Web-based training in school to increase learning success during dissection in biology classes

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Abstract

Dissecting organs at school offers special learning opportunities. Due to ethical considerations, dissections in classrooms should be used for maximum educational benefit. Therefore we analyzed the effect of a web-based training (WBT) which prepared students for the dissection of a pig heart. A part of the WBT is a short video demonstrating the steps of the dissection and reflecting the exact situation in the classroom (the same dissection tray, preparation utensils and object to be dissected). In this study 8 classes were prepared for performing a dissection with the help of a WBT. A control group comprised 8 other classes with students not being prepared for the dissection day. Due to the German school system, half of the group belonged to a gymnasium and the other half to an integrated comprehensive school, both of them representing two different types of schools. For the study 401 students were given questionnaires at three points in time (pre-test, post-test and delayed post-test), and 77 out of 122 teams were monitored through teacher observation. The study showed that WBT accompanying an actual dissection increased students' learning success, helping the students conduct a more competent dissection, since they made fewer wrong cuts and they worked faster. By presenting the real situation with the video as a part of the WBT students knew what to expect. This decreased feelings of disgust and thus failures. The delayed post-test indicated that content knowledge afterwards was better if students were prepared with the help of the WBT. Based on our results of the investigation, the use of WBT at schools makes sense. Slower learners and visual learners in particular benefited from the clearer structure and the use of realistic video

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clips for preparation. The intensive preparation at home resulted in better conceptual understanding and better memorization of terms after the dissection day.

Keywords: e-learning, flipped classroom, learning success, peer feedback, pig heart dissection, web-based training

1. Introduction

Biology teachers try to use real objects during lessons since they presume that it might be conducive to learning (Petto & Russell, 2003). The advantages of using real animals in learning have long been recognized (Mayer and Hinton, 1990; Keiser & Hamm, 1991; Offner, 1993; Hepner, 1994). However, there has been considerable discussion of the pros and cons of animal dissections (Orlans, 1988). Ethical concerns often make students reluctant to participate in the dissection of animals, and some students refuse (Balcombe, 1997). Virtual dissections have been discussed and used as an alternative many times. Several studies have indicated that factual knowledge about respiration, cardiovascular anatomy and physiology can be improved when substituting the dissection (Leonard, 1992; Erickson & Clegg; 1993, Lilienfield & Broering, 1994; Samsel et al., 1994; Lunsford & Herzog, 1997; Lombardi et al., 2014). Nevertheless, current German teaching methodology in Biology demands the study of real objects as a fundamental form of studying in Biology lessons, such as the preparation of plants and animals (Köhler, 2012; Gropengießer et al., 2013; Otteni, 2014; Graf, 2016; Killermann et al, 2016). One ethical implication of the debate is that if dissection is used in schools, it should be used for maximum educational benefit. However, unprepared students do not achieve the same learning success as primed students. In several studies, e-learning resources prior to laboratory sessions reduced cognitive load and improved students' self-efficacy and understanding of practical activities (Jones & Edwards, 2010; Peteroy-Kelly, 2010; Al-Khalili & Coppoc, 2014; Whittle & Bickerdike, 2015). The current study investigates whether the preparation for a dissection improves students' results in problem-based learning. Due to the large differences between the real object and two-dimensional abstractions, such as worksheets used to prepare for a pig heart dissection (Spörhase-Eichmann, 2005), a film sequence was used for the preparation. The delivery of videoclips through

e-learning opportunities is much easier than giving an USB flash drive to each student or sending an e-mail with a huge attachment.

WBT was therefore designed to optimize the preparation for the dissection day. We hoped for positive effects similar to the ones in Steed's study (1999:31) "Studies have shown that interactive versions of training programs increase the learner's understanding of the course material by as much as 56% over the classroom version."

The film sequence used in our WBT shows only the beginning of a dissection. We ensured that the video showed the optimum procedure for the dissection without revealing any results. To this end the arterial openings were indicated as the ideal site to place a cut with the scissors and the cutting technique with the knife in the direction of the ventricle walls shown. However, the video did not show the opened heart with a view of the inner ventricles or the structure of the heart valves. Therefore problem-based learning is still possible, which is more nurturing and enjoyable compared with conventional instructional approaches (Albanese & Mitchel, 1993). In our problem-based learning the students needed to find out the anatomy and function of the heart valves. The colour and moving display of the object in the video of the WBT should have decreased the distance of the students from the task. To achieve maximal recognition effect from the video, the preparation instruments, preparation trays and utensils were the same as for the dissection in school. This should have reduced the degree of abstraction, since the students knew where, when and with what each cut was to be made (Hommel & Stränger 1994). The overall research question in this study was:

Do students who perform a dissection after having a preparatory WBT show i) better dissection attitudes before, during and after the actual dissection, ii) better dissection skills during the dissection, and iii) better content knowledge afterwards, compared to students who perform the dissection without the prior WBT?

We pursued the following six working hypotheses:

1. Students show a more positive attitude towards the real object, since they are familiar with it and have been shown an open-minded handling of the object.

2. Students feel more confident and better prepared if they have already seen the beginning of the dissection in the video.
3. The quality of the essential dissection skills increases, since individual steps of the dissection are explained in detail in the video.
4. The students complete the dissection in less time, since they already know where to place the cuts and which instruments to use.
5. The students have a more positive attitude towards the dissection based on a retrospective view, since they began the dissection day with a more positive attitude.
6. The participation in WBT has a positive effect on students' learning success, since they spend more time investigating the essential structures of the organ.

2. Methods

2.1 Subjects

The schools in our investigation were all within a town with 50.000 inhabitants, which lies to the north of the metropolitan area of Frankfurt am Main, Germany. Students of both schools came from middle-class families. Both schools are co-educational. The subject group in our investigation included 48% female students. Due to the peculiarities of the German school system and to assess the effect of differences of the students' "level of performance", the two schools chosen for our study present two types of schools with different school-leaving qualifications. The 'Gymnasium' (secondary school with higher performing courses) leads to an A-Level, whereas the neighbouring 'IGS' (integrated comprehensive school with lower performing courses) offers an intermediate school-leaving qualification (GCE Ordinary level). In total 16 classes took part in this study, with 8 classes at each school.

The students showed different degrees of familiarity with the subject matter: for 7 classes the structure and function of the heart was covered several weeks before our investigation, for 5 classes the dissection coincided with their regular curriculum, and 4 classes had not yet covered this topic in their curriculum. The students' familiarity with the teacher varied: each dissection was taught by one of three teachers from the regular teaching staff of the gymnasium. These teachers alternated teaching the dissection class. The teachers

taught two of the form 5 and form 9 classes in our study as part of their regular teaching schedule. Four heart dissection classes therefore were taught to students by their regular teacher and 12 classes were taught by an unfamiliar teacher. Most dissections began at 8am, four started at 10am, two at 12noon and one at 2pm. Including the pre-test and the introduction to the dissection, teachers had 90 minutes available for each lesson, although the actual dissection required much less time.

Two grade levels were identified to assess the effect of differences of the students' "development status". Based on curriculum requirements, a heart dissection could be integrated usefully in form 5 (10-year-old students) and form 9 (14- year-old students). The fundamentals of the cardiovascular system as well as respiration and metabolism are addressed in the curriculum of form 5 students. Four years later form 9 students study blood groups and the immune system. This provides an opportunity for a renewed look at the cardiovascular system. The 401 students from 16 classes carried out the dissections in teams of mainly 3-4 persons. Of all 122 teams, 77 teams (37 teams in classes without WBT, 42 teams in classes with WBT) were monitored by teacher observers.

2.2 The self-learning course: WBT

As can be expected in Germany (Behrens & Rathgeb, 2015), all students had access to a computer at home with internet access. This was the basis for a preparatory homework task and to develop a self-learning course, which was available as WBT. The WBT was not meant to replace conventional teaching, but to support and prepare before the actual lesson in class (compare with Petko, 2014).

Self-determined learning is advantageous, since the students themselves determine when and how long they study. If they want, they can repeat elements of the course and monitor their progress themselves (Kubler LaBoskey, 2004). However, students often find it difficult to study the material themselves, since the motivation of being part of a social group is absent. By studying alone, there is a danger that the course is not completed (Kerres, 2001; 2013). These benefits and problems were weighed with the 'Autorensystem Lernbar' (Krömker, 2016), a relatively short WBT package with 15 pages, which can be completed in 20 minutes. This prevents students aged 10 to 14 from ending the course prematurely because of temporal overload. Furthermore, students

were asked to print the last page, which provided an overview to the previously completed pages, and bring it to the dissection day. This allowed teachers to check whether the preparatory homework was completed.

The core element of the self-learning course is a video (Gerhard & Wrede, 2016; DiLullo et al., 2006) which shows students the dissection cutting technique. Students can learn a lot by observing in particular: the site of applying the cuts on arteries, the distance of the cuts from the groove between the ventricles, known as the anterior interventricular sulcus, the appropriate use of knife or scissors, and the application of slicing rather than pressing cuts. The video also contains the colour and size of the heart, the size in relation to a person's hands, as well as how to handle a pig heart. A voiceover on the video describes the individual steps of the dissection, as well as introducing and explaining essential technical terms and dissection skills in detail.

Following the video, 10 diagrams were presented covering the content of the video. All questions could be answered based on the video alone. Since well-defined lower skills were required to answer all questions, answers were presented as multiple choice. There were two to six possible answers. Students had three tries to give a correct answer before viewing the next diagram: they could check their answer as the correct answer was shown, and they could use the reset button to retry the question. After each answer, feedback was shown to inform the students further. Some questions included advice on which part of the video answers the question. After viewing the video again, students could tackle the question anew. The questions overall were to increase the attention of students on the content of the video and to retain the information.

2.3 Implementing the pig heart dissection

The human heart discussed in the curriculum is similar to a pig heart in structure and size, hence the latter were chosen for this dissection. It took approximately two months for a butcher to gather the necessary amount of hearts. Approximately 140 hearts were stored in a freezer in the school until the dissection day. The hearts were thawed once before to remove the enclosing membrane, the pericardium and any adipose or fatty tissue. The veins and arteries were shortened. Pulmonary and body arteries were separated from each other by cutting the connective tissue, so they are easier to recognise. Thawed hearts, like any other meat, develop an odour over time. It is therefore recommended to place the hearts thawed the evening before the dissec-

tion in lukewarm water for a half hour and to speed up the thawing period by flushing the heart with water shortly before the dissection. Flushing the heart is also important to remove blood clots from the ventricles. Such clots are not recognised as such by students and can increase their revulsion towards a dissection.

According to the concept of problem-based learning, before initiating the dissection the question was raised with the students, "Why does each side of the heart only pump blood in one direction?" (Raschke, 2009). Often students suspect an answer to this question analogous to a technical solution, such as a bicycle valve. Such statements were kept in mind as a working hypothesis. The dissection therefore begins with an investigation into the structures which prevent the blood from flowing backwards. For this reason, the self-learning courses only covered the dissection technique and did not discuss or show the opened heart. The experimental and control groups only differed in the preparation by the WBT. Apart from that, the same applied to both groups. Every team used preparation trays and preparation instruments, including knife, scissors, glass rod and tweezers, as well as other equipment such as disposable gloves and paper towels. Both groups, experimental and control, received a dissection guide in the form of two information pages. These were meant to help the students in imagining the real structures of the heart and therefore organise the information in their minds (Schaal, 2012). This guide was designed to match the video. It contained an overview diagram with labels of the heart and a step-by-step guide with sketches of each cut.

Since the students in the control group did not take part in the WBT, a detailed description was necessary for them to accomplish the dissection properly. This is particularly important for this dissection, since completed cuts cannot be corrected, especially when interesting structures are already cut. Since the time was short, a detailed guide was necessary to complete the dissection in time (Otteni, 2010). The experimental group received the same guide and all conditions on the dissection day were kept the same. To reduce the number of hearts needed and promote co-operation, the students worked in teams. Most often this resulted in working groups of 3 or 4, seldom in pairs or larger groups. This also allowed students who did not want to participate in the dissection themselves to observe.

The dissection itself consisted of two main parts:

External inspection. A glass rod was used to trace the path of blood through the heart and to mark the nine visible parts of the heart using small labels: the arteries, the veins, the four chambers and the groove between the ventricles. The labelling was monitored by the teacher before the team was allowed to progress in their dissection.

Inner inspection. Two cuts into the heart were made. Each cut was placed into the appropriate artery to open the right or left ventricle. Structures that belonged to the atrioventricular valves, the chordae tendineae, were quickly discovered. The colourless, close membrane of the semilunar valves were discovered much later, often only with help see below. When the dissection was complete the hearts were collected in a separate container und the dissection equipment cleaned.

Before the end of the problem-based lesson students were reminded of the question asked at the beginning of the lesson: "Why does each side of the heart only pump blood in one direction?" The discussion considered the statements of the students which were kept in mind as a working hypothesis. Through this the prior knowledge about technical solutions, such as a bicycle pump valve, was added by biological solutions, such as atrioventricular and semilunar valves.

2.4 Research design

The present quasi experimental design compared students who received conventional teaching with those who received WBT. We used a two factorial design (Table 1) in a fully crossed design (Bates et al., 1996). We analysed the independent variables "preparation" (WBT yes / no) versus "level of performance" (school type) as well as "preparation" (WBT yes / no) versus "development status" (age of students).

Table 1 Number of classes of the two 2x2 factorial designs with the independent variables "preparation" versus "level of performance" as well as "preparation" versus "development status".

	"level of performance" (school type)		"development status" (age of students)	
"preparation"	Gymnasium	IGS	form 5	form 9
WBT yes	4	4	4	4
WBT no	4	4	4	4

In total, 401 students performed a dissection in 122 teams of mainly 3 or 4 students. One half of the 16 classes, the experimental group, received WBT and the other 8 classes formed the control group without WBT. Always two classes each of following combinations: Gymnasium/form 5, Gymnasium/form 9, IGS/form 5 and IGS/form 9, together 8 classes, formed one group. Initially we assessed potentially confounding variables. Most important for the performance skills and attitude are familiarity with the teacher, time point in which the dissection topic was addressed within the school year and time of day. The participating classes were distributed into experimental and control groups so that the confounding variables were present to the same degree. This was used to control the confounding variables by group matching.

To check whether the use of the WBT changed the learning success we used different methods:

Questionnaires. The students of the experimental group and the control group were given a questionnaire to determine a pre and post dissection change. This allowed us to investigate non-observable behaviour, such as opinions and attitudes, by self-evaluation. The completion of the questionnaire was done anonymously and at the same time by the whole class. We used a pre-test-post-test-control (PCC) design: shortly before their dissection (t1), one week after the dissection (t2), and half a year after the dissection (t3). During the 6 months none of the classes performed a further dissection in Biology lessons.

To focus on the dependent variable "better dissection attitudes" the pre-test (t1) contained five items the students used to estimate their attitude towards a heart dissection (Figure 1a) and a further 5 items which enquired about the level of preparation for the dissection (Figure 1b). The post-test after a week (t2) referred to the same variable. It contained five items where students needed to self-assess their attitudes due to the dissection based on a retrospective

view (Figure 1c). The "change of dissection attitudes" towards the real object (pig heart) is evident in 3 items, which were enquired about at all three points of time t1-t3 (Table 2). These were all closed questions using a four-level Likert scale, which made indecision impossible (Creswell, 2012), since there was no middle value allowing a "neither agree nor disagree" or alternative allowing a "don't know" option. For statistical analysis the chi-square test (χ^2) was used. In the figures the percentage of agreeing to the statement, i.e. levels 3 (rather agree) and 4 (fully agree) of the Likert scale are displayed as bar graphs with their vertical axis on the left side. The mean and standard deviation are displayed with their vertical axis on the right side.

The questionnaires at all three points of time t1-t3 gathered data about the dependent variable "knowledge concerning dissection skills". One item about the correct cut is depicted in Table 3. Therefore students were given three illustrations to choose from: a correct cutting procedure (from arteries along the septum), a faulty cut (from the veins along the outer sides of the heart), or a false cut (perpendicular to the septum). In the faulty case the position of the cut was wrong but the direction of the cut was correct. The possibility to choose the faulty cut revealed a student's partial understanding.

The dependent variable "acquired content knowledge" was elevated only in the delayed post-test (t3), with an open question to express students' opinions freely (Seliger & Shohamy, 2013).

Their ideas about the aim of the problem-based learning, "Why does blood only flow in one direction?" were categorized into concepts (Table 4). Five concepts differing in complexity were identified following the qualitative methodology of thematic analysis (Braun and Clarke, 2006). Furthermore, we analyzed whether technical terms were used in answers or not.

Observations: In order to identify if students after the preparation by WBT showed better dissection attitudes, additional teachers as observers monitored the dissections of 77 teams. Before the dissection day the observers were briefed and used a standardized observation sheet during the dissection. Beside some open answers there were closed questions using a four-level Likert scale, exactly like in the questionnaires. The results of five items about the general impression of attitudes during the dissection are shown in Figure 2a. Five items of the observation of the quality of the essential dissection skills

are shown in Figure 2b. Additionally, the working speed during the dissection was monitored by the observers and sometimes documented by photographs. Altogether we were able to specify the working speed of the external inspection for 92 out of 122 teams and the internal inspection for 87 teams. In the statistical analysis the null hypothesis was checked with the Student's t-test.

3. Results

3.1 Self-assessment by students

Clear and significant differences were found between the groups in their self-assessed level of preparation for the dissection (Figure 1a). Students having prepared with the WBT indicated more frequently that they knew the steps of the dissection. They also claimed to know which instruments to use and which components of the heart they would see. The students in the WBT group also indicated they knew in which direction to place the cuts. Overall the students felt more confident and better prepared, since they had already seen the beginning of the dissection in the video. Partly the participation in the WBT changed the attitude and feeling of students towards a real pig heart. The answers of the students showed ambivalent attitudes toward the dissection. On the one hand students felt more confident because of their increased knowledge due to "preparation" by WBT. They also had a clearer and more accurate idea of what a heart looks like after completing the video preparation (Figure 1b). However, on the other hand the students could not imagine any more what a dissection feels like than students from the control group. Both groups were relaxed shortly before the dissection (Figure 1b).

Surprisingly, after the dissection day the students did not have more positive attitudes towards a dissection due to the dissection based on a retrospective view, although they felt more confident because of their increased knowledge at the beginning of the dissection day. On the contrary, following the dissection, all group differences in the students' self-assessment disappeared (Figure 1c). Both groups showed the same degree of fascination towards the dissection. Most students agreed with the statement that they learned a lot during the dissection, that they would remember the structure of the heart, and that they would remember each step of the dissection. Both groups of students showed an interest in dissecting other organs in class.

The "change of dissection attitudes" towards the real object (a pig heart), was not very obvious either. The willingness to touch the pig heart was similar before (t1) and a week after (t2) the dissection among the experimental and the control group (Table 2a). After half a year (t3) students prepared by a WBT were more willing to touch a heart. The willingness strongly decreased in all control groups. It increased among students with WBT in form 9 and in the IGS. The WBT affected the groups of both school types in a different way concerning the willingness to cut the heart themselves (Table 2b). It was the willingness of the IGS students, which rose, as opposed to the willingness of students of the Gymnasium, which decreased first (t1 und t2). Shortly before the dissection (t1) the students who knew what to expect stated more often that cutting a heart was disgusting for them, as opposed to students who were not prepared.

A week after the dissection (t2) the number of students who felt disgusted increased in both groups. However, the increase of disgust of the control group was clearly stronger than the one of the experimental group.

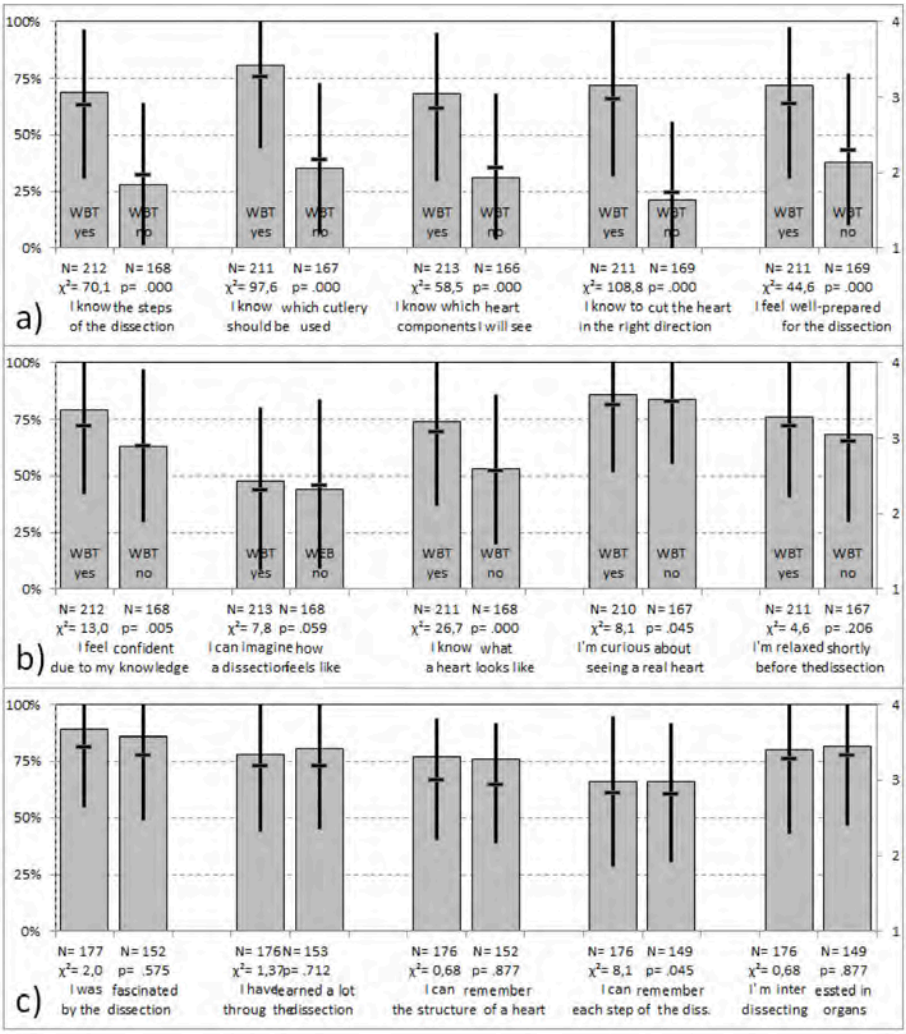

Figure 1 Attitudes of students as self-assessed in questionnaires in the experimental (WBT yes) and control (WBT no) groups, with median and standard deviation of Likert scales (right vertical axis) and degree of agreeing to the statement as a bar graph (left vertical axis). Items concerning: a) the level of preparation for the dissection-day (pre-test t1), b) a heart dissection before dissection day (pre-test t1), c) the dissection based on a retrospective view (post-test t2).

After a long period of time (t3) the disgust towards the pig heart seemed to be remembered clearly more strongly (Table 2 c). Students of the IGS accounted for the largest share of this result. The groups in this school type, both the experimental and the control groups, show a stronger difference at all times (t1-t3) than the groups in the Gymnasium. The WBT seemed to

stabilize the way form 5 students felt disgust towards the cutting of a pig heart (74% t2, t3), whereas the share of unprepared students in form 5 increased strongly due to the dissection (63% t1 to 88% t2) and afterwards decreased again back to the start value (63% t3).

Table 2 Change of attitude towards the pig heart, degree of agreeing to the statement (I agree: levels 3 and 4 of Likert scales) to the statements of students in the experimental (WBT yes) and control (WBT no) groups; date: pre-test before dissection (t1), post-test one week after the dissection day (t2) and half a year after the dissection day (t3).

WBT		Total			IGS			Gymnasium			form 5			form 9		
											10 years			14 years		
	date	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
Yes	N=	211	177	145	105	83	73	106	94	72	84	62	58	127	115	87
No	N=	168	153	135	68	42	44	100	111	91	65	58	63	103	95	72
	a) Item in the questionnaires: I want to touch the pig heart.															
Yes	I agree %	83	86	89	88	90	95	78	82	83	81	79	81	84	90	94
No	I agree %	81	87	75	78	86	70	83	87	77	80	86	75	82	87	75
	b) Item in the questionnaires: I want to cut the pig heart myself.															
Yes	I agree %	82	87	79	81	90	79	83	84	78	86	82	75	80	89	82
No	I agree %	84	87	74	74	80	80	91	90	71	86	88	73	83	87	75
	c) Item in the questionnaires: Cutting the pig heart disgusts me.															
Yes	I agree %	75	81	83	78	86	92	71	78	74	70	74	74	78	85	89
No	I agree %	71	85	67	54	81	64	73	86	68	63	88	63	76	83	71

The preparation due to WBT affected the students, despite the contradiction that there was more disgust in the long run. However, it also increased the students' willingness to touch and cut the pig heart themselves. Attitudes of form 5 students varied less and those of IGS students towards the real object increased the most.

3.2 Observations in class

The observing teachers stated that the attitudes of students who were part of the experimental group were affected by the "preparation" due to WBT. As the results of the "performance level" (i.e. different school types) and the "development status" (i.e. age of students) hardly differed when compared with the overall result of all participating students, they are not depicted in

our figures.

The general impression of attitudes during the dissection was that students after the preparation due to WBT dealt with a pig heart in a more relaxed way. Following WBT, for example, students appeared less inhibited or reserved towards the pig heart (Figure 2a, left diagram). They touched and investigated the heart more frequently and sooner. This enabled them to discover the posterior venous entrances to the heart faster. The teams in the experimental WBT group in general appeared more interested, displaying visible enthusiasm and discussions focused on the biological value of the organ (Figure 2a). If students had not encountered the object in a video previously they turned away from the heart or even left the room, thereby missing further observations.

These more positive attitudes helped students to concentrate on the dissection. The teams who completed the WBT dissected more correctly (Figure 2a) and discussed the figures given in the guide more frequently (Figure 2a). The prepared students needed less help and guidance from their teacher. However, this was not the case concerning basic dissection skills. The groups hardly differed in the positioning of the heart, and both could identify the left and right ventricles correctly (Figure 2b). Nevertheless, the observers stated that the essential dissection skills were performed significantly, more autonomously, and in a better way due to the preparation after the WBT.

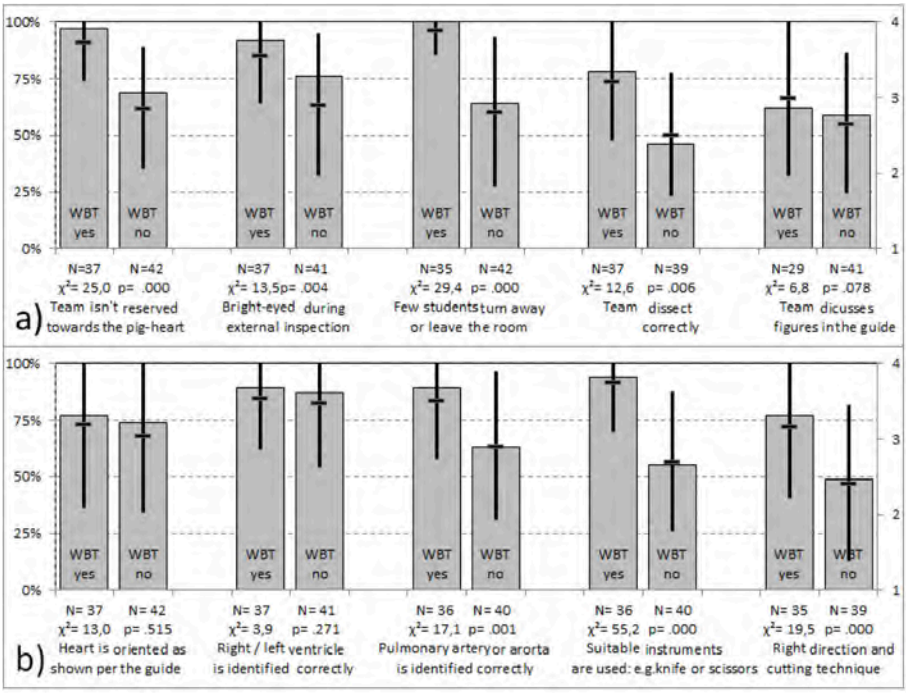

Figure 2 Dissection expertise as observed by teachers of experimental (yes WBT yes) and control (WBT no) groups, with median and standard deviation of the Likert scales (right vertical axis) and degree of agreeing to the statement displayed as a bar graph (left vertical axis). a) their general impression of students' attitudes , b) the essential dissection skills.

The WBT, however, significantly improved the speed and accuracy of students in identifying the pulmonary artery and aorta (Figure 2b). Teams from the experimental group also placed the initial cuts more appropriately: a slicing motion from the arteries into the ventricles in the direction of the cardiac septum. They also more frequently used the appropriate preparation instruments: scissors for arteries, knife for heart wall. Although both groups showed a clear distinction concerning the behaviour related to the dissection, the general school related behaviour did not differ. There were many interactions of students within all teams. Macabre interactions with the pig heart were rare and did not differ between groups. During the course of the dissection the organ engaged the students' attention more and more. For this reason, we did not observe significant differences in the number of free riders or distracting or disrupting students. We observed two students who distanced themselves clearly from the pig heart, one of which was Muslim. However, both students

were very interested in increasing their knowledge and therefore observed the dissected pig heart halves for a long time. However, we could not attribute these observations clearly to either experimental or control group.

3.3 Students' knowledge

In order to determine the positive effect on the learning process in the questionnaires there were items concerning the acquired knowledge. With regard to the students' knowledge about the cutting techniques, significantly more students in the experimental group could indicate the correct method of cutting before the dissection than in the control group (Table 3). In the pre-test the result had to be expected as only the experimental group had watched the video with the instruction for the dissection. One week after the dissection day (t2), when also the control group had learned about and applied the cutting technique, the choosing of the correct illustration increased. At this point in time, the illustration with the false cut (perpendicular to the septum) was particularly chosen less, whereas the faulty cut, which could be easily confused with the correct cut, was chosen more often.

The knowledge they acquired in the video was maintained for half a year until the delayed post-test. Obviously the WBT led to keeping the correct cutting technique in mind longer because choosing the correct illustration in the post-test (t3) decreased more strongly in the control group than in the experimental group. Table 3 indicates which students could improve their dissection skills due to the WBT most. It was the students in the IGS who improved most because the strongest differences between the experimental and the control groups were evident in the post-test (t2).

Table 3 Responses of students in experimental (WBT yes) and control (WBT no) groups regarding the correct cutting procedure (from arteries along the septum) rather than the faulty cut (from the veins along the outer sides of the heart) or false cut (perpendicular to the septum). Time points: before the dissection day (t1), one week after the dissection day (t2) and half a year after the dissection day (t3).

WBT		Total			IGS			Gymnasium			form 5 10 years			form 9 14 years		
Yes	**Date**	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
	N=	207	177	144	104	83	71	103	94	73	83	62	59	124	115	85
	correct %	94	87	90	90	81	87	97	93	92	96	92	92	92	84	88
	faulty %	5	8	7	8	11	7	2	6	7	2	6	6	6	10	7
	false %	1	5	3	2	8	6	1	1	1	1	2	2	2	6	5
No	**N=**	160	150	137	63	40	45	97	110	92	61	58	63	99	92	74
	correct %	56	75	66	59	55	56	55	82	65	49	74	71	61	75	61
	faulty %	20	19	27	16	40	33	23	11	22	30	16	24	14	21	30
	false %	20	7	7	25	5	11	23	7	5	21	10	3	25	4	9

The aim of the problem-based learning during the dissection day was that students find an answer to the question, "Why does blood flow in only one direction when the heart pumps." In their answers after half a year (delayed post-test t3) students in the experimental group used more expert scientific terms (52%) than the control group (35%), such as heart valves, semilunar valves and atrioventricular valves.

Table 4 Students' ideas concerning the aim of the problem-based learning in experimental (WBT yes) and control (WBT no) groups half a year after the dissection day, answers to open questions were categorized into five concepts (a-e), ranked according to their complexity.

	WBT	total	IGS	Gymnasium	form 5 10y	form 9 14y
Concepts explaining why does blood only flow in one direction.	yes N=	163	81	82	73	90
	no N=	125	43	82	54	71
a) Students did not answer as "Because it is so". Often they expressed uncertainty or that the preparation day was too long ago.	yes %	38	46	30	42	35
	no %	56	57	55	80	37
b) Students stated an incomplete concept, such as "venous valves" / "the heart pumps"	yes %	9	6	12	10	7
	no %	8	9	7	9	7
c) Students stated a basic concept: "through / because of", often including "heart valves".	yes %	17	18	16	18	16
	no %	10	7	11	5	12
d) A commonly known concept is known, such as "something opens and closes" or "something stops the blood from flowing back".	yes %	20	15	25	19	21
	no %	16	21	14	1	28
e) Students stated a complex concept: "atrioventricular valve releases blood from atrium into ventricle", "aortic valve fills with blood".	yes %	17	17	17	10	23
	no %	9	2	13	5	13

Students in the experimental WBT-group showed more accurate and more complex understanding than the control group (Table 4, percentages of concepts b-e). Both groups, the experimental and the control group had partly inappropriate ideas concerning this question half a year after the dissection (Table 4a). However, there was 18% of inappropriate ideas across all students, and up to 38% in form 5 students due to the preparation through WBT. Therefore, Table 3 indicates which students could improve their content knowledge with WBT the most. It is the students of form 5 who improved most, with noticeably more complex ideas were expressed in the experimental group.

4. Discussion

As the results show, the student's expectations towards the dissection day did not differ significantly, regardless of whether they completed a WBT program or not. The dissection itself, specifically interacting with the real object, fascinated both groups equally, leading students to estimate their learning success similarly. This corresponds to Kinzie et al. (1993), a study in which all

students also reported a significant gain in dissection self-efficacy, and no between-group differences were found. Approximately two thirds of the students in our experimental group indicated that they were less repulsed by the heart due to the expectations formed following the video. Their objectively estimated level of disgust was reduced (cf. Randler et al., 2012), and they were more likely to want to touch the heart, both effects lasting long after the dissection itself and increasing over time. We therefore cannot fully accept the working hypothesis concerning students' more positive attitude towards the real object.

There is widespread agreement that appropriate pre-laboratory preparation is beneficial to students as it facilitates their learning and understanding (Gregory & Di Trapani, 2012; Jones & Edwards, 2010; Chittleborough et al., 2007). However, the preparation alters a number of factors significantly: the participants in the WBT felt more prepared and more often thought they knew all the necessary steps. Nearly 90% of the experimental group thought this was in connection with viewing the video clip. Our observations indicated a faster orientation and better completed dissection because of it. However, the video clip merely decreased the time students needed to view the exterior of the heart. The students mainly used the remaining piece of the aortic arch, which turns to the left-hand side, or the curved groove between the ventricles along the anterior side, to find the correct orientation of the heart. Students who did not complete the WBT needed significantly more help in this. This applies for the experiences of laboratory demonstrators who spent more time helping students resolve complex issues rather than trivialities after their students were prepared by blended learning (Gregory & Di Trapani, 2012). The teachers benefited from preparation due to WBT as well. In a typical classroom with up to 30 students, in which a single instructor is hard-pressed to lend assistance to all student teams conducting a dissection, well-prepared students could be less exhausting (Kinzie et al. 1993)

Teams in our study that showed a high degree of distance from the real object only turned the heart over at a late time point, which resulted in the side facing upwards by chance to be viewed for a long time. This occurred most for teams without WBT preparation. The time needed for the inner inspection, to cut and open the heart, was similar for both groups. Teams in the experimental group needed less help from the teacher, completed the cuts faster, had to correct fewer cuts and prepared the inner view of the heart better. This left

them more time to determine the direction of blood flow and examined vital structures, such as heart valves, for longer. Gregory & Di Trapani (2012) also stated that students using online pre-laboratory preparation were able to plan and manage experimental time more effectively. This confirms three of our working hypothesis: students felt better prepared, showed a better quality of dissection skills and dissected faster when they completed a WBT beforehand. Encounters with real objects at school often tends to be very time-consuming, especially as the dissection of living things or organs is costly in terms of preparation and teaching time (Lombardi et al., 2014). If dissection is faster, with preparation due to WBT, it could prevent some of these problems dealt with in the classroom.

In both groups the majority of students were interested in doing more dissection. This investigation found no differences in attitude towards the dissection before or after the intervention. These results lead us not to accept the fifth hypothesis. However, we regard it as an indication of the fact that dissection in schools makes learning more motivating and diverse (Elizondo Omaña et al., 2005). There are indications that the use of an interactive simulation as a preparation for dissection affects the learning of anatomy positively (Kinzie et al. 1993; Akpan & Andre, 2000). Crucial for the use of a WBT in school, however, is the clearly positive effect on learning success (our 6th hypothesis): the participation in our WBT led to better recall of the task, more scientific concepts and more frequent use of technical terms up to half a year after the WBT and dissection day.

With a view towards a successful outcome, executing the dissection correctly is very important. Cuts cannot be adjusted easily for very delicate objects and the most interesting structures may be destroyed before the investigation. In these cases a preparatory WBT is very useful. The WBT and self-learning was meant to give a better overview of the field, and thereby differ from a time-consuming and often laborious internet-based search for materials, which would require analysis and understanding (Döring, 2000). Our impression is that form 5 students, who had little experience with dissecting real objects, benefitted most from the clear guidelines and preparation at home (see Murphy (2004) Leadership for Literacy), particularly since self-evaluation was an integral part of WBT, which ensured a sufficient understanding of the video. Brennan (2003) found that in order to help ensure effective

student learning outcomes, online pedagogy needs to address a variety of factors. Among these are the approaches which are used to enable learners to build new skills based upon the ones they have already acquired, and whether a consistent level of appropriate feedback exists.

We would have liked to communicate the haptic feedback in the video, as this might have reduced the degree of irritation when encountering the organ. However, this is not possible with current technology. The use of new media still had a positive and supportive effect, since form 9 students use these in their spare time and could use them appropriately to increase their learning success (Sofos & Kron, 2010). With regards to the constructivist view of learning, this investigation succeeded in encouraging students to construct their own knowledge (Gerstenmaier & Mandl, 1995) through the intervention of a preparatory web-based training programme. The training allowed and fostered independent thought, which stimulated knowledge that was retained for a long time.

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