Promoting Creativity in the Secondary Design and Technology Classroom in England

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ABSTRACT

This study explores the use and implications of biomimicry as a design method in a secondary school Design and Technology classroom in England. The study's aim was to explore biomimicry as one of the design approaches in a Design and Technology classroom. The goal of this research was to develop an appropriate teaching strategy for including biomimicry in the design process as a means for encouraging students to "use a variety of approaches to generate creative ideas and avoid stereotypical responses when responding to design briefs" (DfE, 2013, p. 2). The Biomimicry approach takes inspiration from natural solutions adopted by nature and imitates the concepts when designing products. Working with a class of year 9 pupils (aged 13 - 14) the research team introduced the principles of biomimicry, which was chosen as an innovative approach for promoting creativity. This action research took a qualitative approach to gain insights into pupils' thought process as they applied biomimicry in the given design brief. Action Research was used to understand if the introduction of biomimicry as an intervention would develop pupils' creativity. The data that was used for analysis includes responses to open-ended questions, drawings, and artefacts. The findings of the study show that with the support of teachers, pupils used inspirations from nature in their design and make tasks to creatively think through and create original artefacts that meet an identified design need. The biomimicry approach was embraced by pupils who developed a range of nature inspired designs. The paper also presents interesting findings on pupils' knowledge and learning process through demonstration of acquired skills of originality and creativity represented through interventions in nature.

Keywords: Biomimicry, Design and Technology, National Curriculum, Creativity

1. INTRODUCTION

As part of the National Curriculum in England, Design and Technology education is a subject taught at both primary and secondary school level until key stage 3 (ages 11-14), thereafter pupils at key stages 4 and 5 (ages 15-18) may choose to study the subject further. As a subject department, Design and technology is made up of several subject specialisms. Consequently, the teaching of Design and Technology assumes different forms depending on the school and the unique context of a specific department (Mburu, 2022). The National Curriculum underscores in its purpose of study for Design and Technology that 'using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts' (Department for Education (DFE, 2013, p.1). With a focus of importance drawn towards this, Nicholl, Flutter, Hosking, & Clarkson (2013) allude that design problems should be based on authentic, real-world problems which can be both meaningful to pupils' and deploy the use of tools in the design community. Katherine K. Fu et al. (2019) outlines design fixation as a blind adherence to a set of ideas or concepts limiting the output of conceptual design which can have negative effects on the design process. Furthermore, they argue that design fixation is relevant to design practitioners and educators through several investigations that observed significant manifestations in both pupils' and experts when provided with an example solution (p.3). Considering the potential negative impact design fixation can have on the design process and outcome, it is crucial to find effective ways to prevent design fixation. Encouraging pupils in Design and Technology classrooms to develop creative solutions to real-life problems by using design inspirations from nature and moving away from design fixation is central to this research.

1.1. Using Biomimicry as a Design Approach in an English Secondary School.

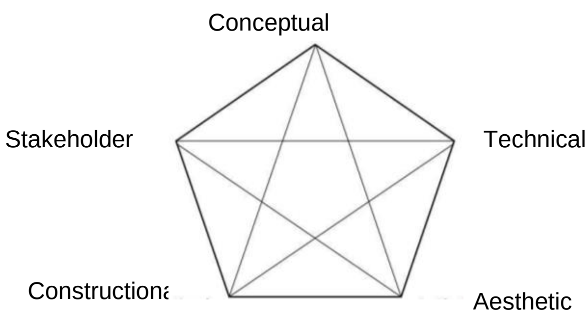
The term 'Biomimicry' first appeared in scientific literature in 1962 and gained popularity among material scientists in the 1980s (Pawlyn, 2019). Biomimicry is an approach used in different branches of science that studies nature's models and processes to solve human problems through design inspirations and imitation. The design process is approached in a way that designers look at nature, ecosystems, or a specific organism by imitating these behavioural processes to solve human problems. Although this approach is not new, it was immensely promoted by biological sciences writer Benyus (1997) who describes biomimicry as a process inspired by nature to drive innovation and improve current methods of product design, manufacturing, and life cycles. In other words, Vierra (2019) and Appio et al. (2017) describe biomimicry as the science and art of emulating nature's best biological and sustainable solutions by emulating patterns and strategies that have been tested through time in nature. Consequently, this approach of imitating design ideas from nature can be useful in helping pupils grasp design concepts and provide an authentic learning experience in design and technology classrooms. This application of using biomimicry as an approach in a Design and Technology classroom in England aligns with the learning objective in the National Curriculum framework DfE (2013) in England which states:

> When designing and making pupils should be taught to use a variety of approaches. For example, biomimicry and user-centred design, to generate creative ideas and avoid stereotypical responses (p. 2).

Biomimicry affords a pedagogical approach which places a pupil as a creative thinker and designer to work jointly with others on an actual real-life design problem. This way of working gives a Design and Technology learner the opportunity to avoid generating product design ideas that are a direct copy of what they are familiar with. Furthermore, the two main categories of using biomimicry as a design approach are; where a designer directly mimics strategies of an organism, a behavioural pattern, or a system in nature and where the designer abstracts ideas and concepts as principles from nature's designs (Elmeligy, 2016). Drawing from Barlex and Steeg's (2017) interdependent decision-making approaches, this study seeks to understand the significance of biomimicry as a design method in a Design and Technology classroom.

According to Barlex and Steeg (2017), designing and making is often seen as the heartland of design and technology education. Mostly, designing and making often go hand in hand in a design and technology classroom. However, each of these could be taught separately to pupils. Barlex (2011) argued that designing is the act of generating, developing, and communicating ideas for products, services, systems, and environments in response to what the user needs and wants. This notion of designing is also associated with ideas that show creativity and originality. Creativity and designing are interconnected. According to Cox (2005) creativity is the generation of new ideas while innovation is the successful exploitation of new ideas and design is the linkage between creativity and innovation. Benson (2017) states design and technology as a subject in schools provide immense opportunities to pupils in many ways to develop their own creative skills (p. 8). Klapwijk and van den Burg (2020) highlight the importance of creating such a space for pupils to stimulate them to develop creativity in learning. However, ensuring pupils generate ideas that show creativity could be challenging for teachers when considering how to meet the national curriculum objectives in design and technology education. Barlex and Steeg (2017) developed a diagram (figure 1) that visualises the concept of decision making that pupils need to undertake when they are designing and making.

Figure 1.
Five key areas of interdependent decision making (Barlex and Steeg, 2017)



The interdependence of these five areas is an important component of making design decisions, as change of decision within one area will affect some if not all of design decisions that are made within the others (p.16). It is the juggling of these various decisions that leads to a clear design proposal that can then be achieved to the point of a fully working prototype. This process of designing and making that requires intellectual rigour is an essential part of design and technology education.

In secondary school Design and Technology classrooms, design challenges are often based on real-life design briefs or imaginary ones. Pupils gather and collate a range of information to help them generate solutions to an identified problem. The solutions are presented using a range of methods including two-dimensional (2D) and three-dimensional (3D) drawings and 3D models. In the final stage in the design cycle pupils make and evaluate their products, which could be working models or prototypes. In this action research the concept of biomimicry is explored in the setting of a classroom intervention to enhance creativity. The concept of decision-making process in the classroom followed the Barlex and Steeg (2017) model. The biomimicry-based project was aimed at encouraging pupils to acquire both knowledge and skills including designing and making. The aim was to help pupils acquire a set of skills to generate design ideas that showed originality and creativity. The main research question is: How do pupils move away from design fixation when exposed to interventions based on nature?

2. METHOD

This study adopted an action research approach, a process that helps practitioners develop a better understanding about the particulars of a specific practice-based situation (Wilson, 2013). It is assumed that in a classroom situation, research action provides teachers with an opportunity to engage in actions that would improve the learning opportunities for their pupils. In this case, the practitioners include a qualified teacher of Design and Technology and a teaching assistant with an advanced degree in design education. The action research applied qualitative methodology to interpret responses to open-ended questions, drawings, and artefacts. The research involved a series of ten lessons adopted from Nicholl et al. (2013) which was divided into pre-intervention, intervention, and post-intervention phases. The pre-intervention phase required preparing a set of teaching resources to introduce pupils to the concept of biomimicry. Pupils were given a design brief that was sent by a real client, which was a primary school neighbouring the school. The design brief emphasised a real-life problem for the client. The client stated that they required 'a range of nature inspired products that would encourage wildlife habitation in their school compound'. The design limitations were to create a range of products that would be safe for the children in the school compound and welcome wildlife such as birds, squirrels, hedgehogs into an identified space in the school.

In the first week, the classroom task involved sharing the design brief with the pupils in a normative classroom setting. This was followed by watching a video on wildlife in their habitat in England. After a short classroom discussion, a questionnaire with open-ended questions was given to pupils. The questionnaire was to be completed during a short visit to a forested area outside of the school. This visit took forty-five-minutes and pupils made observations from nature and recorded them on the questionnaire worksheet. Pupils were also encouraged to write questions that they thought needed to be answered. Pupils recorded their observations as written notes, drawings of nature-based items such as nests of animals, leaves, trees, insects, and fruits. In addition, pupils were given a home learning task that involved compiling a piece of research on the homes, colours, textures, sizes, and behaviour of different wildlife. This was intended to give pupils an opportunity to consider how two or more elements would influence their designs.

Furthermore, this was aimed at encouraging the use of reasoning and thinking skills throughout the process whilst developing their design ideas.

In the second week of the project, pupils were shown images of the client's compound. These images, the information that was collected during a classroom visit to a forested area, knowledge gained from the previous week's lesson, and the additional findings from their home learning task were used as materials to inform the designing tasks. Pupils spent forty-five minutes generating ideas for a product that would home their chosen wildlife in the client's compound. Ideas were recorded using sketches and cardboard models. The lesson (one hour forty minutes) in the third week involved pupils' modelling their ideas using cardboard. This was the intervention phase where pupils were shown images of products that had been designed using the concept of biomimicry. Pupils were encouraged to use their field visit observations, drawings of natural items (as observed and recorded during the field visit session), and the classroom intervention materials to integrate biomimicry concepts in developing their design ideas. Pupils spent another lesson (one hour forty minutes) developing and testing their ideas using cardboard models. The aim of these modelling sessions was to test and try their models whilst using various inspiration from nature. Pupils then developed a final cardboard model in readiness for prototyping. The post-intervention phase involved pupils making their refined final design using pine. This phase took three weeks, that is, five lessons of one hour forty mines. Table 1 presents the structure of the lessons compared to Barlex and Steeg (2017) approaches to decision making.

Table 1.
The structure of lessons compared against Barlex and Steeg (2017)

Lesson	Length (Minutes)	Instructional strategies used in this study	Barlex and Steeg (2017) approach
1 – Pre-intervention	45	Introducing the client Discussing the design brief	Stakeholder Conceptual
	45	Visit to a natural habitat that neighbours the school	Conceptual
2 – Pre-intervention	First 45	Pupils were shown images of the client's compound	Stakeholder Conceptual
	45	Generating ideas Modelling ideas	Aesthetic Technical Constructional
3, 4 and 5 Intervention	140 each	Generating ideas Modelling ideas using cardboard Intervention introduced	Aesthetic Technical Constructional
6, 7 and 8 Post-intervention	140 each	Making the final product	Aesthetic Technical Constructional Stakeholder

3. DATA ANALYSIS

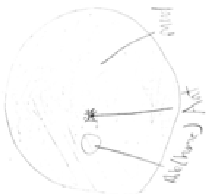
The biomimicry approach in this study was aimed at encouraging pupils to acquire both knowledge and skills in designing and making. This section represents the three stages of the 'think, design and make' process that defined the project methodology. Pupils' curiosity about the environment and different functions of nature were projected through the types of questions they asked. It was observed that pupils were able to express thoughts, ideas, and curiosity about the natural world after intervention through the questionnaire tool that was used by teachers. The questionnaire tool presented questions such as name two or more wildlife that you observed, describe the details of any animal home structures, sizes, behaviours you may have observed, questions you would like to be addressed and note anything you are curious to know more about. This section presents data from four pupils: Alfie, Maria, Thomas, Zafar (pupils names are pseudonyms). The data presented shows pupils' questions, drawings, models, and final products to provide a view of their shift in thinking through their individual design journeys.

Table 2.
Transition in Alfie's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
The nest must be in a place where it's not too crowded and a place where it won't get damaged.	How long does it take for the bees to find their queen and a home?

Considering the above questions in Table 2, Alfie's inquisition moves from general knowledge on the behaviour of the wildlife they were investigating to a more specific question to support his designedly thinking. This process of thinking and the use of nature based intervention materials helps him to ideate a living space for a chosen wildlife, make quick models and develop a prototype, which are shown on Table 3.

Table 3.
Three stages of Alfie's drawing, modelling and making

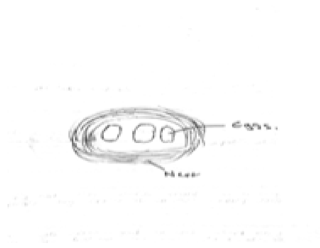
Initial drawing	Final development of the cardboard model	Final prototype
		

The questions asked by Maria in table 4 moves away from the most obvious need of a home for wildlife to identifying other possibilities that are essential. Maria applied her knowledge of spaces which was triggered by the intervention tasks to consider other factors in her ‘think, design and make’ process as shown on Table 5. Her shift in thinking through the transition in questions implies that she was thinking about animal sizes and safety through her observations in nature.

Table 4.
Transition in Maria's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
I want to make more homes for wildlife on the ground so it can attract other animals besides birds	How are we going to find the right space to place the homes we make for the animal?

Table 5
The three stages of Maria's drawing, modelling and making

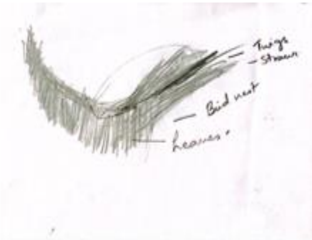
Initial drawing	Final development of the cardboard model	Final prototype
		

In addition, Zafar's question before intervention is an example which implies a shift in thinking from a generic question to a more specific solution-based response. Zafar's thinking is illustrated on table 6 also shows the use of leaves as 'safe homes' to protect wildlife such as birds.

Table 6.
Transition in Zafar's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
How do we make the right home for wildlife?	We could plant more trees around the school to protect the animals and their habitat

Table 7 Three stages of Zafar's drawing, modelling and making

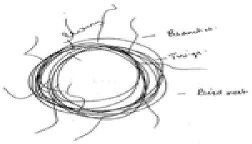
Initial drawing	Final development of the cardboard model	Final prototype
		

Thomas's understanding of the basic behaviour of his chosen wildlife led him to develop a product that is functional as illustrated on Table 8. The guiding principle for Thomas was that the product had to look 'safe' and allow the wildlife to 'come out at night'.

Table 8.
Transition in Thomas's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
There must be more holes and enclosed spaces, so the animals feel safe	Why do hedgehogs come out only at night?

Table 9
Three stages of Thomas's drawing, modelling and making process.

Initial drawing	Final development of the cardboard model	Final prototype
		

The questioning tool allowed pupils to ask questions based on what they observed. For instance, pupils asked questions that showed curiosity about the environment around them. For example, Thomas asks, “why do hedgehogs come out only at night?” or Alfie’s curiosity to know “how long does it take for bees to find the queen and a home”. Engaging in such a thinking process and producing a range of questions indicates pupils' willingness to examine the contextual challenge (meeting clients’ design needs) to inform their decision-making process. These questions, plus the nature-based intervention materials that were provided have the most influence in thinking outside of the obvious solutions when designing a home for wildlife. Classroom teachers would have the most impact in directing pupils away from design fixation and aligning themselves with existing solutions. In this project these problems were countered by taking pupils outside of the classroom to an actual real life outdoor space that they explored.

The importance of this approach was that it motivated and brought a new perspective to pupils'' thinking. Their developed questions as shown in tables 2, 3, 4 and 5 identified elements of wanting to solve real problems that resonated with their local situation. Examples of pupils’ questions in the tables also highlight expressions of developing ecological awareness. For example, in Table 5, Thomas commented that “there must be more holes and enclosed spaces for animals to feel safe”, which suggests that the pupil is beginning to understand the challenges animals could be facing in a wild space, while also trying to find design solutions to these challenges. The contextualization of the challenge made the task become more personal to them. “How are we going to find the right space to place the homes we make for the animal?’’ suggests Maria’s thinking beyond what she had observed. It could be inferred that the pupil is trying to inquire about possibilities for design ideas in designing and building a bird nest.

4. DRAWING, MODELLING AND FINAL PRODUCT PHASE.

The design thinking was inspired by images that pupils collected as a source of inspiration in conjunction with a visit outdoors as intervention materials. Pupils' design models display significant patterns, and mimics features found in nature. Tables 3, 5, 7 and 9 show pupils' initial drawing, final development of the cardboard model and the final prototype. In developing the models, pupils showed the process of introducing alternative solutions following evaluation of existing solutions. As seen in table 3, Alfie decided to construct a product that would attract bees. Specifically, using an insect's body structure as a starting point for the construction of the main structure of his design. The concept of housing items within the body of the insect (like a hive with holes) stimulated the idea of the holes on the product for the bees to live in. Maria took the idea of how an apple fruit keeps its seeds intact and safe inside (see table 5). She used the concept to construct a home for wildlife and in considering the aesthetic element they maintained the natural shape of an apple.

Not only did Zafar base his design in the form of a leaf but also considered the function of a leaf in a plant, as a surface for processing food. He argued that a good leaf must look tough and protect the contents inside of it. Thomas based his design on the rustic look of a tree bark and argued that the protective function of the bark makes it suitable as an outer layer for trees. Therefore, his idea was creating a home for hedgehogs that looked strong and blended in with the surrounding environment to keep them safe. In the pictures displayed in tables 3, 5, 7 and 9, individual pupils chose and designed the most favourable solution that was further improved by imitating solutions found in nature. The models are further developed by constructing prototypes, which show the use of chosen patterns that exist in nature. The final prototypes were placed in their intended environment as shown in Figure 2. The imitation of nature in the models and prototypes is evidence of analytical thinking to creatively apply new learning in design and make tasks.

Figure 2.
Images of the completed artefacts in their intended environment

5. DISCUSSION AND CONCLUSION

The goal of this research was to develop an appropriate teaching strategy for including biomimicry in the design process as a means for encouraging pupils to "use a variety of approaches to generate creative ideas and avoid stereotypical responses" (DfE, 2013, p. 2). The year 9 pupils who participated in the study recognised that they needed a range of resources to develop solutions while using nature for design inspiration. The goal of the visit to the natural habitat next to the school compound was to have pupils' experience a real-life context of wildlife habitation in a natural environment and identify patterns found in nature. This allowed pupils to integrate their observations on how wildlife live with their proposals in responding to the design brief. Discussions with pupils elicited their fixation with patterns found in nature whilst developing their optimal solutions. Pupils' recognition of nature's solutions to problems was evident in the generation and development of ideas. In using biomimicry as an approach, several factors influenced the success of the project.

In this study the design brief was to solve a real-life problem for a client who required 'a range of nature inspired products that would encourage wildlife habitation in their school compound'. In developing solutions, the pupils had to make decisions about the appearance and construction, while considering different stakeholder preferences. Such decisions include how the item works and the technical decisions, which can be a tricky territory. In the case of an item to attract wildlife, for example birds, it works by being relatively inconspicuous – an aesthetic decision. Having the correct size hole to attract certain birds was an important part of observation that was then incorporated in the achieved construction design. If the pupils were trying to attract butterflies, then the decisions would require different observations and would involve different specifications in constructing a suitable home for wildlife. The interventions provided to pupils in their design and task enhanced their responses to the identified design need. The biomimicry approach was embraced by pupils who developed a range of original and creative nature inspired products, and our findings confirm that pupils valued opportunities that involve questioning solutions presented by nature. Each of the twelve pupils produced a prototype that had an inspiration from nature, not only in their form but also the decisions behind how the products would function.

One of the findings in this action research was that the context of the department and the resources that were available to us influenced the outcome of pupils' use of biomimicry as a design approach. Further research could be designed to understand pupils' understanding of biomimicry as a design approach. This would be helpful if integrated with an understanding of how this approach improves pupils' learning outcome in their Design and Technology classroom.

6. REFERENCES

Appio, F., Achiche, S., Martini, A., & Beaudry, C. (2017). On designers' use of biomimicry tools during the new product development process: an empirical investigation. *Technology Analysis & Strategic Management, 29*(7), 775-789. doi: 10.1080/09537325.2016.1236190

Barlex, D. (2011). Dear Minister, This is why design and technology is a very important subject in the school curriculum. *Design and Technology Education: An International Journal, 16*(3), 9-18. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/1660/1561

Barlex, D., & Steeg, T. (2017). *Re-building Design & Technology*. Retrieved June 26, 2022, from David and Torben for D&T: https://dandtfordandt.wordpress.com/resources/re-building-dt/

Benyus, J. (1997) *Biomimicry: Innovation Inspired by Nature*. New York: William Morrow.

Benson, C. (2017). Setting the Context: Design and Technology and Creativity. In C. Benson, & S. Lawson, *Teaching Design and Technology Creatively*. Routledge.

Cox, G. (2005:2, November 1). *Cox Review ofCreativity inBusiness: building on the UK's strengths.* Retrieved June 24, 2022, from STUDYLIB: https://studylib.es/doc/6210390/cox-review-of-creativity-in-business--building-on-the-uk

Department for Education (2013). *Design and technology programmes of study: key stage 3*. Retrieved from https://www.gov.uk: https://www.gov.uk/government/publications/national-curriculum-in-england-design-and-technology-programmes-of-study

Elmeligy, Dina. (2016). Biomimicry for ecologically sustainable design in architecture: a proposed methodological study. 45-57. 10.2495/ARC160051.

Fu, K., Sylcott, B., & Das, K. (2019). Using fMRI to deepen our understanding of design fixation. *Design Science, 5*, E22. doi:10.1017/dsj.2019.21

Klapwijk, R., & van den Burg, N. (2020). Involving students in sharing and clarifying learning intentions related to 21st century skills in primary design and technology education. *Design and Technology Education: An International Journal*, 8-34. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2788

Mburu, P. (2022). Leadership Perceptions in Design and Technology Education. In J. P. Williams, & B. von Mengersen, *Applications of Research in Technology Education: Helping Teachers Develop Research-Informed Practice* (pp. 17- 29). Singapore: Springer.

Pawlyn, M. (2019). Biomimicry in Architecture (2nd ed.). RIBA Publishing. https://doi.org/10.4324/9780429346774

Nicholl, B., Flutter, J., Hosking, I., & Clarkson, P. (2013). Joining up the DOTs: authentic teaching and learning in Design and Technology education. *Cambridge Journal of Education, 43*(4), 435-450. doi:10.1080/0305764X.2013.811219

Roobek, M. (2019) Biomimicry in the Classroom: How Biomimicry can be integrated in the Dutch curriculum. Retrieved June 23, 2022 from https://biolearn.eu/wp-content/uploads/2019/12/Research-Report-Matthijs-Roobeek-How-Biomimicry-can-be-integrated-in-the-Dutch-curriculum.pdf

Vierra, S. (2019, September 21). *Biomimicry: Designing To Model Nature*. Retrieved May 15, 2022, from Whole Building Design Guide: https://www.wbdg.org/resources/biomimicry-designing-model-nature

Wilson, V. (2013). Research Methods: Action Research. *Evidence Based Library and Information Practice, 8*(4), 160-162.