64.4	1.0	0.9	-0.5
FHD5 FVD5	Whole fish	2.42 1.42	(1) 195 39.9	2.0	0.59		1.87 1.34	(1) 313 64	1.0	0.93	-0.4
FHD2 FVD2	Whole mammals	1.47 0.93	(1) 361 73.8	1.0		0.90	1.62 1.19	(1) 351 71.8	1.0	0.9	0.14
FHD3 FVD3	Whole birds	1.42 0.87	(1) 369 75.5	1.0		0.89	1.66 1.21	(1) 345 70.6	1.0	0.91	0.23
FHD4 FVD4	Whole reptiles and amphibians	1.47 0.89	(1) 357 73	1.0		0.73	1.85 1.31	(1) 310 63.4	1.0	0.9	0.34
FHD1 FVD1	Human tissues	1.29 0.77	(1) 412 84.3	1.0		0.41	1.61 1.13	(1) 348 71.2	1.0	0.82	0.33
Cronbach's *alpha*					0.88	0.75				0.96	
Explained variance					48.5	16				78.9	
Eigenvalue					4.4	1.4				7.1	

Note. *FHD6 and FVD6 = Animal organs what can be bought in supermarkets or get in slaughterhouses for human consumption (e. g. pig kidneys; ox eyes)

Frequency of Dissection as Hands-on Activity and Virtual Activity Using Different Kind of Animals in a School Scale

Provided were nine-item (**Table 5**) to discover frequency of different animal actually dissected at school, scaled in a range between never (1) and at almost any chance where possible (5). Cronbach's *alpha* of the hands-on scale was good 0.86, and for virtual scale excellent 0.96, so no items were deleted from the pools.

Statistical Analyses

The data were initially checked for outliers and missing data and cases with a large number of empty fields were deleted. Prior the analyses normality was checked by use of the Kolmogorov-Smirnoff test at the 0.05 significance level. Items, denoted with (R) in scales, were negative worded and were reverse coded prior to the statistical analyses to allow some of the calculations. Reliability was calculated as Cronbach's *alpha* (Gliem, & Gliem, 2003). To raise reliability of the scales procedure *alpha* if item deleted in SPSS was applied. Effect sizes were calculated as Cohen's *d* by use of Psychometrica online engine (Lenhard, & Lenhard, 2016). Following Cohen's recommendations, values around 0.2 were considered as small; 0.5 as medium, and above 0.8 as large effect (Field, 2013).

Where Exploratory Factorial Analysis (EFA) was performed, Principal Component Analysis (PCA) with Direct Oblimin Rotation and Kaiser Normalization was chosen. Direct Oblimin Rotation was a choice because correlation between variables was expected (Field, 2013). Prior to the analysis, Kaiser-Meyer-Olkin (KMO) the measure of sampling adequacy and Bartlett's test of sphericity were used to check data suitability for further analysis. All scales in our research falls in the KMO range above .75 levels and $p < 0.001$ of Barlett's test. Principal components with Eigenvalues above 1, and items with loadings above .4 levels were retained (Kline, 2014) for follow up analyses. Parallel analysis (Costello, 2009) provide stricter criteria for number of factors to be retained and was applied, as well, by use of parallel analysis engine (Patil, Singh, Mishra & Donavan, 2007). Later in **Table 3** results of all components with Eigenvalues above 1 are provided, even if they do not pass stricter criteria to retain width of the opinions and interpretability of results.

RESULTS

Demographic Characteristics of the Sample

Demographic characteristics of the sample included in further analyses are presented in **Table 1**.

Opinions on Suitability of Hands-on and Virtual Dissection

From the statistics of opinions presented in the **Table 2** we can recognize that general opinion toward both variants of dissection are generally positive with more strong attribution of advances in some items to hands-on and in others to the virtual variant. Effect size only in one case (*OH(V)D7*) falls in intermediate range. We were amused to recognize that teachers have more fear that something go wrong with computers than possible injuries in hands-on dissection. All other differences are in small or nonsignificant ($p > 0.05$) range in favour of virtual dissection (positive values) or in favour of virtual alternative (negative values) on a scale between 1 (strongly disagree) and 5 (strongly agree).

The same is true for one component of the exploratory analysis in both variants (PC_{hd} for hands-on and PC_{vd} for virtual dissection in **Table 2**), where differences in loadings between hands-on and virtual dissection are minimal, allowing us to conclude that both variants are in principle valued in similar way. By our research instrument, we were able to explain about one quarter of the variance in both alternatives, which calls for the search of explanations in other domains. In both extracted principal components (PC_{hd} and PC_{vd}) first two items express importance of both variants of dissection. In 70.2% cases, teachers strongly disagree, or disagree that hands-on dissection is a waste of time, and that other types of instruction it would be more beneficial. However, virtual dissection achieved lower support, and 72 % of respondents disagree or hold neutral statement that such dissection is a waste of time. In line with previous statements goes the next statement expressing the attitude toward both variants of dissection; 78.1% of all respondents strongly disagree, or disagree that hands-on dissection is inefficient because everything should be repeated. Nevertheless, the sum of them who strongly disagree and disagree with such a statement about virtual dissection is lover, 34.9 %, respectively. Both statements go hand in hand with the disagreement or a neutral position with the statement that all goals can be achieved through hands-on or virtual dissection. However, the positions are not as strong as in previous two discussed statements, and they mostly disagreed or held neutral position (62.4%) toward the hands-on dissection and in 60.5% toward the virtual alternative.

Despite generally positive attitudes toward both types of dissection, their position about relative importance of dissection, when comparing it with direct instruction, is in favour of direct instructions. Only 18.2 % of respondents disagree that hands-on dissection should be only a supplement to the instructions (*OHD* 4), whereas almost a half of them (45.6 %) agree. The pattern is similar for virtual dissection (*OVD* 4) where differences between both variants are negligible. Underlying arguments toward their preferences toward direct instructions can be recognized from the items *OH(V)D* 9 and *OH(V)D* 10. A great majority (86.5 %) of the teachers mostly strongly disagree, and disagree with the statement that knowledge achieved during hands-on dissection of one organism can be later used for understanding of other organism. The same position (83 % of strongly disagreement and disagreement) the teachers share toward the virtual dissection. The pattern, however, with some lower numbers, was expressed by the disagreement with the statements that the knowledge gained through hands-on or virtual dissection is systematic. About three quarters (76.4 %) of the teachers expressed strong disagreement or disagreement with this statement for hands-on variant, however, they are not so sure about the virtual alternative, where 78.1% teachers disagree or hold neutral position. A wish to control the outcomes of the teaching process can be recognized by the agreement with statements (*OH(V)D*11) (see Appendix 1) about need of detailed manuals. About 75 % of teachers strongly agree and agree with this statement about hands-on dissection and about 67 % of them strongly agree or agree with the statement related to the virtual dissection.

The preference of dissection as first-hand experience over demonstration of it by teachers can be revealed from the answers on items *OH(V)D*15. Nevertheless, in everyday practice demonstrations are a choice because of high costs of hands-on dissection and the lack of computers in virtual variants.

The acceptance of both variants of dissection is related to its performance. About 50 % of the teachers strongly disagree or disagree with the statement, that they would feel uncomfortable, if they did not know the end results of the virtual dissection. While about 28.4 % agree and 29.7 % of the teachers disagree with the statement that they would feel uncomfortable, if they did not know the end results of the hands-on dissection. This fact can be related to the next statement that it is hard to control the student's work. The teachers hold quite different positions about hands-on dissection, because 40.1% of them disagree with this point and 27.6 % of them agree with this statement. They disagree or hold neutral opinion about the statement toward virtual dissection (40.1 %).

Even with recognition of importance of both variants of dissection, teachers believe that students should participate in the decision to dissect or not. However, teachers mostly agree or strongly agree (67 %) with this statement in the case of hands-on dissection, and they are rather cautious (54 % of them hold neutral position or they agree) in the context of the virtual dissection.

Motivation for Actual and Prospective Engagement in Hands-on and Virtual Dissection Scales

From the descriptive statistics (**Table 3**) it can be concluded that teachers are motivated and highly value both alternatives of dissection. Differences on motivation between hands-on and virtual dissection are minimal and all effect size values fall in range between nonsignificant and small. The highest values (*Mdn* = 5; *Mod* = 5 for hands-on and 6 for virtual dissection) were in both variants given to the claim that dissection is interesting. Agreement was little lower with statements that dissections are fun and pleasant. From these results we can conclude that internal motivation is major incentive toward dissection. The claim is supported with high number of them who express disagreement with a motivational variables what shows motivation toward dissections in both worlds.

The findings revealed from descriptive statistics are complementary with findings of PCA. From analysis of factor loadings it can be revealed that the greatest part of explained variance can be attributed to the same constructs in both variants. However, when comparing to the SIMS studies (Guay, Vallerand, & Blanchard, 2000) where four-factor structure was revealed in our study only three components can be retained on the basis of Eigenvalue > 1 criteria, and on the basis of results of parallel analysis engine (Patil, Singh, Mishra & Donavan, 2007) only two factors should be retained. It is out of the scope to discuss differences between theoretically predicted factors proposed by Guay, Vallerand and Blanchard (2000) and our results. The difference can be attributed to merging of IM and IR in one component. One item in this component (Because I am supposed to do it) can be attributed to external regulation (ER). The second component is a combination of variables declared as external regulation and amotivation (AM). The third component is a combination of two AM variables, where most of the respondents disagree with them.

From the answers based on motivation scale, we can construct a ghost teacher as someone who recognizes dissections as interesting and even pleasant and fun activities. Dissections are performed as mostly self-regulated activities with perceived benefits for the students as the dominant incentive, while not recognizing activity as important.

Opinion on Acceptability of Different Organisms for Hands-on and Virtual Dissections in a School Scales

When considering perceived acceptability of classes of organisms suitable for classroom dissection (**Table 4**) we can recognize, that in virtual worlds, except for the human tissues (*AVD*1) where median is at the value *Mdn* = 4, all other medians are at the value *Mdn* = 5 on the completely unacceptable (1) to completely acceptable (5) scale. This is not the case of hands-on dissection, where value *Mdn* = 5 for median was calculated only for lower invertebrates, and animal tissues available at supermarkets, and plants as almost universally acceptable for all.

Table 6. Differences expressed as Cohen's d among frequencies of dissection as hands-on and virtual activity using different kind of animals

CODE	Organism	d hands-on dissection (acceptability – actual dissection)	d virtual dissection (acceptability – actual dissection)
ACH6* FHD6*	Animal organs	-1.29	-2.08
ACH8 FHD8	Lower invertebrates (e.g. snails, worms)	-1.2	-2.09
ACH3* FHD3	Whole birds	-1.16	-1.89
ACH4 FHD4	Whole reptiles and amphibians	-1.13	-1.77
ACH5 FHD5	Whole fish	-1.07	-2.03
ACH7 FHD7	Arthropods (e.g. insects and crabs)	-1.07	-2.17
ACH2 FHD2	Whole mammals	-0.96	-1.86
ACH9 FHD9	Plants	-0.87	-1.91
ACH1 FHD1	Human tissues	-0.61	-1.67

Note. *ACH6 and *FHD6 = Animal organs what can be bought in supermarkets or get in slaughterhouses for human consumption (e. g. pig kidneys; ox eyes)

Teachers do not have any troubles to accept the animal organs which can be bought in supermarkets or get in slaughterhouses for human consumption (e. g. pig kidneys; ox eyes), with values *ACH* 79.4 % and *AVD* 85.5 % for organs which are completely acceptable, or acceptable for them. Median 4 is a result for fish, all other vertebrates are at the value 3. Differences between acceptability of different vertebrate classes differs from the class to class. Dissection of human tissues, even if convenient, can be recognized as unacceptable practice for almost all teachers.

With the application of PCA two components were identified in both variants. The first components are assembled from vertebrates, where only fish are recognized as acceptable organisms for dissection. The second component is a combination of plants, arthropods, invertebrates and animal tissues available from grocery shops. General acceptability of virtual dissection of vertebrates and human tissues can be recognized as potential advance, especially in the cases where organisms are not available.

Frequency of Dissection as Hands-on Activity and Virtual Activity Using Different Kind of Animals in a School Scale

From the **Table 5** it can be revealed that regularly only plants are actually hands-on dissected (Mdn = 5, Mode = 5) followed by arthropods, lower invertebrates and animal tissues (Mdn = 3). For all other organisms (except fish in the hands-on variant (Mdn = 2)) both in real and virtual worlds medians and modes have value one (never). In all cases, differences calculated as the effect size are in favour of hands-on dissection, which is, if applied, the dominant form of school dissection practice. The largest differences are between plants, arthropods and lower invertebrates which are actually dissected groups of organisms. In other cases differences are in small and median levels, as a recognition that both variants of dissection are rarely or never applied in teaching. Differences between acceptability of a class of organisms and actual performance calculated as Cohen's d, both for hands-on dissection and virtual dissection (**Table 5**), are mostly in a large or very large rank. Effect size values were calculated on a basis of results, presented in **Tables 5** and **6**. The effect size values are much larger for virtual dissection, expressing the idea of the largest number of teachers that such dissection is an acceptable solution, however, rarely or never applied in a classroom (**Table 6**). Numbers are lower, although still in a large ranks, for hands-on dissection. The only difference for human tissues falls in a medium rank expressing the situation that they are not considered as acceptable and they are actually not dissected.

DISCUSSION

Considering the research question, if there are differences in opinions toward suitability of hands-on and virtual dissection, we have revealed that some differences in teachers' approach towards hands-on and virtual dissection exist at statistically significant levels. However, we can realize from effect size values that differences are almost insignificant or small. We uncovered the biggest difference for the statements that the teachers are more afraid of failures of computer technology than possible injuries of their students during dissection labs, showing larger confidence toward traditional methods. Our findings oppose the results from several other studies as reported in a review study of Havlíčková and Bílek (2015).

We can most probably attribute differences in opinions (attitudes) toward different variants of dissection to previous experiences, or to the lack of them. The respondent teachers got more often hands-on than virtual dissection experiences at universities, while only a few hands-on dissected at the elementary or secondary schools, and almost nobody in virtual words at all levels. According to this finding, it can be noted that teachers have most probably gained more positive attitude towards hands-on dissection, which can be influenced by their previous experiences.

Teachers from our study obviously prefer dissection as an individual lab activity of their students in both variants above performing dissection as a demonstration, which is contrary to the situation recognized by Oakley (2012), where teachers prefer hands-on dissection as a demonstration due to the lack of finances to buy dissection materials.

In the case of hands-on dissection we can attribute this finding to the wish to give the students an opportunity to gain first-hand experience. Another plausible reason for avoidance of demonstrations can be attributed to the lack of confidence because of possible failure of a demonstration. Reluctance toward any news, hands-on dissection experiences, and higher costs (Smith, 1994) cannot be considered as factors favouring demonstrations. The lack of experience with virtual dissection, and the fact that schools are not equipped with adequate ICT are probably the most important reasons for a low usage of virtual alternatives.

Several articles mentioned in the overview study (Havlíčková, & Bílek, 2015) describe significant differences in accepting of hands-on and virtual dissections between men and women, as well as students and teachers and secondary school teachers and the other teachers groups (Balcombe 2000; Fančovičová, Prokop, & Lešková, 2013; Fazal, Khan, & Yunus, 2012; Holstermann, Ainley, Grube, Roick, & Bögeholz, 2012). However, all examined differences (results not reported) between different groups were on insignificant and small levels. Therefore, it is possible to say that in the Czech Republic, teachers are quite unique in their homogeneity with hands-on and virtual dissections. Because we didn't find differences between men and women unlike some foreign studies.

Considering the research question if there are differences in motivation toward actual and prospective engagement in hands-on and virtual dissections, we were not able to find significant differences toward both practices.

It can be recognized that all teachers hold more or less the same positive positions towards hands-on as well as virtual dissections and they are motivated to implement both of dissection variants into their lessons. Although it is possible, that approach toward hands-on and virtual dissection will change during the time according to the results of Balcombe (2000) and Fančovičová and Prokop (2014). Balcombe (2000) has reported that the approach towards hands-on dissection slowly changed and the students prefer the use of the virtual and other dissection alternative, a finding not supported by the results of our study. The most plausible scenario is the cohabitation of both types in the positive scenario and the exclusion of hands-on dissection without virtual replacement in the negative scenario.

Balcombe (2000) recommends as an option to overcome problematic issues of hands-on dissections' acceptance in offering a choice to participate on hands-on or virtual dissections. At the same time many teachers (Balcombe, 2000; Lock, 2007) do not allow their students to choose the dissection variant, which can cause some stress due the enforcement participation on hands-on dissection of their students. Contrary to this, Špernjak and Šorgo (2017a) report that most students would like to dissect more often. The prevailing opinion of teachers from our study is that they want to enable their students to choose between hands-on and virtual dissection. A closer analysis of this phenomenon should be the subject of further research.

The differences between actual dissection and opinion of suitability in using different kind of organisms at school can be large or even very large. It can be recognized that the teachers never implemented virtual dissection of plant into their lessons, but they perform hands-on dissection of plant as many times as possible, because they recognize the plants as the most acceptable organism for hands-on dissection performance. The lower effect size than the effect size for plants was calculated for arthropods. It means that teachers do not hands-on dissect them regularly, as in the case of plants. However, they do not use or will not use the virtual dissection as the substitution in both variants. The lowest values of effect sizes belong to whole vertebrates, human tissues, and animal organs that can be bought in supermarkets or got in slaughterhouses. Somehow, the higher effect sizes were calculated for lower invertebrates and arthropods. Teachers occasionally dissect these animals as hands-on dissection, although not as virtual dissection.

CONCLUSIONS

Conclusions are presented as answers to the research questions.

1. Are there differences in opinions toward suitability of hands-on and virtual dissection?

According the results of our study, teachers value positively both variants of dissection; furthermore, differences are small or even negligible.

2. Are there differences in motivation toward actual and prospective engagement in hands-on and virtual dissections?

As in the case of opinions, difference on motivational scale are small or even negligible. From the answers based on the motivation scale, we can construct a ghost teacher as someone who recognizes both variants of dissections as interesting and even pleasant and fun activities. Dissections are performed as mostly self-regulated activities with perceived benefits for the students as the dominant incentive, while not recognizing the activity as important.

3. Are there differences in opinions on acceptability of different organisms for hands-on and virtual dissections at school?

The differences exist both between the acceptability of a different kind of organisms for hands-on and virtual dissection, as well as in the actual school practice. From the results it can be concluded that virtual dissection is probably not recognized as a plausible alternative for hands-on dissection of plants, some lower invertebrates and organs which can be bought in supermarket. However, virtual dissection can be recognized as a winner in dissection of higher vertebrates or humans.

In the long term perspective, most probable is the cohabitation of both dissection variants.

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APPENDIX 1

Code	Statement	M SD	Mode %	Med PC$_{hd}$	M SD	Mode %	Med PC$_{vd}$	*d*
OHD13ex OVD13ex	Skills gained through hands-on (virtual) dissection are not important for students' further labour and study success.	2.47 1.19	(2) 201 41.1	2.0	2.52 1.07	(2) 186 38	2.0	0.04
OHD2ex OVD 2ex	Because of expenses, I perform most of the hands-on dissections as demonstrations. / Because not enough computers, I perform most of the virtual dissections as demonstrations.	3.07 1.1	(4) 147 30.1	3.0	2.9 1.25	(3) 150 30.7	3.0	-0.14
OHD8ex OVD8ex	I would feel uncomfortable, if I did not know the end results of the hands-on (virtual) dissections.	2.96 1.16	(4) 145 29.7	3.0	2.61 1.56	(2) 132 27	2.0	-0.25
OHD15ex OVD15ex	Through teacher's demonstration of the hands-on (virtual) dissection, students cannot achieve same level of knowledge as when experiment is performed by the students.	3.23 1.08	(4) 201 41.1	3.0	3.40 1.05	(4) 169 34.6	3.0	0.16
OHD11ex OVD11ex	Manuals for hands-on (virtual) dissection should be very detailed.	3.95 0.95	(4) 222 45.4	4.0	3.83 0.95	(4) 205 41.9	4.0	-0.13
OHD14ex OVD14ex	Students should participate in decision to dissect or not.	3.70 1.08	(4) 215 44	4.0	3.36 1.21	(4) 162 33.1	4.0	-0.30

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