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Aliens and dragons: purposefully-framed play and non-standard learning methods in teaching evolutionary processes to primary school pupils

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Abstract

Evolutionary processes lie at the base of the entire observable biodiversity, both at present and in the geological past (i.e., in the fossil record). For this reason, the teaching of evolution should receive more recognition than it currently has (e.g., in Poland) and become accurately applied from the early formal education stages onwards. To test the possibility of effective teaching of evolution to primary school pupils, workshops using non-standard learning methods ('purposefully-framed play') were organised during childrens' university (UNIKIDS) courses of one-hour sessions for 33 groups, comprising several to 20 participants, aged 7 to 12. The final task for all participants was to predict future evolutionary processes by creating new species adapted to given environmental factors. Pupils effectively completed this task, but a few misconceptions also become clear. These workshop scenarios suggest that evolution can be taught effectively at least in extracurricular settings to primary school pupils, but for a detailed insight, a quantitative analysis and application of such scenarios in school programmes should be tested in future.

Keywords: non-formal education, biological education, palaeontological education, geoeducation

1. Introduction

The teaching of evolution at primary schools is important because it forms the basis of biological diversity; Mutanen & Uitto (2020, p. 1) stated this succinctly when they wrote, 'Biology education should be relevant to young students so that they can become interested in biology and understand biological topics in their everyday and vocational lives'. Under some conditions, purposefully-framed play or subject-performed tasks have proved to be effective ways of learning for children (Kotarski, 2017; Antczak, 2021).

Purposefully-framed play refers to the experience in which the act of playing is supported by material provided by the teacher and in which open-ended play is followed by modelled play and teacher-child interactions (Cutter-Mackenzie & Edwards, 2013). It is a combination of play-based learning and typical academic approach, where play is performed according to a scenario. This allows to teach scientific topics through elements of play (e.g., Antczak, 2021) and provides opportunities for exploration and discovery, which are important for supporting learning (White et al., 2007; Cutter-Mackenzie & Edwards, 2013). It has been shown that even early-year children may participate in subject-performed workshops on natural sciences and draw proper conclusions (Cascarosa et al., 2020).

Traditional learning methods include listening to lectures, taking notes and self-reading without additional tools (Parasuram et al., 2014). Non-standard learning methods use technology and interactive elements (Parasuram et al., 2014), as well as other-than-listening/reading coding styles and subject-performed tasks; in other words, learning through practice (Kotarski, 2017).

If we add a certain action to the information we intend to assimilate, particularly of an unusual nature, this will strengthen the memory trace (Mulligan & Hornstein, 2003; Nyberg et al., 2003). Previous research has presented the teaching of evolution by using monological reading sessions and clinical interviews (e.g., Emmons et al., 2017). Frejd et al. (2020) proposed a different approach, including classroom setting and interactive read-aloud. Herein, this approach is extended by implementing different non-standard learning methods in the form of purposefully-framed play.

The objectives of the current project were to establish the most common misconceptions in understanding evolution as a long-termed process and to determine whether or not primary school pupils (and to what extent) are able to understand the basics of evolution and its impact on modern biodiversity, also in the early years of education, when evolution is not included in the curriculum (see below, 'Scientific background').

2. Scientific background

In many countries evolution is either rarely taught, judging from curricula for primary education such as in Poland (Dz.U. z 2017 r., poz. 356) or the US (Tolman et al., 2021), or along with non-scientific hypotheses such as creationism (Williams, 2008; Plutzer et al., 2020). In other countries, teachers feel that their pupils have a poor understanding of evolution (Hermann, 2013). Evolution may be omitted from the curriculum in terms of local religious beliefs (e.g., Saudi Arabia and Iran; see Burton 2011; RSA; see Sanders & Ngxola, 2009), political issues or a mix of these factors (e.g., US, UK; see Williams, 2008; Khazan, 2019). Specifically in Poland the new curriculum, dating from 2016, marginalises the teaching of evolution, which met with the disapproval of the scientific community (Kwiatek, 2016). Polish primary education comprises eight years of study and the curriculum is divided into two steps. The first includes the Ist–IIIrd grades, for which education is integrated (including environmental education). From the IVth grade onwards, separate classes of environmental studies start, and geography and biology are taught from the Vth grade onwards, to be followed in the VIIth grade by chemistry and physics. In this curriculum, for grades Ist–IIIrd, no evolutionary problems are included. In biology classes, the chapter on evolution is the shortest, with merely three subchapters (contrary to, for instance, genetics with nine chapters, or biodiversity and human anatomy with over a dozen chapters for each) (Dz.U. z 2017 r., poz. 356).

Limitations of the school curriculum do not affect additional activities of non-formal education, advantages of which include, according to Grzesiak (2016), the non-institutional character, informal relations between learners, voluntariness, greater accessibility and permanence (i.e., the possibility of education at different ages). Additionally, extracurricular work may favourably impact the multilateral development of pupils' personalities (Domoń, 2015). Such activity can also be consulted and co-worked with public schools. While schools often cannot catch up with technological development, they can still co-operate with institutions such as museums, science centres (Warchoł, 2018) or childrens' universities. Although even a simple enlargement of traditional methods may yield sufficient results (e.g., watching the film WALL-E [2008]; see Korfiatis et al., 2020) to achieve an effective understanding of biological processes purposefully-framed play should be applied.

During recent years evolution has been taught at primary schools in various countries (Frejd et al., 2020), as well as in the form of different kinds of non-formal activities, also at preschools (Nadelson et al., 2009; Campos & Sá-Pinto, 2013; Horwitz et al., 2013; Frejd et al., 2020). Although from a child's perspective play and learning are not always separate (Samuelsson & Carlsson, 2008), in practice, simple play does not yield the same results as purposefully-framed play (e.g., Hedges & Cullen, 2005). Frejd et al. (2020, p. 1) stated that, 'Although these directions provide interesting ideas on how to introduce evolution to young children, more evidence-based research is required to inform how evolution can be taught and how children at these levels make meaning about evolution'. The research presented herein is an attempt to meet this requirement.

3. Method (conceptual framework)

During several academic years (2016–2020) 33 groups (4 to 25 participants in each group, ~500 pupils) of primary school pupils (aged 7–12) participated in workshops about evolution and speciation at childrens' universities (UNIKIDS) in Poznań, Wągrowiec and Leszno (Greater Poland). Childrens' universities propose weekend science activities for primary school pupils with a non-standard teaching/learning approach, focusing on 'purposefully-framed play' (as defined in Cutter-Mackenzie & Edwards, 2013). This means active participation of pupils in specially designed activities and experiments, as well as drawing conclusions by themselves (guided by the lecturer).

Workshops were provided in an academic setting (university buildings), houses of culture or school buildings during the winter and summer breaks. One group was set in their usual educational environment (Belward Private School) and a scenario was applied during additional environmental (I[st] grade) and biology (VI[th] grade) classes. This particular school had a set of extracurricular activities for pupils, including additional language and information technology lessons, frequent educational trips and co-operation with UNIKIDS. Additional environmental classes were provided, such as at childrens' university meetings, by specialists in a certain field, including academic researchers.

Unfortunately, during most of these activities, no quantitative data were collected. Only for the group of 17 participants from Belward Private School, where additional scientific activities were added to the environmental (biology and geography) courses along with the curriculum, were data noted. However, because all workshops were organised by the author, and results were consulted with the organisers of childrens' university (UNIKIDS) classes and parents of the participants, qualitative conclusions may now be presented.

In the research conducted (workshops – Table 1), four different scenarios were used, albeit all based on the same idea: presentation of the main evolutionary concepts with the help of interactive materials (photographs, short videos, short activities with natural exhibits, e.g., fossils) and discussion between participants moderated by the lecturer (Fig. 1). The materials were designed to spark an interest in pupils and engage their curiosity. To allow proper appraisal of the minor activities and especially the final task, all workshops started with a discussion so as to gauge the pupils' knowledge of evolution.

All exhibited observations are followed by questions and riddles proposed by the lecturer; e.g., *What do you think it served for? Why do two mussels have shells of different thicknesses?* To moderate the

Fig. 1. Purposefully-framed play activities in the teaching of evolution. **A –** Discussion moderated by a lecturer; **B –** Fossil preparation during the workshop; **C –** Aquatic giraffe – an example of workshop outcome; **D –** Searching for signs of life in rocks (extrasolar planets scenario), both macro- and microscopically.
Credits: A, B: K. Waindzioch, workshops provided during Biologists' Night at University of Opole in January 2023. C: work submitted to the competition organised by Opole University based on the Red Queen scenario by 7-year-old Malwina). D: M. Antczak.

discussion properly, the individual who provides the workshops should be an expert in his or her field (in experiments done by the author this was based on a PhD degree in Earth sciences). Adult moderation of children's play is an important factor in purposefully-framed play (Siraj-Blatchford, 2007; Jordan, 2009; Fleer, 2010).

Active exposure to the material is also needed for a better learning retention (e.g., Huitt & Hummel, 2003); for example, shells with different thicknesses to discuss why such changes in bivalves might occur (see Table 1). While this is not learning the practice of scientific work, these practical simulations facilitate mastering the underlying theory of that work (Kotarski, 2017). Pupils also discuss, ask additional questions and draw conclusions by themselves; as previously suggested, self-explanations (Chi et al., 1989; 1994) and asking 'inquisitive' questions (Martin & Pressley, 1991) are better for strengthening the memory trace than simple reading or repetition of the material (Dunlosky et al., 2013). Environmental education yielded similar results (e.g., Gomez & Gavidia, 2015).

Table 1. Workshop scenarios – a proposed framework for the teaching of evolution at primary schools.

Scenario	Number of groups	Description	Examples of additional tasks	Final task mechanics
Red queen	19	Presenting basics of evolution referring to Red Queen Hypothesis (Van Valen, 1973) and changes occurring in Earth's history (climate changes, continental drift, sea-level fluctuations, etc).	Boardgame "*How many beetles*" presenting natural selection (earthlearningidea.com). Investigation of fossils and modern exhibits in terms of adaptations (e.g. placodont teeth and clams with different shell thickness). Finding 'masters of camouflage' on pictures. Analyzing examples of possible future species forms from "*After man*" (Dixon, 1982).	**Forming a species that will live on Earth in 50–100–150 million years** from now, that evolved from chosen modern species, using a **jumble of paper elements** – different kinds of animal legs, bellies, heads, jaws, horns, ears, eyes, tails, floral elements, etc.
Extrasolar planets	5	Presenting basics of evolution referring to the possibilities of finding life at some exoplanets surface.	Searching for macro- (in rocks) and microfossils (in rock thin section under binocular). Investigation of fossils and modern exhibits in terms of adaptations. Analyzing examples of species that could evolve on different exoplanets (similar to examples from Trefil & Summers, 2020).	**Forming a species that could live on chosen exoplanet** and is well-adapted to its surroundings (environment, climate, or other representatives of extraterrestrial fauna), using **Minecraft Creative mode**.
Dragon legends	8	Presenting basics of evolution on the example of mythical creatures and dinosaurs (assuming that dragon legends originated from fossil findings) referring to well-known in Poland Wawel Dragon (Bodzioch & Wężowicz-Ziółkowska, 2016).	Discussion: dragons, fossils, and dinosaurs. Investigation of fossils and modern exhibits in terms of adaptations (e.g. different types of teeth and feeding habits). Movement game showing dangers in transporting information without writing.	Forming **a drawing of a 'dragon' with a given fossil 'paste' within the drawing** and explanation of adaptation of this element (and possibly other elements that were drawn by participants).
Biodiversity	1	Presenting basics of evolution as the cause of modern life diversity.	Investigation of fossils and modern exhibits (adaptations). Discussion on the photographs of unique animals and plants to discover adaptations (in terms of four main concepts). Finding 'masters of camouflage' on pictures. Analyzing examples of possible future species forms from "*After man*" (Dixon, 1982).	**Forming a species that will live on Earth in 50–100–150 million years** from now, that evolved from chosen modern species, using **plasticine.**

The workshop activities present age-appropriate (often without using scientific terms) explanations of phenomena and processes such as adaptation, speciation, natural selection, evolutionary radiation, mimetism, Red Queen hypothesis and symbiosis. First, concepts of heritage, ancestors, descendants and family trees were presented as an introduction to relationships between all modern and fossil organisms. The introduction was followed by small-scale activities (Table 1) and moderated discussion presenting the concept of adaptations for defence, predation, climate and environment (Table 2). The final task in all scenarios was to create a new species that could evolve from one of present-day animals in future (or species that could evolve on another planet) and to explain how it will adapt to its surroundings using one of the concepts mentioned. The new species were made from a jumble of elements, using Minecraft creative mode, drawing or plasticine, depending of the scenario (Table 1, example shown in Fig. 1). The results of the final tasks (imagined species projects) were presented to the group or consulted with the lecturer.

4. Results

Through direct observation during the project, pupils appeared deeply engaged during the workshops and following an entire weekend at a childrens' university, pointed out the evolutionary classes as the most entertaining (pers. comm. with organisers). However, even if pupils appear engaged and enjoy the play, this does not guarantee effective learning (Frensley et al., 2020), which is why a final task was created as a test for understanding the material presented.

Although at the beginning of the workshops only a few participants in each group admitted that they were familiar with the term evolution, following the workshops (based on purposefully-framed play) most of them performed their assigned task adequately and were able to explain the concepts behind the new species that they proposed. However, in younger pupils (7–8 years), the number of correct constructions usually was lower and extra explanations were needed. No distinct difference among boys and girls between understanding and explanation of concepts was observed. The same goes for groups in an out-of-school and in-school settings, although quantitative data and greater numbers of in-school-setting groups should be tested in future.

The most popular misconceptions in forming a new species during the final task (simultaneously explained) according to evolutionary laws were:

- Joining several species in speciation (*'My species evolved from a lion and an elephant…'*)
- Purposefulness and awareness of evolution (*'He has fins now because he wanted to become a marine animal'*)
- Pokémon evolution style (very fast and glamorous evolution)
- Drastic changes, like a change of a vertebrate construction plan (*'My species has six legs, wings and two heads)*
- Numerous fantastic adaptations (*'My species can spit venom, ice and fire'*)

When considering misconceptions among the youngest pupils, their limited vocabulary has to be taken into account. It is possible that their understanding of evolutionary processes was better, but that explanations were not expressed sufficiently.

Table 2. Evolutionary concepts and examples provided by participants (combined from two groups – 17 respondents).

Evolutionary concept	Examples provided by participants
Defense against predation*	Shells, horns, etc.
More effective feeding	Changes in dentition, the occurrence of claws
Climate	The occurrence of fur and feathers
Environment	The occurrence of fins, wings

* special case – becoming invisible (camouflage).

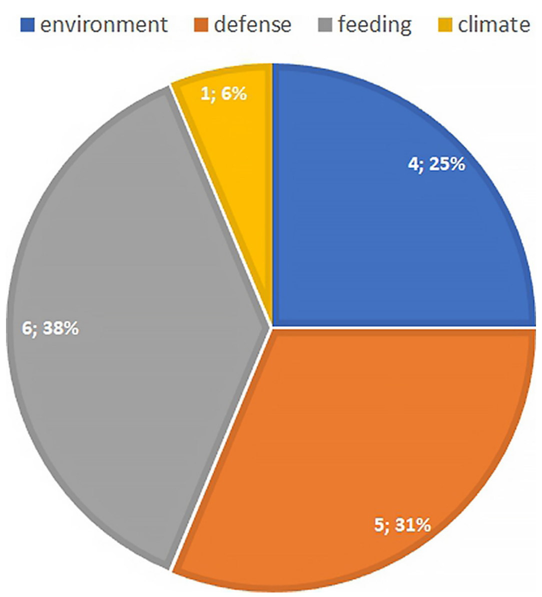

Fig. 2. Use of adaptation concepts in the final task (based on a group of 17 participants from Belward Private School at Poznań, with percentage of pupils that used each concept).

The most popular concepts used (among the four presented during the workshop) was adaptation for acquiring food (mostly predation) and defence against predators. Less common was adaptation to environmental changes and the least frequent concept was climate changes (Fig. 2). Frejd et al. (2020) mentioned that feeding was the most popular concept among children as this is an activity closest to their everyday behaviour (in contrast to, for instance, 'building nests, going into hibernation'). The present study does show that pupils are able to deal with concepts like defence against predators or adaptation to environments (Table 2; Fig. 2).

5. Conclusions

After several years of non-formal education, as participants in childrens' universities (UNIKIDS) for primary school pupils, around 500 children participated in workshops about evolution. Observations made during the workshops allow to consider purposefully-framed play to be effectively applied for teaching evolution. This confirms the outcome of earlier research (e.g., Cutter-Mackenzie & Edwards, 2013; Campos & Sa-Pinto, 2013), but applies it to a specific subject and proposes specific scenarios for workshops.

While the theory of evolution lies at the base of all aspects of the biological sciences, this might be important because in certain countries evolution is not extensively presented in schools or it is presented along with non-scientific hypotheses such as creationism. Often adult citizens are not convinced that evolution is a legitimate scientific theory (Miller et al., 2006).

The basics of evolution can be successfully taught; however, a proper model of teaching should be applied. The experience presented here shows that non-standard learning methods (such as those presented by Dunlosky et al., 2013 and Kotarski, 2017), along with purposefully-framed play, including modelled activities, discussion and interaction with an animator/moderator who is an expert in the field, provide significant results.

While at the beginning of the workshops only few participants were familiar with evolutionary processes, most of them did their final tasks in a proper fashion, verifying an understanding of the basics of evolution of the chosen evolutionary concepts presented during the workshop. Purposefully-framed play on evolution also allows for refuting some misconceptions that are common among children (joining species, awareness of evolution, Pokémon evolution style).

While the data presented are mostly qualitative, more detailed quantitative analysis would be helpful in future research.

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