Journal of
Zoological and Botanical Gardens

MDPI

Article

Science Education in Primary Students in Ireland: Examining the Use of Zoological Specimens for Learning

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Abstract: The COVID-19 pandemic forced many educators out of their traditional settings and into web-based learning environments. Zoos were no different, and throughout the pandemic they strived to reach their supporters using different approaches. By adapting quickly and using outreach activities and online learning, zoos continued to serve society through the pandemic. This study examined whether an in-person educational interaction with zoological specimens can enhance cognitive learning and increase primary-level students' attitudes towards animals and science. Additionally, attention was drawn to the effectiveness of online learning methods for young pupils. A total of 165 paired questionnaires from primary-level students in three schools were analysed. Findings indicate significant positive increases in attitude but not in learning achievements. Thus, zoological specimens can be utilised for enhancing scientific attitudes in primary-level students. The effect of a face-to-face lesson on learning compared with online methods was positive but the difference was not statistically significant. This, taken together with a significant positive effect of a face-to-face lesson on attitude improvements, is sufficient to determine the importance of a traditional learning environment for students of this educational level. Additionally, gender differences relating to scientific attitudes and understanding are not apparent at primary level but this may become more apparent at secondary level. This research may be used for further investigations into the relationship between age, gender, and scientific learning. It may also be used to support studies examining the effectiveness of zoo outreach programs in schools versus zoo visits.

Keywords: science; education; zoology; specimens; learning; attitude; STEM; online education; zoo

Citation: Byrne, K.; Collins, C.; Bolger, M.K.; Butler, F. Science Education in Primary Students in Ireland: Examining the Use of Zoological Specimens for Learning. *J. Zool. Bot. Gard.* **2023**, *4*, 507–526. https://doi.org/10.3390/jzbg4030037

Academic Editor: Kevin Cianfaglione

Received: 16 April 2023
Revised: 15 June 2023
Accepted: 27 June 2023
Published: 10 July 2023

1. Introduction

Science is key for human development, without which social injustice [1], deteriorating human health, and the environmentally damaging impacts of climate change prevail [2,3]. The younger generation will, therefore, suffer the outcome of an unsustainable and unjust future [1,4,5]. With increased dependency on modern technology equating with an increased dependency on scientifically competent individuals, it is of vital importance to encourage in children the attitudes, skills, and knowledge needed to develop scientific competence and solve global problems [1,5]. Effective science education at primary level is crucial to this objective, with interest in science typically established among children before entry to second-level educational institutions [6]. Now, more than ever, educators must employ strategies to encourage an interest in science in students. The introduction of the current primary school curriculum in Ireland in 1999 [7] required the teaching of science programs to all students at primary level. Original requirements of the 1971 curriculum required only the fifth and sixth classes (approximate ages 11–12) to study science as a subject [7]. However, low interest in science as a subject and as a career choice remains a concern in Ireland [6,8].

A 'swing from science' describes a general decline of career pursuits and interest in science, a common trend in European countries [9,10]. The Relevance of Science Education

(ROSE) project developed a method of measuring the attitudes of 15-year-old students towards science and technology in over 40 countries and found that more developed countries have a declining trend in interest in the study of science [10]. Despite a slightly above-average performance in science, Ireland is on the negative end of this scale [11]. With a lack of formal assessment for primary level science, difficulties arise in attaining similar evidence in younger students [12].

Declining sales of primary school science equipment [13] and a minimum of one-hour per week spent on the subject according to the unchanged suggested time allocation of the primary school curriculum [14] highlight a lack of prioritisation for science education at this level. Additionally, a scientific background is not a requirement in Initial Teacher Education (ITE) programs, despite quality of teaching being the major determinant of scientific interest [6]. A 1997 study identified a lack of confidence in Scottish teachers in their knowledge of science [15]. For example, the study found that teachers rely heavily on textbooks with step-by-step instructions, underplay student questions and discussion, and generally avoid teaching science [15]. UK inspector reports indicate that science is not taught every day, and often atypical science lessons are organised and delivered only when schools are given advanced warning of a science survey visit [16].

To promote a long-lasting interest and enjoyment in science among students in Ireland, the current curriculum highlights the importance of activities for learning [17]. Conventional activities for teaching science involve 'design and making' for practical problem solving, for example the creation of a rain gauge using classroom and household materials to reinforce a lesson on weather [17]. Many school children, particularly in urban areas, have limited interaction with nature and animals despite a connection to nature being important for personal well-being and development [18,19]. Therefore, teachers often organise visits to outdoor learning centres such as zoos to promote scientific interest in pupils or arrange to have an onsite visit from a zoo [20,21].

Research shows that the majority of zoos worldwide report education as their highest priority [22]. In 2011, a large-scale study conducted on 7–15-year-olds found a significant increase in scientific knowledge about animals from pre- to post-zoo visit and determined that an educational presentation significantly increased conservation understanding compared to self-guided visits [23]. Many schools continue to use self-guided visits with teachers who may not be knowledgeable about science [24]. A 2020 study also indicated positive differences in knowledge and attitude, particularly among those who received an educational intervention to maximise their zoo experience [25]. Thus, interactions with individuals such as zoo staff, museum guides, or general educators from outside a student's social group (i.e., the classroom setting) positively influence learning [25]. An educational interaction with zoo staff has also been shown to positively impact students learning when this interaction occurs within the classroom, with the multi-visit in-school zoo outreach program offered by Chester Zoo significantly improving conservation-related knowledge and attitudes in students aged 7–11 [21].

While visiting live animals at zoos is an effective learning tool, successful education can be achieved through employing the use of inanimate artefacts. A 2013 study presented young children with live animals and physically similar toy versions of these animals in a play session [26]. The authors found that children had increased interactions with live animals, discussed them more, and asked more questions about them [26]. In the same study, parents directed the attention of their children towards the live animals more frequently, highlighting an attraction to live animals versus artefacts.

Despite this affinity for animals among humans, live and preserved specimens have been considered equally effective instruments for promoting both short- and long-term cognitive learning [27]. Studies have shown that people consider dry, preserved animals as significant tools for education as they are more suited to physical examination, and intimate, up-close inspection of details that would not be possible if the animal was alive [28,29]. Small exhibitions or 'touch tables' presented by zoo staff have proven successful in promoting the long-term biological and ecological understanding of visitors after their zoo visit [30]. The learning achieved through zoo visits and touch tables can be argued to fall within the 'living things' and the 'environmental awareness' strands of the Irish primary school science curriculum, which include topics on plants, animals, and environmental awareness [7].

Education studies regarding online versus face-to-face learning are increasingly important following the COVID-19 pandemic, where students of all ages were forced to participate in web-based learning. Multiple reports found no significant difference between online versus face-to-face learning in relation to assessment and grades [31–33] and some even indicate better learning outcomes for online learning [34,35]. Summers et al. [33] reported no significant difference in grades between online and face-to-face learning but found that online participants were significantly less satisfied with the online course. More recently, in 2018, Soffer and Nachmias [35] examined effectiveness of three online courses versus three face-to-face courses with the same format, content and educator, to find higher engagement with course material and satisfaction during online courses. Results were obtained through the utilisation of several variables, including grades, engagement, satisfaction, and completion rate, to suggest that online courses are equally as, if not more, effective than face-to-face courses. A novel approach in 2014 showed that mobile phone-based learning using WhatsApp had a positive impact on student test results, with reports that instant messaging made learning easier, improved problem solving, and reduced learning difficulties due to the social aspect of sharing content and knowledge [36].

Contrary to this, multiple studies [31,34] show slight but not significant improvements, and it is difficult to determine a definite answer as to which teaching method is better from these mixed results. Additionally, online learning introduces many barriers to education including financial constraints regarding program and equipment costs [37], slow internet connection, and eye strain [38]. Research in this area is also heavily populated by higher education studies and, in our current world where students were recently forced to adapt to web-based distance education due to COVID-19, it is important to better understand the effects of different approaches to learning on our younger students. This is particularly important as by the age of 14, a student's level of interest in science is largely formed [6].

The aim of the current research is to understand if an informative educational interaction with zoological specimens enhances cognitive learning or promotes science-positive attitudes in primary level students. This study presented an opportunity for primary level students to participate in three novel approaches to learning a scientific topic, in this case animal dentition and skull adaptations for feeding. Through direct comparison of these three approaches to learning, including a traditional face-to-face seminar and two methods of online learning via both video conference and web-based technologies, this study also considered the effectiveness of online learning for younger students undertaking their education in a world impacted by COVID-19 (SARS-CoV-2).

2. Materials and Methods

2.1. Site and Study Group

The research took place in County Cork and County Wexford, Ireland, between November and December 2020. Schools with at least two 5th class (year 7) groups, or two 6th class (year 8) groups were asked to participate in this research. These class years correspond with the approximate ages of 10–12 in Ireland. These ages were chosen with consideration of upcoming educational changes for students. Typically, Irish students begin second-level education after year 8 at age 12–13, where they can partially choose their own school subjects based on their own interests. Each of three participating schools was of mixed gender and class size ranged from 20–25 pupils. This yielded a sample size of 184 students from eight classes across three individual primary schools, identified as schools 1, 2, and 3 based on the order in which they agreed to participate.

2.2. Procedure

Pre- and post-educational intervention questionnaires were distributed to schools to analyse differences in students' attitudes and learning. Schools were chosen using personal contacts. The school principal was contacted in order to obtain permission and establish contact with the class teacher. Once a school agreed to take part, one class in each year was randomly allocated lesson-type 1 or 3 (hereafter referred to as an 'in-person' or 'video' lesson, respectively), while the other was allocated lesson-type 2 (hereafter referred to as a 'web-based' lesson) in order to continuously compare a primarily theoretical lesson with a lesson involving specimens (Table 1 and Figure 1).

Table 1. Description of each method of teaching or 'lesson-type' delivered to participating students and the number of individual students who participated in each.

Lesson-Type	Description	Participants
1: In-person	Examples of carnivore, herbivore and omnivore skull specimens were brought into schools by an external educator and displayed for students to see. Students were given the opportunity to see these specimens up close as animal dentition and skull adaptations for feeding were explained via a 'face-to-face' lesson. This lesson took approximately 1 h to complete, including student questions.	49
2: Web-based	Animal dentition and skull adaptations for feeding were explained using a specifically designed website. This included definitions and photographs of different types of teeth and the three varying skull examples. Students were guided through this website by an external educator. The lesson took approximately 1 h to complete, including student questions.	92
3: Video	Animal dentition and skull adaptations for feeding were explained using examples of carnivore, herbivore and omnivore skull specimens, shown virtually via video call. This lesson was guided by an external educator, and took approximately one hour to complete, including student questions.	42

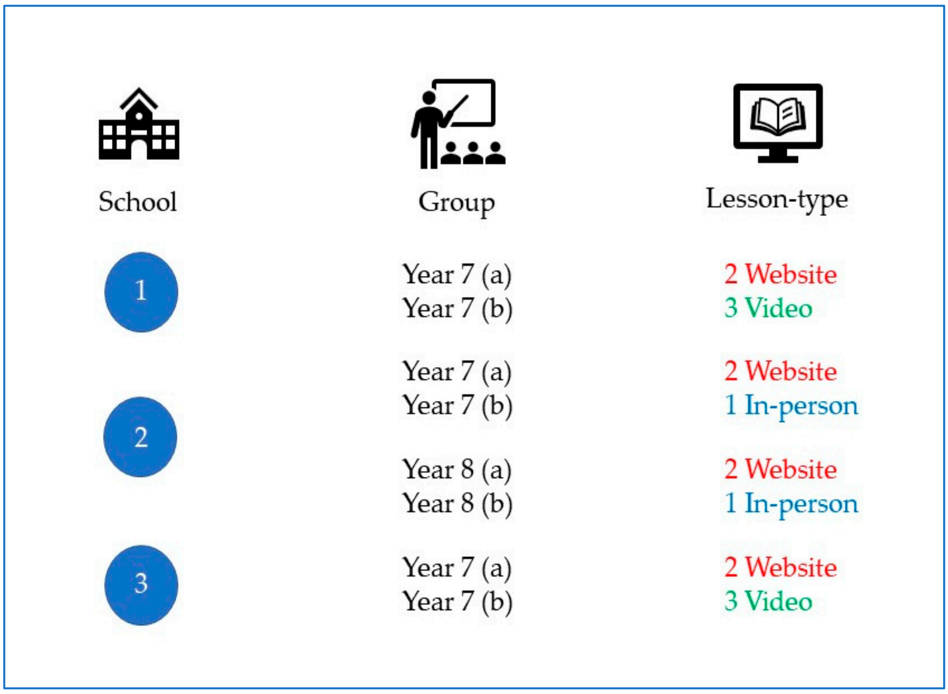


Figure 1. A diagrammatic presentation of the sampling outline. Three different schools, eight year groups, and three differing lesson-types were sampled.

With COVID-19 restrictions in place, options for in-person school visits were limited. Thus, the allocation of an in-person lesson was initially decided based on schools whose policies allowed external visitors, before being randomly allocated to one of two 5th class or 6th class groups within this school. In each year group, one class would always participate in a web-based lesson, while the alternate class in that year would participate in either an in-person or video lesson (Figure 1). Hence, the natural division of year groups allowed direct comparisons to be drawn between similar demographic groups experiencing either a structurally theoretical web-based lesson, or one where they could see tangible (in-person) or virtual (video) examples of specimens to study the same topic (Table 1). Each lesson-type was delivered by the same external educator. In all cases, students were given time to ask as many questions as they wished, which were answered during the lesson, and each class group was sent a follow-up document outlining all of their questions accompanied by written responses. Students and teachers had no knowledge of the contents of the questionnaire prior to the study. After completing the pre-questionnaire, each lesson-type was delivered within two to three days, followed by the post-questionnaire, which, in all cases, was taken within one to two days after lesson delivery. Thus, each step of the study (pre-questionnaire, lesson, and post-questionnaire) was completed within one week for each school.

2.3. Questionnaire

Participating teachers were asked to allocate a 'student number' to each of their students to allow for anonymity. The questionnaire began with basic demographic questions relating to year (7 or 8) and gender (male or female). Student number, age, and gender information was used to develop a 'case number' for each participant. Following this, the questionnaire was arranged in two sections to explore: (1) attitude and (2) knowledge. A multiple-methods approach was employed which included Likert scales, open-ended questions, and selected response questions. To allow for direct comparison, identical questionnaires were distributed to each of the three treatment groups. Additionally, post-questionnaires and pre-questionnaires were identical. See Appendix A for the complete questionnaire.

The first section of the questionnaire examined students' attitudes towards science as a subject and learning about animals. Students were asked to name their favourite school subjects [25], which were subsequently categorized into 'STEM'—an abbreviation commonly used to group subjects related to science, technology, engineering, and maths—'arts', and 'other' (Table 2). Students were asked to only choose one subject. 'STEM' subject answers were given a high score of three, 'arts' subjects were given a score of two, and 'other' subjects were given a score of one as these were considered least similar to any STEM subject. Next, pupils were asked to rate their level of enjoyment from learning about both science and animals in two 3-point Likert scale questions. These included the response options; Agree, Unsure, or Disagree. A 3-point scale was adopted over the typical 5-point Likert scale to present straight-forward options to students and minimise confusion. Scaled responses allowed for changes in attitude to be observed between the pre-questionnaire and post-questionnaire [23], regardless of whether treatments encouraged positive or negative changes. A high score of three corresponded with a science-positive statement (Agree), while a low score of one corresponded with a negative statement (Disagree).

Section two examined knowledge of animal dentition and ability to classify animal skulls as either carnivorous, herbivorous, or omnivorous. Two question-types were employed in this section. First, 'match-up' questions were presented, where one of three or four options corresponded to a correct answer. Students were asked to draw a line to match-up options A, B, C or D with what they believed to be the correct answer. Correct match-ups were given a score of two, incorrect match-ups were scored one, and 'no-attempts' were scored zero. Multiple choice questions (MCQ) were also presented, where response options included one correct answer, two incorrect answers and a 'don't know' option. Correct answers were given a score of two, incorrect answers were scored one, and 'don't know' answers were scored zero. Incorrect answers and 'don't know' answers were scored differently to allow for recognition of cases where students may not have known an answer in the pre-questionnaire but felt comfortable enough to take a guess in the post-questionnaire even if this resulted in an incorrect answer. If a question was not answered it was scored zero, similar to a 'don't know' response.

Table 2. Subjects placed under each subject category, and the number of times each individual subject was listed as a student's 'favourite' subject in the pre-questionnaire.

Category	Subjects	Number of Times Each Subject Was Chosen (Pre-Questionnaire)
S.T.E.M	Science	2
	Maths	16
Arts	English	3
	Irish	4
	History	22
	Geography	2
	Music	4
	Art	32
	Drama	8
Other	P.E	72

Since the aim of this study was to examine the differences in attitude and knowledge regarding science and animals before and after three varying lesson types, questionnaires that did not have a matched pair were excluded for data analysis. In total, 165 matched-pair questionnaires were analysed.

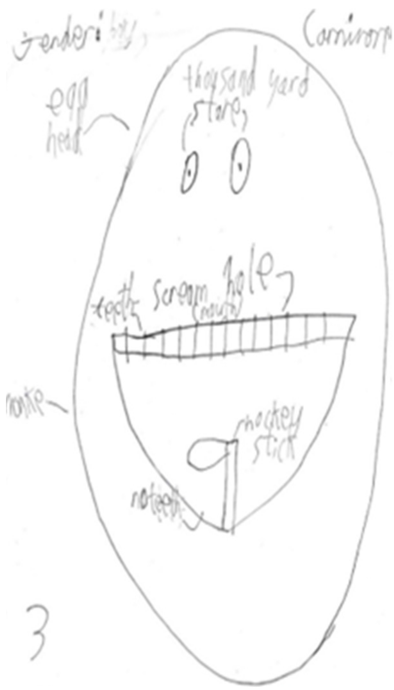
2.4. Educational Intervention

Each lesson type included an introduction to dentition and descriptions of the function of different types of teeth (canines, incisors, molars and premolars). The lesson highlighted to students that a canine tooth is generally sharp and pointed for gripping and tearing food; an incisor is strong, flat, and sharp for biting; a molar is strong and flat for grinding and chewing food; and a premolar is similarly flat for crushing and grinding food. The educational intervention also included introductions to the specific diets of carnivores, herbivores, and omnivores, who primarily eat meat, plants, and a combination of both, respectively. Students were given an explanation of the specific dental and skull feeding adaptations of carnivores, herbivores, and omnivores, and examples were provided for each type of animal so that students could recognise the form and relate it to the function. Dentition and the skeletal system of the skull can be categorised in the 'Living things' and 'Environmental awareness' strands of the science curriculum in Ireland [7]. Studying these systems can help students learn about adaptations for feeding habits in relation to both themselves and other animals, and initiate an awareness of interactions between animals and the environment. For in-person and video lessons, where students were shown physical examples of each skull type, a lion skull (*Panthera leo*) was shown as a carnivore example, a sheep skull (*Ovis aries*) was shown as a herbivore example and a pig skull (*Sus scrofa domesticus*) was shown as an example of an omnivore. In each case, students were also encouraged to examine their own teeth as omnivorous examples.

Studies on informal learning should not rely exclusively on self-reporting measures associated with surveys or questionnaires [24]. Thus, directly after each lesson, students participated in a short session during which they drew a known or imaginary animal or character with their mouth open to show their teeth. Students were asked to choose between a carnivore, herbivore, or omnivore and to give this animal/character the corresponding teeth they would require for their specific diet type. After the figure was drawn, students had the opportunity to play a game with their peers, who guessed what diet type each animal/character had, based on the dentition the student had drawn. After their peers had guessed, students revealed and described what type of animal they had drawn, what kinds of teeth they had drawn and for what reason. These details were then labelled for grading. Drawing tasks can provide a medium of expression that is accessible to all students regardless of their linguistic abilities [23,24].

Since the grading of drawings is relatively subjective, a random sample (n = 25) of drawings was selected and marked by a second trained coder to maintain coder reliability [39]. To quantify whether students' drawings were indicative or non-indicative of learning in this study, strict guideline criteria were developed (Table 3).

Table 3. Criteria for classifying drawings as either indicative or non-indicative of learning.

Criteria	Indicative of Learning	Non-Indicative of Learning
1.	Clear title/classification of animal type (carnivore, omnivore, or herbivore)	May not include a title, labels, descriptions, or a combination of the three.
2.	At least two indications of features corresponding to title/classification, including: (a) Tooth morphology (e.g., a clear attempt at drawings sharp teeth for a drawing classified as a carnivore, flat molars and premolars or a diastema for a drawing classified as an herbivore). (b) Labels (e.g., the label 'incisors' correctly pointing to the teeth at the forefront of the mouth) (c) Descriptions (an explanation of each label where possible, e.g., incisors are important for clipping vegetation in herbivores, molars are for grinding).	May include a single label such as 'molar', or a single tooth description such as 'grinding' but no corresponding information to indicate understanding.
3.	Where there is no clear classification of animal type, drawings may also be considered indicative of learning where clear understanding of types of teeth are highlighted, e.g., position of tooth correctly corresponding to labels and descriptions.	May not clearly show dentition at all.
Examples	Case number 130351  Clearly titled 'carnivore' with correctly identified corresponding features, including: correct labelling and positioning of all four teeth types. Clear indication of sharp teeth and enlarged canines, though descriptions are not provided to further show understanding of each feature.	Case number 220362  Labelled 'carnivore' though no corresponding features are indicated. Teeth are uniformly flat and not labelled individually. Irrelevant labels such as 'hockey stick' and 'scream hole' are included in place of correct labels and descriptions.

2.5. Data Analysis

Data were tested for normality by visually inspecting histograms and quantile-quantile plots. Where data were found to be non-normal, non-parametric statistics were used unless otherwise stated. Data analysis was conducted using SPSS version 22 and the accepted alpha level for these analyses was $p < 0.05$.

In the first section, descriptive statistics were used and the results for individual questionnaire items are represented in Tables 4 and 5. Next, the total knowledge and total attitude scores were calculated for each section by adding the results of the individual questions. The Wilcoxon signed ranks test was used to test for differences between total pre- and post-test scores for the knowledge and attitude sections. Then, following Collins et al. [25], to test the impact of the education program on students' learning, separate linear regression models were used for the knowledge and attitude scores. The difference in total score (between pre- and post-test) for each section was the independent variable, which was tested against three explanatory variables (school, gender, and treatment type) with treatment type and gender included as an interaction term. First, a model with all variables included was fitted to the data and then a backwards stepwise approach was used to remove non-significant variables with the largest p-values from the model. All assumptions of the test were met and a histogram of residuals was plotted, residuals were plotted against the fitted values, and linearity of models was checked.

Table 4. Mean pre- and post-survey results * for each individual question of Section 1 (attitudes), presented by lesson-type.

	Lesson-Type 1 (In-Person)		**Lesson-Type 2 (Website)**		**Lesson-Type 3 (Video)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Question 1 **'What is your favourite subject in school?'** [3 = S.T.E.M subject (positive response), 2 = Arts subject, 1 = Other (negative response)]	1.86 **(62.0%)**	2.05 **(68.3%)**	1.68 **(56.0%)**	1.71 **(57.0%)**	1.48 **(49.3%)**	1.48 **(49.3%)**
Question 2 **'I enjoy learning about science.'** Agree/Unsure/Disagree	2.67 **(89.0%)**	2.88 **(96.0%)**	2.50 **(83.3%)**	2.63 **(87.6%)**	2.48 **(82.6%)**	2.62 **(87.3%)**
Question 3 **'I enjoy learning about animals.'** Agree/Unsure/Disagree	2.54 **(84.6%)**	2.93 **(97.6%)**	2.85 **(95.0%)**	2.83 **(94.3%)**	2.88 **(96.0%)**	2.86 **(95.3%)**

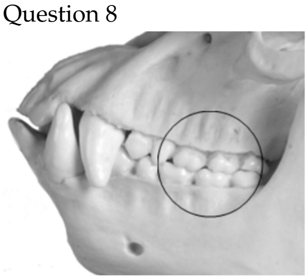
* Answers are shown in **bold** as a % out of 100 (100% = 3). As this section sought to understand students' attitudes towards science, there are no correct or incorrect answers, and higher percentages simply indicate more science-positive answers.

Finally, Chi-square tests were used to investigate the association between lesson-type and learning achievements as assessed by students' drawings.

Table 5. Mean pre- and post-survey results * for each individual question of Section 2 (knowledge), presented by lesson-type.

Question	**Lesson-Type 1 (In-Person)**		**Lesson-Type 2 (Website)**		**Lesson-Type 3 (Video)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Question 4 **'Please draw a line to connect the type of animal to what food source you think they eat. If you do not know, you can take a guess.'** [Highest score = 6 (positive, 100%), 2 points for each correct answer in three sub-questions]	5.79 **(96.5%)**	5.76 **(96.0%)**	5.18 **(86.3%)**	5.49 **(91.5%)**	5.54 **(92.3%)**	5.76 **(96.0%)**

Table 5. *Cont.*

Question	**Lesson-Type 1 (In-Person)**		**Lesson-Type 2 (Website)**		**Lesson-Type 3 (Video)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Question 5  **'This animal is a __________.** Carnivore/Omnivore/Herbivore/Don't know' [Correct answer = 2 (100%), incorrect = 1, don't know/unanswered = 0]	1.50 **(75.0%)**	1.98 **(99.0%)**	1.18 **(59.0%)**	1.84 **(92.0%)**	1.39 **(69.5%)**	1.78 **(89.0%)**
Question 6  **'This animal is a __________.'** Carnivore/Omnivore/Herbivore/Don't know' [Correct answer = 2 (100%), incorrect = 1, don't know/unanswered = 0]	1.40 **(70.0%)**	1.83 **(91.5%)**	1.06 **(53.0%)**	1.68 **(84.0%)**	1.07 **(53.5%)**	1.76 **(88.0%)**
Question 7 **'Please draw a line to connect the photo of each tooth to the correct name. If you do not know, you can take a guess.'** [Highest score = 8 (positive, 100%), 2 points for each correct answer in four sub-questions]	5.48 **(68.5%)**	6.38 **(79.8%)**	5.09 **(63.6%)**	5.77 **(72.1%)**	5.41 **(67.6%)**	5.58 **(69.8%)**
Question 8  **'The teeth circled are most important for __________ food.'** Biting/Grinding/Shredding/Don't know [Correct answer = 2 (100%), incorrect = 1, don't know/unanswered = 0]	1.48 **(74.0%)**	1.79 **(89.5%)**	1.18 **(59.0%)**	1.48 **(74.0%)**	1.37 **(68.5%)**	1.66 **(83.0%)**

* Answers are shown in **bold** as a % out of 100.

3. Results

3.1. Attitude

Prior to lesson participation, STEM subjects were found to be the least preferred among all three lesson-types (Table 4), with only 10.9% (n = 18) of students stating either science or maths as their favourite subject.

In-person and website participants showed positive changes in their answer to Question 1: "what is your favourite subject in school" from pre- to post- questionnaire. For video participants, there was no mean change in score from pre- to post-questionnaire, with students showing neither less nor more interest in STEM subjects. Mean changes in response to Question 2 were positive for all three lesson-types, with students stating they enjoyed learning about science more after their respective educational interventions. For in-person participants, there was an increase in the number of students who enjoyed learning about animals (question 3) after their educational intervention. For website and video participants, there was a slight decrease in positive answers to question 3, showing a decreased enjoyment in learning about animals post-intervention.

A total mean attitude score of 0.78 was recorded among students based on pre-intervention questionnaires, with a total mean attitude score of 0.81 recorded based on post-intervention questionnaires. The Wilcoxon signed ranks test revealed a significant difference between total pre and post-test scores for attitude ($Z = -4.104$; $p < 0.001$).

For differences in attitude between pre- and post-test scores, model selection resulted in a final model with lesson-type as the only remaining explanatory variable, which was statistically significant ($F = 8.968$; $p < 0.001$). Students who participated in an in-person lesson with an up-close interaction with zoological specimens were the most likely to have an increase in their attitude score, with a 0.79 (8.7%) increase from pre- to post-test (Figure 2).

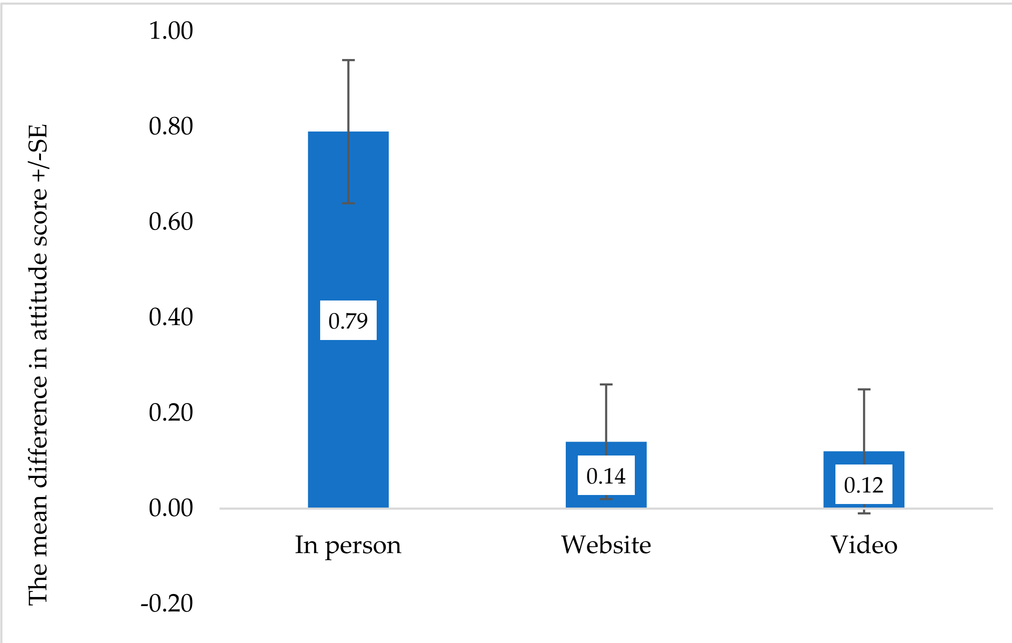


Figure 2. The mean (+/− SE) difference in attitude scores between pre- and post-test among students who received different types of lessons a) in-person b) website and c) video. [0.79 = 8.7% difference, 0.14 = 1.5% difference, 0.12 = 1.3% difference].

3.2. Knowledge

Knowledge attainment was seen to generally increase after each lesson-type, with the exception of answers to Question 4 in in-person participants, as indicated by the increased mean scores for each question from pre- to post-questionnaire (Table 5).

A total mean knowledge score of 0.72 was recorded among students based on pre-intervention questionnaires, with a total mean knowledge score of 0.84 recorded based on post-intervention questionnaires. Post-intervention scores were significantly higher (Wilcoxon signed ranks $Z = -7.687$; $p < 0.001$).

The impact of three explanatory variables (school, gender, and treatment type) on the difference in knowledge scores between pre- and post-test, was assessed. Model selection resulted in a final model with gender as the only remaining explanatory variable, which was statistically significant (F = 45.616; $p < 0.001$) Girls were more likely than boys to have an increase in their knowledge score from pre- to post-test (Figure 3).

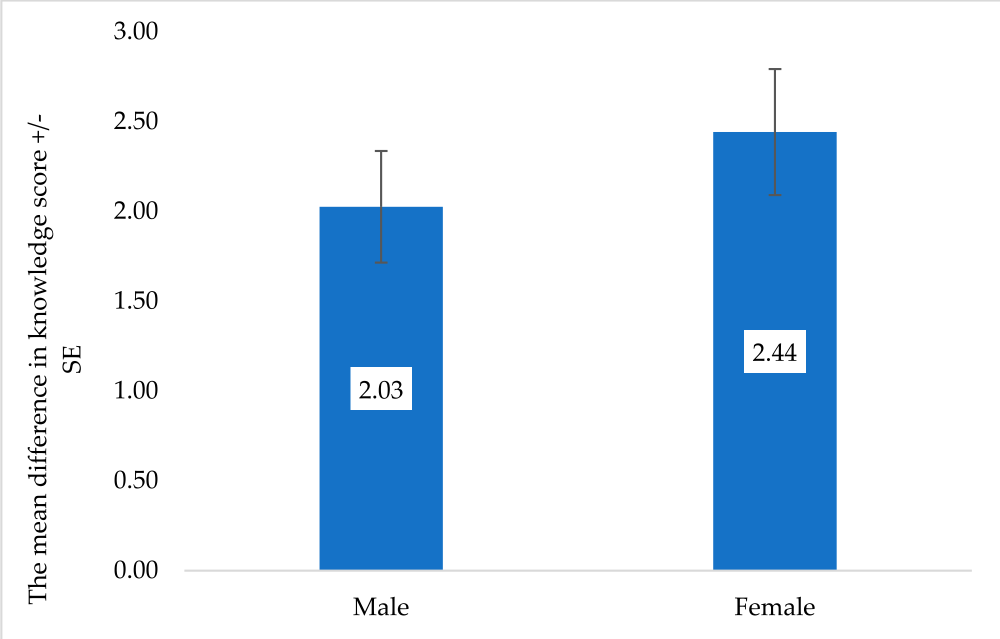


Figure 3. The mean (+/− SE) difference in male and female knowledge scores between pre- and post-test. [2.03 = 10.15% difference, 2.44 = 12.2% difference].

4. Discussion

Until now, little attention has been paid to how online learning may impact primary-level students. This study examined how teaching children online during a pandemic compares to teaching in the standard classroom environment, in terms of both attitude and knowledge. Additionally, this study highlighted how an interaction with zoological specimens facilitated by an external educator can enhance primary-level students' attitudes towards animals and science. While this study found a non-significant relationship between the zoo-specimen themed seminar and learning improvements, differences in learning achievements were explained by gender, which is consistent across multiple studies [40–42].

This study discovered an initial low ranking of science among students' favourite subjects (Table 2), with only 1.2% ($n = 2$) of students preferring this subject over any other, highlighting the 'swing from science' trend. This result may be a consequence of curriculum time allocations, as repeated exposure is beneficial for the development of learning and interests in children [43,44], and a reduced time receiving instruction can result in reduced learning engagement [45]. The Primary School Curriculum [14] suggests a time framework for each subject to aid teachers and schools in the balanced planning and implementation of the curriculum. However, primary level science constitutes only one of three components of the generalised subject 'Social, Environmental and Scientific Education' (SESE), which includes History and Geography. While the suggested weekly time framework for SESE may be three hours for full day students (years 3–8), it is not unusual that in a school week consisting of 28 h and 20 min [46], only one hour might be spent on scientific education [7]. While the goal of the primary level science curriculum in Ireland is to promote positive attitudes towards science and foster an appreciation of the relevance of science and its contributions to society [14], it is questionable as to how this can be successfully achieved with so little time allocated to the subject.

In this study, physical education (P.E.) was recorded as a students' favourite subject a multiple of 36 times more than science, highlighting a considerable difference between classroom attitudes towards these subjects. Anecdotally, it has been reported that having a class in P.E, as well as other activity-based subjects such as art and music, which are also ranked at a higher preference than science, is often presented to students as a fun reward for good behaviour in the classroom. This has also been reported in the United States [47,48]. This may enforce the idea that P.E is a 'fun' subject that is to be looked forward to over others, which in turn may indirectly marginalise 'non-reward' subjects such as science. To prevent the marginalisation of science, scientific lessons may be structured and presented as activities to be enjoyed.

Students responded well to face-to-face learning and the opportunity to view authentic zoological specimens up-close. This idea is mirrored in the significant relationship between lesson-type and attitude, where in-person participants showed significantly greater attitude improvements. Only slight differences in attitude improvements were found between the two online learning formats, the web-based and video lessons (Figure 2), suggesting that, while interactions with educators outside of a students' social group might influence cognitive learning, as previously addressed, it does not influence attitudes in the same way, at least when these interactions are online-synchronous and not a face-to-face dynamic. However, website participants showed less enthusiasm than other groups when given an opportunity to ask questions and verbally engage at the end of the lesson (author's personal observation), a factor which is difficult to account for in statistical analysis.

Conversely, the result that lesson-type did not have a significant effect on knowledge indicates that there were no distinct differences between the three methods of lesson-delivery on learning achievements. If students can effectively learn a topic at home, online using web-based technologies, this could indicate the usefulness of employing more independent learning tools at this level for effective teaching. This could free up class resources and time, which in turn could have positive impacts for students' perceptions of subjects that previously may have not been a priority in classroom scheduling.

Despite a statistically non-significant effect of lesson-type on learning, results still indicate learning improvements in in-person participants for four out of five knowledge-testing questions (Table 5). This, coupled with significantly greater attitude changes among the same group of students, provides sufficient evidence to highlight the importance of (1) novel activities and (2) tangible interactions in the education of younger children.

First, many studies support the idea that student motivation, interest, and knowledge are enhanced through experiential learning via field trips [49], classroom play activities [50], and interactions with external educators. Second, traditional face-to-face education provides more opportunity for social interaction, which is a key factor for enhancing learning and perception and empowering learners [51–55]. Students have reported enjoying sitting next to friends in the classroom setting to share ideas about work, and they also enjoy seeing work displayed to gain ideas from their peers' work and attain a sense of pride of their own work being exhibited [56]. Additionally, the role of a teacher is very important in a young students' life, with positive teacher–child relationships positively linked to academic success [57,58] and student emotion [59]. Because traditional classroom environments and interactions play such a crucial role for younger students' learning and development, this could be why we see progressively more virtual learning occurring at higher educational levels, which was viewed first-hand in relation to the COVID-19 pandemic, when universities and other third-level institutions were the first to make the move to online learning and still had not returned to face-to-face learning procedures a year later. Early-level educational institutions, such as secondary schools and, more distinctively, primary schools, were prioritised in terms of a return to the physical classroom [personal observation].

Non-significant results for the effect of gender on attitude were surprising, considering the increased attention that is drawn to the gender divide in STEM [60,61]. Male children are more likely to have STEM career aspirations and be encouraged and supported in this area by their parents than female children [11,62]. However, the age of participants in the current study may be too young to definitively determine these gender differences, and indeed, previous studies have shown that science positive attitudes decrease with age [63,64]. Female responses to the ROSE study [10,65] are slightly more negative than males at age 15, so females may be more subject than males to decreasing attitudes towards science as they age. This supports the suggestion that the gender gap in scientific attitudes and understanding begins at secondary level.

Several studies confirm this idea with reports of greater scientific aspirations in adolescent males than females [11] and subsequent under representation of females in STEM careers [66] as well as greater confidence in adult males in their knowledge of science as analysed by self-report data [67]. This indicates that more attention should be paid to factors that influence gender divides at a young age, to prevent stereotype divisions. Moreover, females are known to perform better or have a greater interest in biology, and because this research examined a biological subject area, it is possible that different, and perhaps significant, gender results for attitude would have been obtained if the area examined was physics- or chemistry-related.

The overall findings of this study—that interacting with zoological specimens can enhance attitudes towards animals and science but not significantly affect cognitive learning achievements—are consistent with studies regarding live animals. Anderson et al. [68] evaluated the attitudes of zoo visitors after they viewed otter training sessions and found positive results in terms of visitors' attitudes and perceptions of training. They did not examine learning, instead suggesting that public training sessions might promote informal learning, however it has been reported that interactions with live animals do not promote learning any more than interactions with dried specimens [27]. Similar to this study, an investigation into the impact of a zoo visit on adult visitors' learning [69] reported a positive relationship with conservation attitudes, but no significant change in knowledge. The authors reported that a large volume of people had greater than expected knowledge of the topic prior to the zoo visit, which may explain the non-significant relationship between the zoo visit and knowledge improvements [6]. While these studies support the findings of the current study, results are drawn from the experience of adults, rather than young children.

The current research displayed similar limitations to those of the study by Falk et al. [69] in assessing knowledge. An analysis of pre-questionnaire responses to Q4 (Appendix A) highlighted that 126 (Approximately 76%) of the 165 participants achieved full marks prior to intervention (Appendix B.1). Additionally, all participating students attempted Q4 in both the pre- and post-questionnaires, while for every other question of the knowledge section, numerous 'no-attempts' were recorded (Appendix B.3). This suggests that a question pertaining to the primary dietary intake of a herbivore, carnivore, or omnivore might be too simple for children of approximately 10–12 years old. A total 16.3% of students achieved full marks in their answers to Q7 of the pre-questionnaire. In their answers to the same question on the post-questionnaire, still only 32% of students achieved full marks, highlighting that 68% of students could not completely distinguish between the four different tooth types, incisors, canines, molars, and premolars, even after intervention (Appendix B.1). Upon closer inspection of individual questionnaires, it appeared that most students struggling with this question confused molars and premolars, possibly because photos were used for this match-up question, and these teeth are visually similar.

Question 8 of the questionnaire revealed a 43% success rate for pre-questionnaires, which only increased to 66% for post-questionnaires (Appendix B.1). Again, reasons for this relatively small increase may be due to confusing imagery used in the questionnaire design. A large canine tooth in the specimen photograph provided for Q8 (Appendix A) may mislead students to believe this specimen was a carnivore and therefore, that the teeth circled in the question may be for 'shredding' rather than grinding food. If this study were to be repeated, questionnaire design issues such as this would be minimised where possible, with more careful choice of imagery. A further limitation of this research involved the inability to distinguish between legitimately correct answers and 'lucky' student guesses. This was an unavoidable issue; however, 'don't know' response answers were provided for suitable questions to eliminate guesses as much as possible.

5. Conclusions

Student engagement with zoological specimens in a face-to-face educational setting is an effective tool for enhancing primary students' attitudes towards science but does not significantly improve scientific knowledge. Traditional classrooms are more effective than online settings for the education of primary students. Finally, a science-related 'gender gap' is not apparent at primary level. These findings may be used as a basis for further investigations into the relationship between age, gender, and scientific achievements and attitudes. Furthermore, the methods used in this study (travelling to schools and delivering an educational seminar with the use of zoological artefacts) could be employed by zoos in an in-school outreach program to spark early interest in animals, the environment, and conservation. Further investigations based on this study may involve more schools so that greater confidence in the results can be achieved and may also include the distribution of questionnaires to teachers in the data collection stage in order to examine their backgrounds in science and the effects of this on their students' attitudes and learning.

Author Contributions: Conceptualization, K.B. and F.B.; methodology, K.B., F.B. and C.C.; software, K.B.; validation, K.B. and F.B.; formal analysis, K.B.; investigation, K.B.; resources, K.B., F.B., C.C. and M.K.B.; data curation, K.B.; writing—original draft preparation, K.B.; writing—review and editing, F.B., C.C., M.K.B.; visualization, K.B.; supervision, F.B.; project administration, K.B.; funding acquisition, not applicable. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was reviewed by the School of BEES Executive Management Committee of University College Cork.

Data Availability Statement: The data presented in this study can be requested from the corresponding author.

Acknowledgments: The School of Biological, Earth, and Environmental Sciences at University College Cork for the use of their zoological specimens. The staff of all the schools that participated in this study, for the opportunity to conduct this research, and for their assistance in the organisation of each lesson and video-call, and in particular all the students who enthusiastically participated in each lesson, for their invaluable contribution to this research, thought-provoking inputs, curiosity, and beautiful artworks.

Conflicts of Interest: The authors declare no conflict of interest.

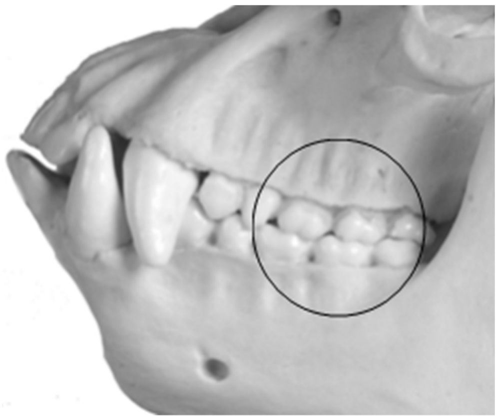
Appendix A. The Questionnaire Administered to All Students

Student number: ________________	**Gender** (please circle):	Girl	Boy
What class are you in? Please circle your answer.			
5th	6th		
	Section 1.		
1. **What is your favourite subject in school?** ________________			
	***		
Please read each sentence and circle the answer that relates to you.			
2. **I enjoy learning about science.**			
Agree	Unsure	Disagree	

3. **I enjoy learning about animals.**			
Agree	Unsure	Disagree	
Section 2.			
4. **Please draw a line to connect the type of animal to what food source you think they eat. If you do not know, you can take a guess.**			
Animal:			Food source:
a. HERBIVORE			MEAT
b. OMNIVORE			MEAT AND PLANTS
c. CARNIVORE			PLANTS
For the next twoquestions, please circle the answer you think is correct. If you are unsure or do not know what any option means, please circle 'don't know'.			
5. 			
This animal is a _____________.			
Carnivore	Omnivore	Herbivore	Don't know
6. 			
This animal is a ____________.			
Carnivore	Omnivore	Herbivore	Don't know

7.	**Pleasedraw a line to connect the photo of each tooth to the correct name. If you do not know, you can take a guess**	
	Photo:	**Name of Tooth:**
a.		MOLAR
b.		INCISOR
c.		CANINE

8. **Please circle the answer you think is correct. If you are unsure or do not know what any option means, please circle ‘don’t know’.**



The teethcircledare most important for ____________ food.

Biting	Grinding	Shredding	Don’t know

😊 **THANK YOU** 😊

Appendix B. Additional Findings

Appendix B.1

Table A1. A comparison of % of students who answered each question correctly or achieved full marks in match-up questions, in the knowledge section of pre- and post-questionnaires.

Question	Pre-Questionnaire		Post-Questionnaire		Difference
	Number of students who answered correctly (or scored full marks, in terms of Q5 AND Q8)	% out of overall number of participants (165)	Number of students who answered correctly (or scored full marks, in terms of Q5 AND Q8)	% out of overall number of participants (165)	Difference in number of students answering correctly/scoring full marks from pre- to post-questionnaire (%)
Q4	126	76.4%	140	84.8%	+14 (+8.5%)
Q5	91	55.2%	146	88.5%	+55 (+33.3%)
Q6	77	46.7%	130	78.8%	+53 (+32.1%)
Q7	27	16.4%	52	31.5%	+25 (+15.2%)
Q8	71	43.0%	110	66.6%	+39 (+23.6%)

Appendix B.2

Table A2. A comparison of the number of students who, for each question, improved on their original score in the post-questionnaire, or showed a decrease in their original score.

Question	Number (% out of 165) of Students Who Showed *Increased* Knowledge Scores from Pre- to Post-Questionnaire	Number (% out of 165) of Students Who Showed *Decreased* Knowledge Scores from Pre- to Post-Questionnaire
Q4	25 (15.2%)	11 (7.0%)
Q5	66 (40.0%)	6 (3.6%)
Q6	76 (46%)	10 (6.1%)
Q7	73 (44.2%)	36 (21.8%)
Q8	61 (37.0%)	20 (12.1%)

Appendix B.3

Table A3. Students who did not attempt or chose 'don't know' in each question of the pre-questionnaire, and the number of students (%) of these who, in the post-questionnaire, made an attempt at each question, whether right or wrong. This shows how many students increased confidence in their ability to answer each question of the knowledge section of the questionnaire.

Question	Number (%) of Students Who Did Not Answer or Chose 'Don't Know' in Pre-Questionnaire.	Out of Those Students Who Did Not Answer or Chose Don't Know, the Number (%) who Attempted to Answer in the Post-Questionnaire.
Q4	0 (0.0%)	N/A
Q5	39 (23.6%)	37 (95.0%)
Q6	52 (31.5%)	47 (90.4%)
Q7	7 (4.2%)	5 (71.4%)
Q8	21 (12.7%)	16 (76.1%)

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