DIGITAL NATURAL HISTORY REPOSITORIES AND TOOLS FOR INQUIRY-BASED EDUCATION

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Abstract

The need for improving science education and literacy has been a central topic for the last decades in Europe and the term *Inquiry* has a persistent history in characterizing good science teaching and learning. Young children must learn skills related to inquiry, decision- making, and problem solving. Moreover, learning methods need to provide them with real experiences, which are meaningful to them. Five essential features of inquiry have been identified, regardless of grade level: (1) students are engaged with scientifically oriented questions; (2) students collect evidence in real contexts to answer questions; (3) students develop explanations based on evidence; (4) students evaluate their explanations and may include alternatives that reflect scientific understanding; and (5) students communicate and justify the proposed explanations.

A growing movement documents science education as more effective and meaningful to learners when Information and Communication Technologies are used, with a primary goal to help students develop the knowledge and skills necessary for dealing with real world scientific issues. As a result, new proposals of curricula are inquiry-based, involving new forms of technology and proposing the use of Learning Outside the Classroom (LOtC) institutions as a way of assuring the contact with real contexts. Natural history and science museums represent ideal LOtC institutions allowing students to explore on their own and interact with collection objects that add value to their classroom everyday experiences.

The educational pathways created within the Natural Europe project (http://www.natural-europe.eu/) integrate digital contents to help teachers and students to develop inquiry based activities using the National Museum of Natural History and Science exhibitions. These pathways were tested by teachers and their students from 10 to 14 years old and results suggest that such digital educational resources are effective in promoting knowledge and awareness about natural sciences contents.

Keywords: science education; inquiry; digital resources

Resumo

A promoção da literacia científica tem sido destacada no contexto europeu nas últimas décadas e o termo "Inquiry" corresponde atualmente a qualidade no ensino e aprendizagem da ciência. As metodologias de aprendizagem devem promover a experiência em contextos reais, próximos do quotidiano de crianças e adolescentes, de forma a permitir a aquisição de competências para a resolução de problemas. Assim, estão identificadas cinco características essenciais da metodologia de aprendizagem ativa das ciências: (1) a curiosidade dos alunos é desperta para promover a formulação de questões científicas; (2) os alunos recolhem evidências em contextos reais para responder às questões; (3) os alunos desenvolvem explicações baseadas nas evidências recolhidas; (4) os alunos avaliam as suas hipóteses explicativas e incluem alternativas que refletem a compreensão sobre o tema e (5) os alunos comunicam as suas teorias e justificam-nas.

A educação da ciência é hoje considerada mais efetiva quando utiliza as tecnologias de informação e comunicação. Como resultado, as propostas de currículo incluem atualmente metodologias ativas com utilização das novas tecnologias e sugerem a utilização de instituições de aprendizagem fora da sala de aula como forma de garantir o contacto com contextos reais. Os museus de história natural e de ciência são locais privilegiados, uma vez que permitem aos alunos uma interação direta com objetos das coleções e o desenvolvimento de um plano de investigação próprio, que aplica conteúdos aprendidos na sala de aula.

Os roteiros pedagógicos criados no âmbito do projeto Natural Europe integram conteúdos digitais que auxiliam professores e alunos no desenvolvimento de atividades para aprendizagem ativa, utilizando exposições do Museu Nacional de História Natural e da Ciência. Estes roteiros foram testados por professores e alunos dos 10 aos 14 anos e os resultados demonstram a importância destes recursos educativos digitais para a promoção da sensibilização e conhecimento sobre ciências naturais.

Palavras-chave: educação da ciência; metodologias ativas; recursos digitais

1. Introduction

In this United Nations decade for Education for Sustainable Development (ESD), the need for improving science education and literacy has been a central topic in Europe (Osborne & Dillon, 2008) and the term *Inquiry* has a persistent history in characterizing good science teaching and learning (Anderson, 2002). The inquiry-based science education (IBSE) is described through five essential features, regardless of grade level (Barrow, 2006): (1) students are engaged with scientifically oriented questions; (2) students collect evidence in real contexts to answer questions; (3) students develop explanations based on evidence; (4) students evaluate their explanations and may include alternatives that reflect scientific understanding; and (5) students communicate and justify the proposed explanations.

This teaching method must therefore provide children and teenagers with real experiences, which are meaningful to them in order to learn skills related to decision making and problem solving (Basile, 2010). The use of inquiry in science teaching engages the students and improves their understanding of both content and process by inspiring their personal involvement (Gano & Kinzler, 2011). As a result, this method proposes the use of Learning Outside the Classroom (LOtC) institutions as a way of assuring the contact with real contexts that may engage students in the creation of scientifically oriented questions and promote the gathering of evidences within an investigation plan. This direct connection with real objects that link to the everyday life may lead to changes in young people's environmental worldview, including the promotion of pro-environmental attitudes and beliefs (Boeve-de Pauw, Donche & Van Petegem, 2011).

On the other hand, science education has been documented as more effective when Information and Communication Technologies (ICT) are used with a primary goal to help students develop the knowledge and skills necessary for dealing with real world scientific issues. The model of using ICT to support school science assumes an important role in re-shaping the curriculum since it offers a vast range of internet resources that extend opportunities for empirical enquiry, both inside and outside the classroom (Osborne & Hennessy, 2003). Such an educational approach would seek to develop students' scientific reasoning, critical reflection and analytic skills, concurring with the IBSE method in promoting an investigation that incorporates the simultaneous learning about scientific theory and process. Moreover, ICT tools add value to science lessons by promoting the student learning benefits such as clearer understanding (Newton & Rogers, 2003), while the planning decisions made by the teacher about how to use the software are critical to secure those benefits (Hennessy et al., 2007).

As a result, new proposals of curricula are inquiry-based, involving new forms of technology and proposing the use of LOtC contexts. Natural History and Science Museums represent ideal LOtC institutions (Dillon et al., 2006; Larson, Castleberry & Green, 2010) allowing students to explore on their own and to interact with collection objects related to real contexts, developing their knowledge and skills in ways that add value to their classroom everyday experiences (Hofstein & Rosenfeld, 1996). It is therefore essential that such institutions may develop ICT tools aimed for the teachers, to support IBSE activities in their classes and provide them with high quality educational digital resources.

In addition, the process of critical inquiry is also identified as a central learning process of Education for Sustainable Development (ESD), while real environmental issues represent the main content (Dillon & Stevenson, 2010), a fact also shown for the Portuguese reality (Schmidt, Nave & Guerra, 2010). The National Museum of Natural History and Science (MNHNC) of the Lisbon University holds education for science and sustainability as one of its main missions and has a large experience in the development of projects for school communities and the general public, making use both of ICT and the IBSE method, including the investigation about their efficacy. The MNHNC is currently a partner of the *Natural Europe: Natural History & Environmental Cultural Heritage in European Digital Libraries for Education* project (CIP-ICT-PSP-250579, www.natural-europe.eu), which aims to develop digital libraries and to produce online educational pathways based on the Museum's exhibitions, including inquiry-based activities and its assessment.

The main goal of this project is therefore to investigate the influence of online inquiry-based experiences using digital collections in the learning of contents related to science and in the awareness about sustainable development, among students. In this context the teacher's evaluation of the pathways was considered, as well as the students' interest, knowledge about contents and ecological beliefs, taking into account the Theory of Planned Behaviour which establishes beliefs as predictors of attitudes, attitudes as predictors of intention and intention as a direct predictor of behaviour (Ajzen & Fishbein, 2000). Scientific knowledge is also shown to be an essential precursor of attitude formation towards ecological issues (Kaiser, Wolfing & Fuhrer, 1999), a fact taken into account in this United Nations Decade of ESD.

In light of the above, this paper aims to study the influence of inquiry-based digital pathways developed in the National Museum of Natural History and Science in the promotion of knowledge and interest about natural science contents, as well as awareness about nature conservation among students.

2. Objectives and Hypothesis

This study aims to test the effectiveness of using inquiry-based educational pathways about natural history exhibitions to promote knowledge and interest about natural sciences and awareness about nature conservation, considering ecological beliefs, among students from 10 to 14 years old.

In this context we expect:

(H_1) Higher levels of knowledge about the subjects explored in the pathways among classes involved in exploring them, when compared to the control classes.

(H_2) Higher levels of interest about the subjects explored in the pathways among classes involved in exploring them, when compared to the control classes.

(H_3) Higher levels of ecological beliefs among classes involved in exploring the pathways, when compared to the control classes.

The teacher's evaluation of the structure, contents and implementation of the inquiry-based pathways will also be considered.

3. Method

3.1 Participants

Data for the present study were collected within the scope of the Natural Europe project, taking place at the National Museum of Natural History and Science of Lisbon University. For this particular study, 205 students (100 male and 105 female) aged between 10 and 14 years (5th to 8th grade of the Portuguese school system), from 12 classes of six different schools in Lisbon, were invited to participate in the project aiming to raise the interest and knowledge about natural sciences and awareness about nature conservation.

3.2 Procedures

Students were divided as followed: Group 1 included six classes (110 students) tutored by five different teachers, which participated in activities at the Museum and at school, following the proposals of the inquiry-based educational pathways created for three different exhibitions: the Botanic Garden, the *Allosaurus: one dinosaur, two continents?* and the *Earth's Adventure* (http://education.natural-europe.eu/mnhn); Group 2, the control group, included six classes (95 students) tutored by 4 different teachers visiting the same exhibitions at the Museum but without any contact with the educational pathways.

The digital educational pathways propose activities for a pre-visit phase at school to provoke curiosity and engage for the creation of scientifically oriented questions; for a visit phase in the Museum to collect evidence in real contexts and develop possible hypothesis; and for a post-visit phase again at school to discuss and communicate conclusions and alternative explanations, according with the inquiry-based methodologies.

In the pathway *Botanic Garden: A tour through the world of plants* visitors can learn about plant adaptations and biodiversity conservation. In the *Allosaurus: one dinosaur, two continents?* pathway the visitor is invited to follow the steps of a research project about *Allosaurus fragilis* fossil discovery in Portugal and conclude about the possibility of a terrestrial fauna bridge between Euro-Asian and American continents 150 million years ago. In *The Earth's Adventure* pathway visitors can learn about the 4600 million years of the Earth's history and reflect about the human impact on the planet.

All students answered a questionnaire two weeks after the visit to the Museum (so the post-visit activities at school could be held) in order to assess their level of knowledge and interest regarding the subjects approached in each one of the pathways and also of ecological beliefs as indicators of their awareness about nature conservation.
The teachers who followed the pathways answered also a questionnaire about their structure, contents and implementation.

3.3 Variables

Knowledge. Four questions were included about the scientific contents of each one of the considered exhibitions and the students were asked to tick the correct answer over four different options. The results were transformed into a scale with five levels: 1- none of the four answers was correct; 2- only one correct answer; 3 – two correct answers; 4- three correct answers and 5- four correct answers.

Interest. Seven items were included to assess the interest of the students in the performed activities to answer from 1 – *Strongly disagree* to 5 – *Strongly agree*: 1) What I learned during the proposed activities is very important for me; 2) When I worked on the tasks, I felt interested; 3) I was efficient when performing the activities; 4) I did not participate actively in the proposed activities; 5) I thought the activities were boring; 6) What I learned during the activities relates to my personal goals; 7) The activities did not hold my attention at all.

Ecological beliefs. Seven items were included to tap the beliefs about the impact of the human kind on nature to answer from 1 – *Strongly disagree* to 5 – *Strongly agree*: 1) People worry too much about pollution; 2) Humankind will die if we don't live in tune with nature; 3) Society will continue to solve even biggest environmental problems; 4) Humans have the right to change nature as they see fit; 5) Human beings are more important than other creatures; 6) Our planet has unlimited resources; 7) Only plants and animals of economical importance need to be protected.

Teacher's evaluation of the pathways: Eight items were included to consider the teacher's evaluation of the educational pathways (EP) to answer from 1 – *Strongly disagree* to 5 – *Strongly agree*: 1) The EP fulfilled my requirements as a teacher; 2) The content of the EP was appropriate; 3) The structure of the EP was coherent; 4) It was easy to implement the EP; 5) The digital learning material of the EP was an enrichment; 6) The prescribed time for the EP was sufficient; 7) The EP is curriculum related and 8) The EP brings new approaches for the learning contents.

3.4 Data analysis

An ANOVA was performed in order to compare the means for the knowledge about the scientific contents explored in the exhibitions, for the interest in the activities and for the pro-environmental beliefs, between students following the activities and contents presented in the inquiry-based educational pathways (Group 1) and students not knowing about them (Group 2).

4. Results

Results presented in Table 1 show that students from Group 1 demonstrate more knowledge about the scientific contents of the exhibitions than control students from Group 2 ($M_{Ed.Path}$ = 3.41 and $M_{Control}$ = 3.08; F = 4.156; p<0.043), as predicted in (H_1). This is in line with the results for the interest in the contents (H_2), since Group 1 shows statistically significant higher levels than the control group for the learning during the proposed activities being very important ($M_{Ed.Path}$ = 3.78 and $M_{Control}$ = 3.43; F = 3.971; p<0.048), and lower levels for not participating actively in the activities ($M_{Ed.Path}$ = 1.98 and $M_{Control}$ = 2.63; F = 11.563; p<0.001). If we consider p<0.1, higher levels than the control group were also found for students feeling efficient during activities ($M_{Ed.Path}$ = 3.64 and $M_{Control}$ = 3.32; F = 3.150; p<0.077) and lower levels for the activities not holding their attention ($M_{Ed.Path}$ = 2.37 and $M_{Control}$ = 2.74; F = 3.250; p<0.073).

Considering ecological beliefs, results show statistically significant lower levels for Group 1 when compared to the control group for the belief about society continuing to solve all environmental problems ($M_{Ed.Path}$ = 2.95 and $M_{Control}$ = 3.70; F = 4.473; p<0.038), for the belief about humans having the right to change nature ($M_{Ed.Path}$ = 1.69 and $M_{Control}$ = 2.22; F = 6.349; p<0.013), for the belief about the planet having unlimited resources ($M_{Ed.Path}$ = 2.27 and $M_{Control}$ = 2.90; F = 8.713; p<0.004) and for the belief about the need to protect only animals and plants with economical importance ($M_{Ed.Path}$ = 1.69 and $M_{Control}$ = 2.20; F = 7.178; p<0.009). If we consider p<0.1, lower levels for Group 1 were also observed for the belief about humans being more important than other creatures, ($M_{Ed.Path}$ = 1.91 and $M_{Control}$ = 2.28; F = 3.408; $p<0.066$). These results were predicted in (H_3) since lower results are associated with higher pro-ecological beliefs, considering that questions were built in a negative form (anti-ecological beliefs).

The Figure 1 shows the results of the teacher's evaluation about the quality of the educational pathways: all items show mean levels above 4 except the items about the pathway being easy to implement (M=3.4) and about the prescribed time being sufficient (M=2.8).

5. Discussion

National and international reports increasingly focus the urgent need to develop inquiry-based education initiatives in the context of the Education for Sustainable Development (ESD), using science centers like Botanic Gardens and Natural History Museums. Such activities may promote the proximity with real life contexts, the eco-affinity and the environmental knowledge among young people (Dillon et al., 2006), as well as changes in young people's environmental worldview, including environmental attitudes and beliefs (Boeve-de Pauw et al., 2011), as promoters of conservation behaviors according with the Theory of Planned Behavior (Ajzen & Fishbein, 2000). Moreover, ICT tools have been shown to assure good learning results (Hennessy et al., 2007), inspiring the need to develop new approaches to help science teachers to engage their students for the development of an investigation plan of their own with the support of existing digital resources.

The Natural Europe project allowed the development of such tools – digital educational pathways – to explore three exhibitions in the National Museum of Natural History and Science, and their assessment among students. The activities included in the educational pathways bridge the formal education contents with learning outside the school contexts, using the Museum collections to suggest the creation of an investigation plan, as proposed in the inquiry-based educational methodologies.

The results of this study in the scope of the Natural Europe project show that students who followed the pathways for the development of an investigation plan through the phases of pre-visit, visit to the Museum and post-visit, demonstrated higher knowledge and interest about the respective scientific contents and lower levels of anti-ecological beliefs, than students who just visited the Museum without following the pathways and related activities (control). Such results about the scientific knowledge and interest are in line with recent research and demonstrate that institutions offering non-formal science education like science centers and Natural History Museums can have a crucial role in the preparation of inquiry-based activities, tools and materials, using the visit to real contexts to enrich the school curriculum. This bridge with formal education will help science teachers to engage students through the development of investigation plans which include the collection of evidences and the discussion of hypothesis about scientific issues, rather than just listen about them. As already mentioned, this innovative educational methodology in science teaching engages the students and improves their understanding of both content and process by inspiring their personal involvement (Gano & Kinzler, 2011), assuring not only the *hands on* but also the *minds on* and *hearts on* approaches. The use of ICT tools may in fact reinforce the student engagement when exploring new technologies and contribute to positive results in science learning.

Considering the results about the ecological awareness, we can also conclude that the inquiry-based educational approach using digital resources was effective in promoting the rejection of anti-ecological beliefs about nature and biodiversity conservation. In other words, it may have promoted the conservation awareness among students participating in the proposed activities when compared to the control group. These results are important considering the Theory of Planned Behaviour which establishes beliefs as predictors of attitudes, attitudes as predictors of intention and intention as a direct predictor of behaviour (Ajzen & Fishbein, 2000). The increase of conservation beliefs may therefore promote the increase of conservation behaviours, the final goal of educating for the sustainable development.

In addition, the teacher’s feedback on the quality of the educational pathways was extremely positive. The lowest values in this evaluation are related to the easiness to implement the pathway and the time prescribed to this activity, which may be associated to the lack of time reported by the teachers to include active methodologies in long school curricula. Changes in the school directives should therefore be a priority in order to allow teachers to implement the inquiry-based approach.

Geographical representativeness is a constraint of this study, as it does not include students from different country regions, but exclusively from schools in Lisbon. A further limitation may be the fact that this particular study does not consider the students' situation regarding the considered variables previously to the intervention. However, the allocation of classes to the two groups was random and both groups included classes from different schools. Therefore, we can consider these post results represent Lisbon schools heterogeneously.

6. Conclusion

This study supports the positive role of the inquiry-based science education process in promoting the knowledge about natural sciences contents, the interest in scientific activities and the conservation awareness among young students. This was achieved by engaging students to create and develop their own investigation plans (as advocated in IBSE) but also by making use of digital tools, which teenagers are keen to use in this era of information and communication technologies.

Future research should include both the study of changes between initial and final results for the considered variables and the influence of such educational approach in the students' success at school. It would also be interesting to assess the changes in the teachers' professional development and to verify if the IBSE students enhance their scientific knowledge, conservation awareness and even their pro-environmental behaviour through their families, more than non-IBSE students.

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Tables

Table 1 – Results of an ANOVA comparison for all the items considered between the group of students following the contents and activities of the educational pathways and the control group.

	Educational Pathways			**No Educational Pathways (control)**				
	N	*M*	*SD*	*N*	*M*	*SD*	*F*	*p*
Knowledge	109	3.41	1.18	92	3.08	1.15	4.156	0.043
Learning Importance	110	3.78	1.09	93	3.43	1.42	3.971	0.048
Tasks interest	110	3.90	1.19	93	3.68	1.48	1.530	ns
Tasks efficient	108	3.64	1.06	91	3.32	1.47	3.156	0.077
No active participation	109	1.98	1.11	92	2.63	1.59	11.563	0.001
Boring activities	109	2.16	1.38	91	2.37	1.41	1.206	ns
Personal goals	109	2.89	1.39	91	2.87	1.49	0.010	ns
Not holding attention	109	2.34	1.41	92	2.74	1.51	3.250	0.073
Belief pollution	110	1.61	1.05	88	1.66	1.13	0.103	ns
Belief humankind	110	4.02	1.29	89	3.75	1.55	1.730	ns
Belief in society	110	2.95	1.25	89	3.70	3.46	4.473	0.038
Belief human right	110	1.69	1.31	89	2.22	1.68	6.349	0.013
Belief human more	109	1.91	1.29	90	2.28	1.53	3.408	0.066
Belief planet	109	2.27	1.39	89	2.90	1.62	8.713	0.004
Belief economics	110	1.69	1.11	90	2.20	1.57	7.178	0.009

	Educational Pathways			No Educational Pathways (control)				
	N	*M*	*SD*	*N*	*M*	*SD*	*F*	*p*
Knowledge	109	3.41	1.18	92	3.08	1.15	4.156	0.043
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No active participation	109	1.98	1.11	92	2.63	1.59	11.563	0.001
Boring activities	109	2.16	1.38	91	2.37	1.41	1.206	ns
Personal goals	109	2.89	1.39	91	2.87	1.49	0.010	ns
Not holding attention	109	2.34	1.41	92	2.74	1.51	3.250	0.073
Belief pollution	110	1.61	1.05	88	1.66	1.13	0.103	ns
Belief humankind	110	4.02	1.29	89	3.75	1.55	1.730	ns
Belief in society	110	2.95	1.25	89	3.70	3.46	4.473	0.038
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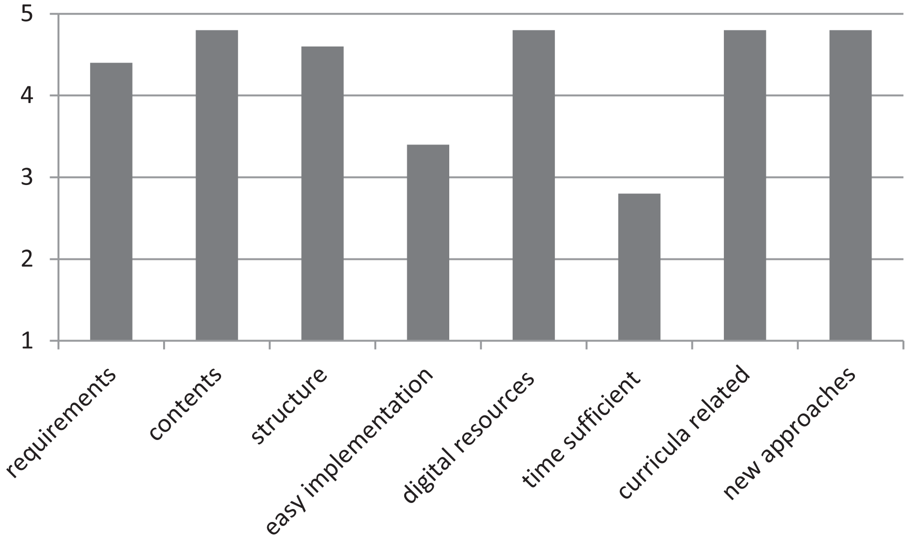
Belief human more	109	1.91	1.29	90	2.28	1.53	3.408	0.066

Figures

Figure 1 – Results of the teacher's evaluation (from 1 to 5) about the Educational Pathways (N = 5)


5
4
3
2
1
requirements
contents
structure
easy implementation
digital resources
time sufficient
curricula related
new approaches