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Does teaching about artificial reefs trigger students' situational interest in marine biology?

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ABSTRACT

The lack of interest among pre-university students to choose STEM subjects for their higher education is a heavily debated issue in many western-world countries. To boost Danish students' interest in biology, a study event on artificial reefs was introduced when teaching marine biology in lower secondary school and upper secondary school (student age 13-20 years). The purpose was to investigate if the focus on artificial reefs could generate an increased interest in natural science and marine biology among the students. The students' interest in science was evaluated using electronic questionnaires before and after they had completed the teaching program. The students were significantly more interested in natural sciences and marine biology after than before the teaching program. The development in situational interest in science and in the oceans was different for males and females with females being most interested. Thus, it is possible to trigger a situational interest for science and marine biology by teaching about artificial reefs, but the way interest is triggered differs between different age groups and sexes.

KEYWORDS:

Artificial Reefs; Marine Biology; Interest development; Gender differences; Live-stream; Technology; STEM

Introduction

Studies have shown a decreasing interest in natural sciences among young people (Potvin and Hasni 2014; Troelsen 2005). By 2025, Danish universities will be faced with a predicted shortfall of 13,000 master graduates within the fields of engineering and natural sciences, despite increased admissions (Danish Industry 2015). Similar studies in other European countries show the same tendency (Business Europe 2011; European Commission 2004; Osbourne and Dillon 2008; Shapiro, Østergård and Hougård 2015). Furthermore, STEM disciplines (Science, Technology, Engineering, Mathematics) will be struggling with the highest drop-out rates among university students (OECD, 2008; Danish Industry, 2015), causing a severe lack of qualified graduates for the job market.

Even though children start in the educational system with a high interest in nature and science, they leave school with a low interest in these subjects (Osborne and Dillon, 2008). Their motivation for learning is likewise decreasing throughout their primary and secondary education. There are several explanations for the decrease in interest. During adolescence, many students change their focus towards themselves and their own development rather than learning about the world around them (Renninger and Hidi, 2011). In addition, natural sciences are difficult to learn, often supplying counter-intuitive explanations to 'common sense' problems. For example, the scientific fact that a feather and a ball will fall towards the ground with equal speeds in vacuum is still mind-boggling not only for school children but also for adults, even some 400 years after Galileo Galilei proved this through experiments (Paludan, 2000).

Different innovative means have been introduced in the curriculum of schools to counteract the lack of interest in natural science among young people and enhance the number of students within STEM disciplines (Hasni and Potvin, 2015; Potvin and Hasni, 2014). These actions often focus on initiatives at the school or in collaboration with science centers and aquaria, either through excursions to external institutions or by using teaching material produced by external partners. Such activities and materials are not necessarily updated with the most recent scientific knowledge, even though including the latest scientific findings may result in more exciting teaching. Another way to trigger the students' interest may be to introduce novel ways of teaching (Ainley and Ainley, 2010; Kashdan and Silvia, 2009). Here, the universities could play a larger role in supplying schools with exciting cutting-edge knowledge to increase fascination and interest. Furthermore, by using new teaching technologies, this may open up the amazing stories hidden in the world of science (Archer et al., 2010). By participating in newly developed teaching programs, students can be excited by not only learning known facts by heart, but also obtain a feeling for what it is like to be a 'real' scientist. This approach requires authentic teaching programs that include actual and current science projects from the universities and

dedicated scientists which can produce authentic experiences for the students. In this way, scientists can take a more active role in attracting young people to the STEM educations. Through practical involvement, scientists can provide opportunities for the students to understand how we discover more about the natural world (Fortner and Mayer, 1989; Katarzyté et al., 2017).

Denmark is among the countries in the world with the longest coastline per inhabitant. Anywhere in Denmark, you are not longer than 50 kilometers from the coast. Many Danes enjoy spare-time activities close to the sea, such as angling, sailing, walking along the beach, or winter bathing. Besides, Danish waters are economically important for fisheries, transportation, and oil/gas production. Issues related to the marine environment are often presented in the public debate in national newspapers, television, and radio, such as: which areas should be used for fishing, should the aquaculture section be allowed to grow, and should farmers be allowed to release more nutrients for their farm fields that will eventually lead to a higher nutrition load in coastal waters. Also, the caravan of international large transportation ships sailing through the inner Danish waters is at constant risk of accidents involving oil spills and other pollutants.

Large efforts are invested in creating awareness of environmental issues regarding the oceans (Ducrotoy et al., 2000; Katarzyté et al., 2017), but teaching and education about the oceans present challenges due to the inaccessible environment (Fortner and Mayer, 1989; Lambert, 2005). This study used new technologies to show live-stream video from an artificial reef (a sunken ferry) when teaching Danish students' marine biology (see Seidelin et al., 2018). The purpose was to investigate if the focus on artificial reefs could generate an increased interest in natural science and marine biology among the students. By using new technology, this study established an 'underwater laboratory' by placing cameras on a sunken ferry. The live images from the ferry functioned as a new and innovative way of teaching about the ocean as an ecosystem, and as a portal to discuss the challenges facing the oceans.

The world's oceans face a number of challenges, for example the extinction of species, the accumulation of plastic debris, and global warming. These threats are also obvious in Danish waters. A number of Danish initiatives have been established to create public awareness of the oceans. The World Wildlife Fund (WWF) has initiated 'Opdag Havet' (Discover the Ocean) where the public has the opportunity to snorkel and read stories about the ocean including the animals in it at interesting/selected sites along the Danish coasts. A number of public aquaria have initiated projects with the focus on the ocean's challenges. Aarhus University has launched 'Hovedet i Havet' (Head in The Ocean), using their research vessel to sail around Denmark and give children a chance to learn

about topics about the ocean. However, none of these initiatives has evaluated the target groups' interest in natural sciences. Therefore, it is not known if these activities had a positive effect on increasing interest in the oceans and natural science.

Theoretical framework. Individual and situational interest

In an educational context, interest is typically referred to as either situational or individual/personal interest. Situational interest is a psychological condition that is influenced by the situation and stimuli from the surroundings (Krapp, 2002; Renninger and Hidi, 2016). Situational interest is temporary and often based on emotions whereas individual interest is more persistent and less affected by the input from the surroundings. Situational interest can be triggered by e.g., field trips, and museum tours (Dohn, 2013; Falk et al., 2007). One fruitful way to describe the development of interest is Hidi and Renninger's (2006) four-phase model. In phase 1, situational interest is triggered, and in phase 2 it is maintained. Later on, in phase 3, the situational interest may evoke individual interest, which may later on develop further to well-developed individual interest in phase 4. According to this model, situational interest has to be triggered by an object, event or stimuli in the surroundings and is always the route towards the development of individual, and more long-term, interest (Hidi and Renninger, 2006; Rotgans and Schmidt, 2017).

In order for student interest to be awakened by teaching, it is important to give the students a sense of meaningfulness of the object of potential interest (Hidi, 1990; Renninger and Hidi, 2016). Thus, the object of interest must be emotionally related to the students, or, put in another way, give the topic a value (Krapp 2005). It should make sense for the students to be interested in the topic, and their interest may be spurred by the teacher making it relevant (Ainley and Ainley, 2010; Eberbach and Crowley 2009). Their interest can be captured using both *eye-opening* and *hands-on* experiences (Dewey 1913; Dohn 2011). Both types of experiences have a direct connection to the object of interest, leading to direct engagement in the topic (Ederbach and Crowley, 2009). Tiberghien (2000) highlights that when teaching secondary school students, their stage in life has to be taken into consideration, including their lack of ability to stay focused for longer periods of time. As a frame of reference, interest always involves focused attention and commitment to the object of interest (Krapp, 2005).

In our study, a teaching program about marine biology - with special emphasis on artificial reefs - was used to teach 14-20 years-old students, and situational interest among students was measured before and after the program. This approach, using questionnaires to investigate the level of interest

among students, has been used in numerous studies (Blankenburg et al., 2016; Holstermann et al., 2010; Lambert, 2005; Lewis, 1993; Madsen and Dohn, 2018; Palmer, 2009; Swirski et al., 2018). Qualitative approaches using interviews, observations, videos etc. can also be used to generate data (Dohn, 2011; Renninger and Bachrach, 2015), as well as longitudinal studies on students' interest in STEM (Seidelin et al., 2019; Sjøberg and Schreiner, 2010; Shahali et al., 2018).

Methodology

Data on student interest were collected with questionnaires from 624 students divided between five secondary schools (207 students, age 13-16 years) and at three upper secondary schools (417 students, age 15-20 years). The schools were all located on the island of Funen (Denmark) and were visited from November 2016 to December 2017. All schools were 100% government funded and followed the same standard curriculum defined by the Danish government (Ministry of Education, 2016).

The teaching program lasted 90 minutes. The program had the same length and content, irrespective of which school was visited and the age of students. The program was designed in accordance with the national curriculum. The teaching program was held by the same person to make sure that it was uniform to avoid bias and was based on live-stream underwater video from a sunken ferry (methodology described in Seidelin et al., 2018). The program included topics in the following order:

- 5 minutes: *Questionnaire* (see below and Table 1). The electronic questionnaires on the students' mobile devices was started in Typeform basic (Typeform, Inc.) without any further instructions from the teacher to prevent bias.
- 15 minutes: *Introduction to marine biology focusing on ecosystems and the importance of artificial reefs.*
- 15 minutes: *The story about the sinking of the Ærø-sund-ferry* from scrap to artificial reef. A Youtube video was shown of the sinking of the ferry in 2014 and the wreck one year after the sinking, and the students were informed about how stones have been removed from the oceans to build piers etc.
- 10 minutes: *Food chains in a Danish artificial reef.* Examples of selected animals. Each animal/group was depicted with a PowerPoint picture.
- 25 minutes: *Use of livestream to identify species from the sunken ferry.* The live-stream was shown on the smart board via projector, and the students were given different handbooks about marine animals to identify the species they found. The students then worked in groups to identify species.

- 10 minutes: *Fun facts about selected Danish species* from the artificial reef (the sunken ferry). This section focused on the species that the groups found on the live-stream.
- 5 minutes: *Sum-up and completion*. Brief sum-up of the teaching program.
- 5 minutes: *Questionnaire* (see Table 1 and below). The students filled out the same questions again using Typeform basic (Typeform, Inc.).

Evaluation of students interest

Before the teaching was initiated and without any further comments, the students were asked to fill out the ‘before questionnaire’. After the program had finished, the students were asked to fill out the ‘after questionnaire’. The students completed an electronic questionnaire made in Typeform basic version (Typeform, Inc.) primarily focusing on their interest in natural science and marine biology using a Likert scale (Likert, 1932) from 1-7. The questions used in the evaluation were self-designed as follows: ‘Your interest in natural science?’ and ‘Your interest in the Oceans?’ Additional questions on the students’ age and general background were not used in the analysis (Table 1).

The same questions were given to the students before and after the teaching program. The students were asked to answer questions regarding their plans after school and their interest in natural science and the oceans. The questionnaires were handed out with no further instruction or comments.

The responses of the two questions before and after the teaching program were compared using a paired Students’ t-tests in MatLab (statistical significance level $p = 0.05$). A Bonferroni correction was applied (with $N=3$ for high school and $N=5$ for secondary school), and thus the efficient level of significance was $p=0.015$. Prior to statistical testing, a F-test was performed to make sure that variances of the data were homogenous. Cohen’s d was calculated to allow for direct comparison of differences between means.

Results

From the 5 secondary school classes participating, we obtained answers on the questionnaire from 417 pupils. From the three high school classes, we obtained a total of 207 answers. The results of the questionnaire are summarized in Tables 3 and 4. Four out of five secondary schools showed a significant increase in student interest in natural sciences and the ocean after the teaching program (Table 3), and similarly, two out of three high schools showed a significant increase in student interest

(Table 4). When pooling all the data from secondary schools and high schools (Fig. 1), a subtle albeit significant increase in students' interest after the teaching was observed.

When splitting responses into female and male replies, there was a difference between grades 7-9 and high schools and between the sexes (Table 2). For secondary schools, girls were significantly more interested both in science in general and the oceans in particular, compared to before the teaching event. For boys, there was a significant increased interest in the oceans, whereas the interest in science was unaltered (Table 2 and 3, Fig. 2). For high schools, males did significantly increase their interest in the oceans, but not in science in general. For high school females, the increase was significant both for interest in science and oceans (Table 2 and 3, Fig. 3).

Discussion

The teaching program about artificial reefs significantly increased grades 7-9 and high school students' interest in natural science and marine biology. The increased interest corroborates earlier findings, that the negative development in young people's interest in natural sciences can be alleviated by modifying traditional teaching methods (Keller et al., 2014). Live-stream video from inaccessible places can be viewed as a good example of such teaching methods increasing the interest for natural science among young people and hopefully enticing them to choose STEM studies. One could also envision using similar techniques to document and make the students participate in 'live' scientific work and other topics to catch the interest of the students (Penuel and Gallagher, 2017).

This new and innovative approach to teaching the students about marine biology supported an increased interest for the topic. The findings of this study can potentially be transferred to prevent drop-outs in the first year of studies among STEM students, which was a major problem for years in many European countries (OECD, 2008). Wyss, Heulskamp and Siebert (2012) used videos of working scientists to generate more interest for the STEM studies among middle-school students. Using newly developed, inspiring technical advancements to obtain observations from nature, such as using live-stream video from the ferry, may alter the fact that many young students start their life in the educational system with a high degree of interest in natural sciences and leave with a much lower interest (Osborne *et al.*, 2008), causing a massive lack of master graduates within these disciplines (Business Europe, 2011; Danish Industry, 2015; European Commission, 2004; Osbourne and Dillon, 2008; Shapiro, Østergård and Hougård 2015). Wyss, Heulskamp and Siebert (2012) showed that it is possible to generate interest in STEM studies by using videos of scientists at work.

By exposing public and high school students to this newly developed teaching content with focus on artificial reefs, we showed that their interest in natural sciences can be boosted.

A crucial question is how interest in natural sciences can be maintained among the students. One challenge is to motivate the academically unmotivated students (Hidi and Harackiewicz, 2000). It calls for caution when designing activities to promote the interest in natural sciences for a certain educational level: if a teaching activity only excites the already interested students, it may have the same effect as *preaching to the choir*. Instead, it seems that ideal teaching activities should spur the interest among the uninterested and excite or maintain the interest in the already motivated students. We suggest that a wider use of live-stream techniques is a way of generating and maintaining more interest in a topic among the students in grade 7-9 and high school, but also potentially at universities. Arher et al. (2010) found it essential to affect the students in the early years, since this is when they decide whether they will choose a technical or natural science education. Therefore, a future perspective for a study like this could be to initiate live research for students in the early years of their school life.

The teaching program experimented with in this study may have created a higher impact for younger-age students than for high school students. Most of the high school students participating in this study were majoring in science, while the secondary school students had not yet any clear plans for their future education. As such, the high school students were presumably already highly motivated to indulge in their studies and therefore also highly interested in natural sciences. This makes it more difficult to affect their interest by the kinds of incentives used here. For students in both age classes, there is a correlation between a high average interest prior to the teaching program and relatively small changes afterwards. The higher interest the group had before the teaching program, the smaller the difference was after compared to before. Efforts to catch student interest in natural sciences could therefore be focused on students with a low degree of interest, as well as targeting the right age group. Quite possibly, many of the incentives made nowadays to promote natural science in schools are not having the desired effect because they often aim at attracting the interest of students that are already inclined to make choices in the direction of natural sciences.

It is unlikely that the situational interest generated by a short teaching event, such as the one used here, can rapidly develop into individual interest for natural sciences. This may have interesting implications for which kind of teaching program to be designed to promote student interest in natural sciences and affect their choice of future education. The teaching material presented here was based on artificial reefs and live-streamed underwater video. It has to be taken into consideration that the

teaching program was offered all year around, and therefore the number and kinds of species observed on the live-stream video varied. This could affect the interest and thereby the answers from the students. Thus, using artificial reefs live transmissions for such material has both its obvious advantages and disadvantages. Observing what is going on below the surface at the very moment of teaching is a powerful way to obtain the interest and attention of the students. On the other hand, the transmission may fail, and the quality of the images is further dependent on light conditions, time of day and time of year. Therefore, all students did not receive exactly the same teaching during this study. Variations in the effect on student interest caused by the teaching may therefore in part be explained by variations in the quality of the teaching, as has also been observed in previous investigations (Abell and Lederman 2007). It is hard to distinguish if the changes in interest is directly generated, and therefore, it could be interesting to do different lineups of teaching programs in the future and expose one to traditional teaching and the other to the teaching program about artificial reefs.

The data on gender differences (Table 2, Fig. 2 and 3) showed that girls in both secondary schools and high schools were significantly more interested in science in general and the oceans after the teaching event. For boys, there was a significant increased interest in the oceans, whereas the interest in science was unaltered for the students in high school and opposite for the students in secondary school. These differences indicate that girls are more prone towards the topics, but also that the gender differences in general were small. This finding aligns with previous findings in gender differences that girls are more responsive when conducting initiatives towards natural science (Baram-Tsabari and Yarden, 2010; Wang and Degol, 2016).

The feedback from the students was obtained right before and after each presentation, thereby investigating the student's situational interest (Renninger and Hidi, 2011). It would be interesting to understand the long-term effects of the teaching program on student interest, which is probably what mostly determines their choice of career. The questionnaire and subsequent analysis should therefore be repeated some months after the program (Krapp and Prenzel, 2011). The teacher's role and enthusiasm in the program is also very important (Dohn, 2011), but it is still not fully understood what influence this has on the students' interest (Keller et al. 2014; Yen and M'hammed, 2011).

This study used a teaching program with focus on artificial reef to teach about marine biology. By trying it out on secondary and high schools, it was shown to be possible to trigger students' interest in natural sciences by such an activity. The result also show that girls were significantly more interested both in science in general and the oceans in particular, after compared to before the teaching

event. For boys, there was a significant increased interest in the oceans, whereas the interest in science was unaltered. This can inspire further development of exciting teaching techniques to inspire students to become more prone to select natural science educations in the future. It shows however, that care must be taken when designing such teaching programs so they evoke desired interest effects in both male and female students of all focal ages.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Ethics

All Danish rules regarding children and students were complied during the study

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Table 1. Questionnaire questions and scales for the replies of students

Question	Scale / choice
Mothers name	-
Month of birth	-
Year of birth	-
Sex	-
Your plans after school	University / other
Could you imagine studying biology after school	Yes / No / Don't know
Your interest in natural science	1-7
Your interest in the Oceans	1-7

Table 2. Results on questionnaire questions about interest in biology and oceans, split between boys and girls for secondary and high schools. Levels of significance: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

	Secondary school		High school	
	Boys	Girls	Boys	Girls
N	223	194	67	140
Interest in biology				
Before	3.8 ± 1.6	3.6 ± 1.5	4.6 ± 1.6	4.6 ± 1.6
After	4.5 ± 1.6	4.5 ± 1.5	4.7 ± 1.5	4.5 ± 1.3
Cohran's delta	0.4	0.6	0.07	0.11
t-test, p	<0.0001***	< 0.001***	0.14	0.002**
Interest in the oceans				
Before	4.2 ± 1.6	3.9 ± 1.6	4.1 ± 1.5	4.1 ± 1.5
After	4.3 ± 1.7	4.3 ± 1.5	4.3 ± 1.3	4.5 ± 1.3
Cohran's delta	0.05	0.2	0.2	0.3
t-test, p	0.3	0.02*	0.01**	<0.001***

Table 3: Summary of statistical tests made on student replies from 5 secondary schools.

Significance levels: *** $p < 0.001$.

Secondary School (Number of students)		School 1 (20)		School 2 (28)		School 3 (94)		School 4 (116)		School 5 (159)	
		<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>
<i>Interest in natural science and the oceans</i>	Average	3.5	4.2	4.4	4.5	3.5	4.0	3.4	4.1	4.1	4.6
	Cohen's d	0.56		0.13		0.42		0.18		0.36	
	t-test, p value	<0.001 ***		0.58		<0.001 ***		<0.001 ***		<0.001 ***	

Table 4: Summary of statistical tests made on student replies from 3 high schools. Significance levels: $p < 0.01$ **, and $p < 0.001$ ***.

High School (Number of students)		School 1 (21)		School 2 (53)		School 3 (133)	
		<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>
<i>Interest in natural science and the oceans</i>	Average	5.4	5.1	3.9	4.3	4.3	4.6
	Cohen's d	-0.39		0.31		0.21	
	t-test, p value	<0.01 **		<0.01 **		<0.001 ***	

Figure captions

Figure 1a. Histogram showing grade 7-9 students reply on a Likert-scale 1-7, averaged between questions about their interest in natural science and the oceans, before and after the teaching program.

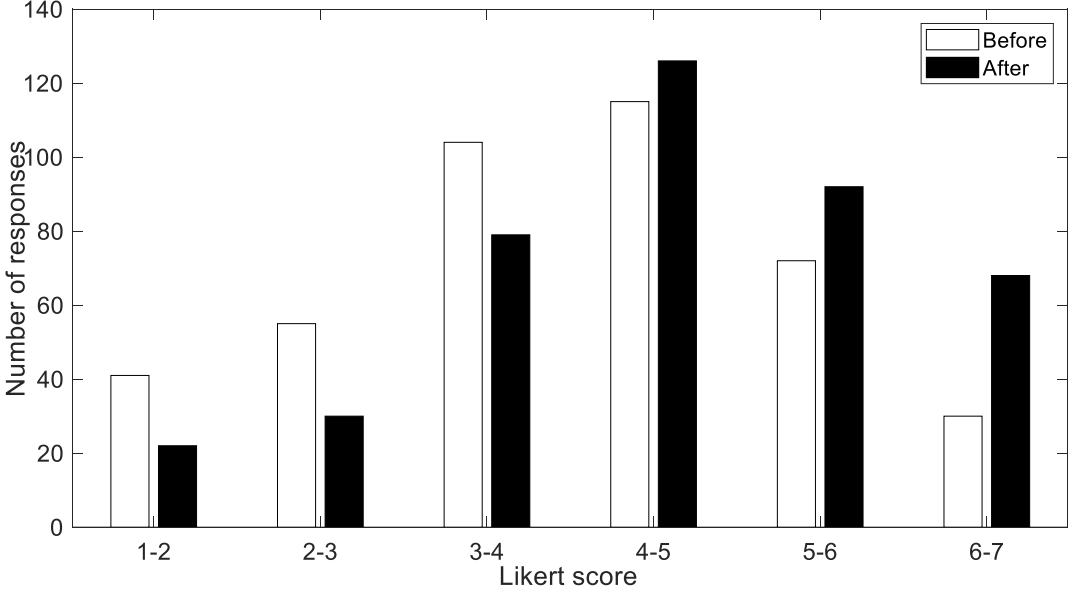
b. Histogram showing high school students' reply on a Likert-scale 1-7, averaged between questions about their interest in natural science and the oceans, before and after the teaching program.

Figure 2. Grade 7-9 male student responses on a Likert-scale 1-7 to interest in (a) science and (b) oceans, and grade 7-9 female student responses on a Likert-scale 1-7 to interest in (c) science and (d) oceans.

Figure 3. High school male responses on a Likert-scale 1-7 to interest in (a) science and (b) oceans, and high school female responses on a Likert-scale 1-7 to interest in (c) science and (d) oceans.

Figure 1

a



b

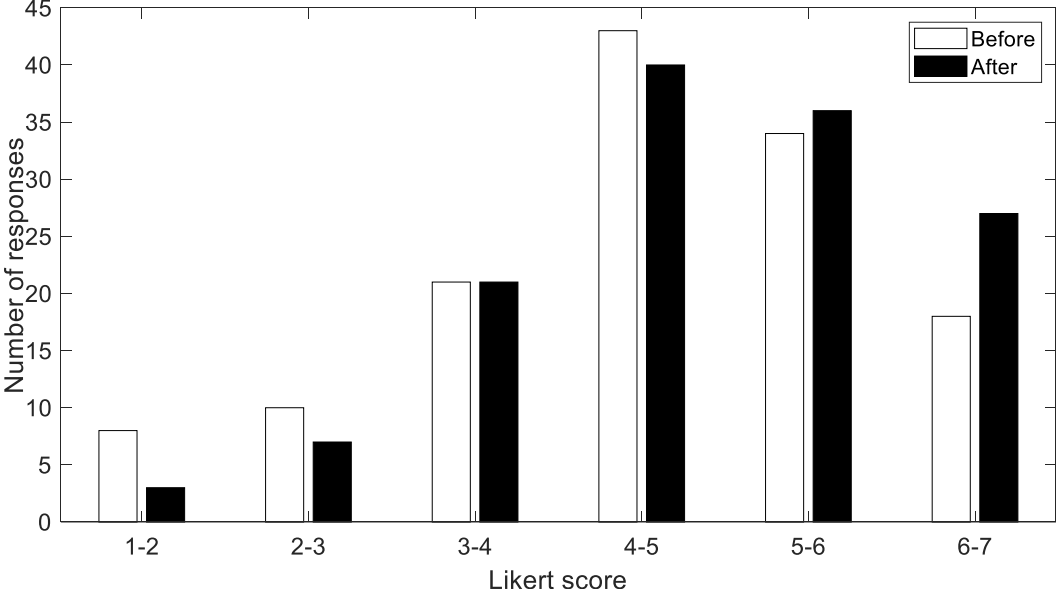
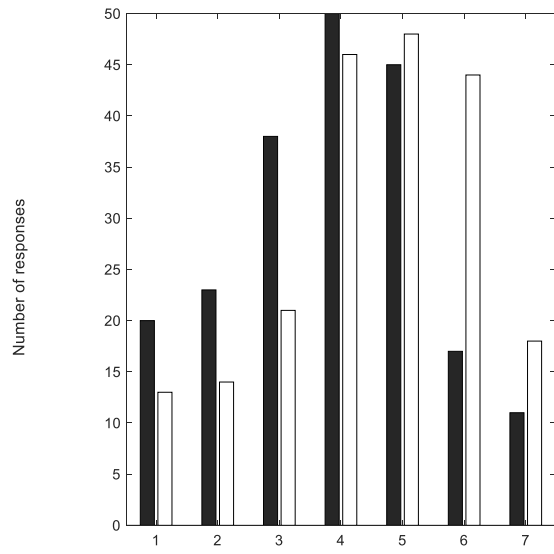
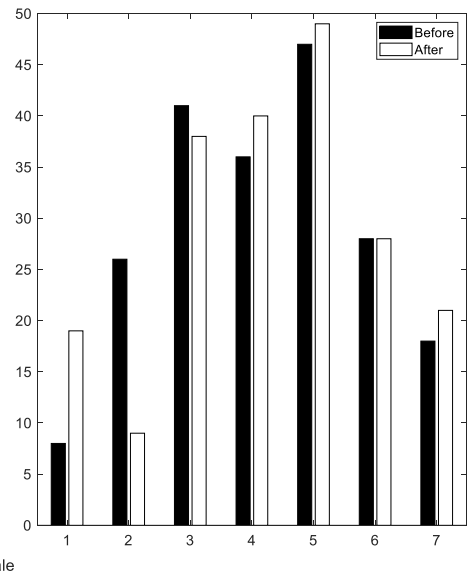


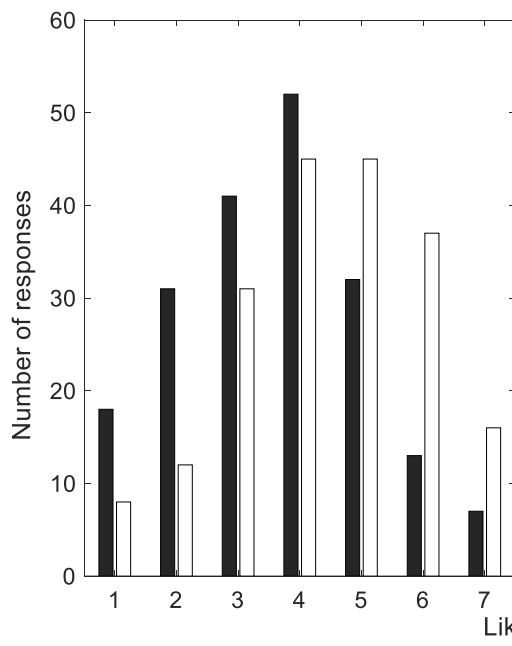
Figure 2



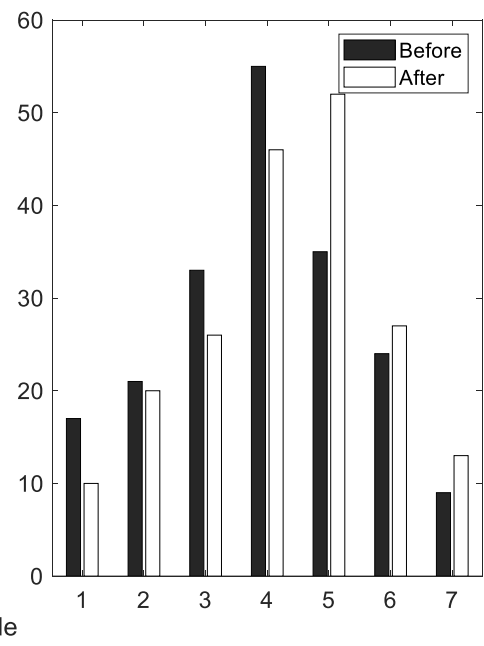
a



b

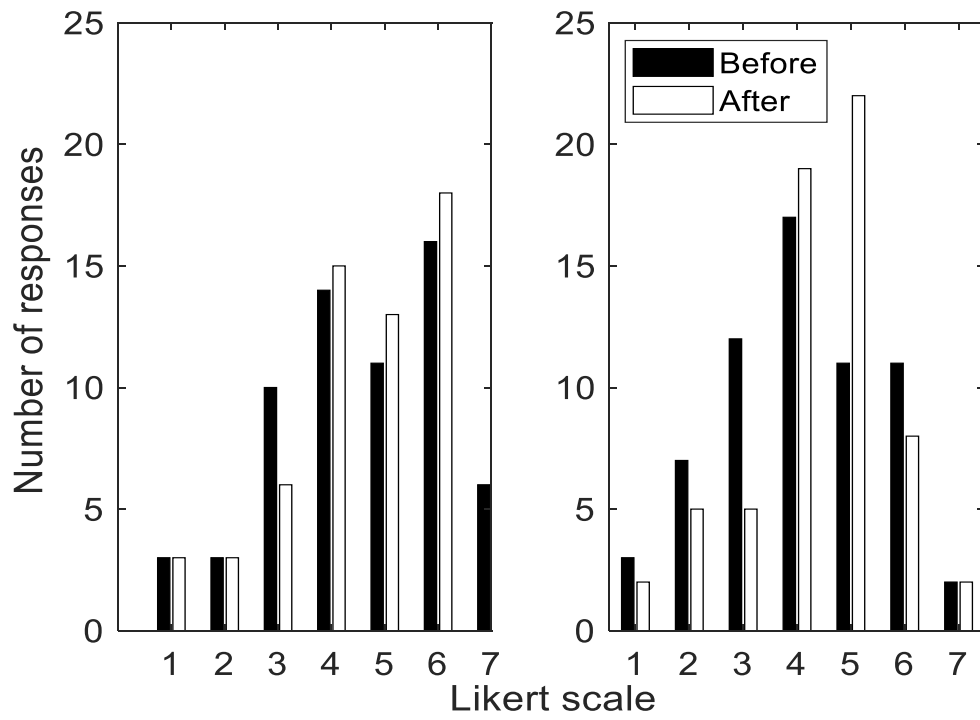


c



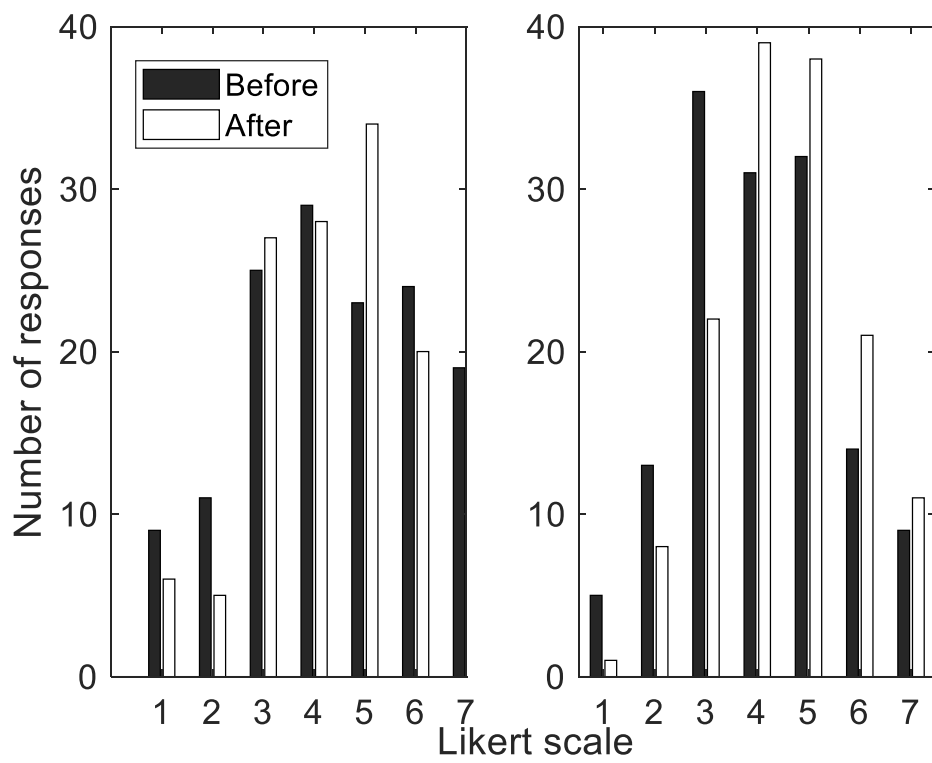
d

Figure 3



a

b



c

d