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Thinking with Card

Tactile and Making-Based Resources for Active Remote Learning in STEM Subjects

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Thinking with Card is an online resource that encourages active learning through making activities linked to subjects within core STEM curricula. The (bilingual) resources are aimed at Key Stage 2 and 3 students (UK) and Middle School students (China) (approx. age 7-14). The project was launched in July 2020 in response to the pandemic and corresponding need for stimulating activities suitable for home and remote learning. The free downloadable models can be printed and constructed using simple tools and have shown to help students understand complex concepts which are difficult to grasp from textbooks or even demonstrations (e.g., the relationship between magnetism and electricity, or the function of a four-stroke engine). The physical nature of these resources is also helpful for those looking for active learning approaches that are more inclusive in relation to dyslexia, where visual thinking and mechanical skills come more naturally. The development of future card models has been built into a course module for industrial design students that promotes and enhances prototyping skills.

Keywords: materiality; making; active learning

Introduction

This project was developed in response to the twin issues of reduced opportunity for making activities in the school timetable and the need for engaging learning materials suitable for use both at home and at school (during and post-Covid). According to a constructivist model, students' ideas and understanding are assembled in the mind of the learner, rather than some kind of 'transmission' of the knowledge. It follows that this learning should be supported by rich, well-designed experiences that challenge preconceptions and encourage an interrogation of the material (Driver et al., 1994). The pursuit of a 'rich' learning experience here fits with the model of learning identified by Kolb (2015): "Rich experiences, such as those which change and surprise or use all the senses, are more memorable." (p. 90). These fuel a process of 'Experiential Learning' where reflective observation and abstract conceptualization complement active experimentation and concrete experience (Kolb 2015). While science subjects have traditionally focused on experiments and lab work, there is evidence that genuine enquiry is being replaced by prescribed pattern "cook-book" type experiments that are less effective in fostering genuine enquiry (Hofstein & Lunetta, 2004). An effective substitute has been found in the use of simulations of experiments that provide meaningful representations that are not often possible with real materials. The use of the term 'model' in relation to the teaching of science and maths has multiple uses including abstract, conceptual, analogical, synthetic, mental, concrete etc. but it is clear that the use of tangible, tactile three-dimensional objects form an important part of this area of learning (Eisenberg, 2002). Our interest in developing this project was to provide straightforward, easily accessible activities that could be undertaken with basic tools – providing not only a novel, concrete experience but also an artefact from which students can reflect and further engage in abstract conceptualization.

Workshops with Card Material

Card-based workshops have been successfully deployed in exhibitions as a way of engaging visitors in more active learning about the subject area (Hughes & Milton, 2006), and the potential for their use in teaching has

been explored in the past, particularly in relation to areas of topography and mathematical models (Yamada & Kihara, 2017). This strategy was adopted in local workshops for schoolchildren (aged 6-11) in an attempt to promote making skills at an earlier age. Students in China have very little opportunity for hands-on making activities in the classroom and early on we found resistance to our offers of workshops and support in this area. These initial activities focused on making card mechanisms and structures linked to stories and festivals. In some cases the components were pre-cut ready for assembly, and in others the kids had to cut them out themselves before assembly and decoration. While the students clearly seemed to enjoy the activities and developed skills out of them, it was evident that this kind of work was deemed low status, not 'serious,' and best undertaken outside of school time by teachers. This was the catalyst for developing a new approach: to integrate making into the existing STEM curriculum as an 'active learning' aid rather than making for its own sake. This 'Trojan Horse' approach seemed to bear fruit, or at least gain traction with certain teachers. Whilst there is a great deal of pressure on both staff and students in the rigid Chinese education system, it has been acknowledged both centrally and by some enlightened teachers that new approaches are needed if the government's aim to foster creativity and innovation are to be achieved (Tatlow, 2019).

Active Learning

Active learning is a way of engaging students rather than treating them simply as 'receptors,' as is the case with a traditional lecture. Studies have shown these to be comparatively ineffective (Cerbin, 2018), even when combined with demonstrations (Crouch et al., 2004), when it comes to comprehension and long-term memory retention. 'Active learning' may involve reading, writing, discussing, analysis, problem-solving, synthesis, evaluation, but in the simplest terms has been described by Bonwell and Eison as: "Instructional activities involving students in doing things and thinking about what they are doing (1991)." Studies have shown that active learning is a highly effective strategy when it comes to teaching STEM subjects (Freeman et al., 2014). Subjects in this category tend to involve increasingly complex and abstract phenomena of which the student has no prior knowledge and cannot observe in a direct sense. In some subjects e.g., anatomy or chemistry, the use of models is well established and has been clearly shown to aid comprehension and reduce achievement gaps (Newman et al., 2018). In other subjects, the use of models is less well established, and the notion of students making the model themselves is completely novel. From a design perspective, this may be equated with the concept of 'learning-by-doing' with an emphasis on the importance of making.

Thinking with Card Project

This project combines both active learning and card-based workshop strategies with the aim that not only will students reap the benefits of increased comprehension and recall of complex phenomena, but that they will learn and develop practical skills in the process. These include: the safe use of knives, rulers and guides; cutting accurate shapes; accurate folding and construction techniques as well as exploration of basic mechanisms, topology of card structures, geometry, angular dimension and transformation (Huse, Bluemel & Taylor, 1994). These are core model making skills and helpful in a diverse range of prototyping activities. While there exist many more sophisticated and accurate modelling tools, it is widely considered that it is the direct experience of manipulating materials assists the kind of enquiry that facilitates a deeper learning experience (Yamada & Kihara, 2017).

The resource is located on a website, www.thinkingwithcard.com, from which teachers or parents can download a range of models for construction at home or school. The subject areas targeted include physical science (e.g., the relationship between magnetism and electricity, Faraday's Law of induction, Lenz's law and the Fleming Right Hand Rule), life science (e.g., the function of the epiglottis) and earth science (e.g., the processes of photosynthesis and respiration in plants). There are a range of models available in different curriculum areas and all models are available in English and Chinese. The website shows an animated version of each model which can be clicked to access the material needed to construct it at home. Each model includes the parts to cut out and a separate sheet of photo instructions to aid with the construction.

In order to make the models as universal as possible, they are each formatted for output in black and white to sheets of thin (e.g., 200gsm) A4 card (usually three or four sheets per model, including the instruction sheets). This means that they can be reproduced cheaply either at home or at school. Some models are also suitable for printing on paper if card is not available.

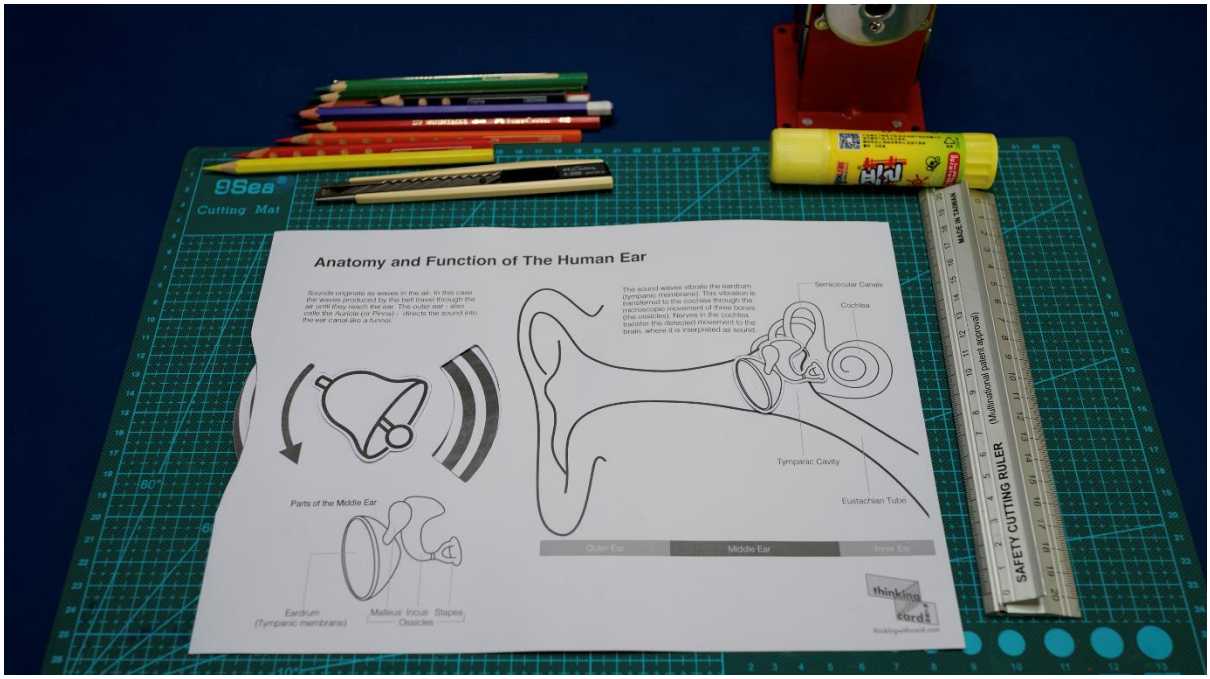

Figure 1. Example of a completed model showing the anatomy and function of the human ear.

Long Term Development of Project Material

A secondary area in which the project is being developed is in the development of the resources themselves. By establishing a standardised format and systematic means of communicating the models, we have been able to create a module for undergraduate and postgraduate students through which new models can be added to the resource. The identification, creation, refining and testing of the models is a deceptively complex challenge and a very rich learning experience. The use of card models is a central focus of the International Design Centre and one that has helped students develop a more hands-on approach to their work. This has been recognised as a crucial skill for designers (Yoshihara et al., 1991), but one that is not widely taught or implemented in China. At the beginning of the module, students are introduced to the project and then taken through a series of workshops to develop their skills in basic model making with card. They are then asked to identify an area of the Middle School curriculum on which they would like to focus on and are then supported through the conception, design and refining of card models in that area. A bid has been made recently to create an online MOOC version of the course which could be used to widen the scope of the project and generate further content.

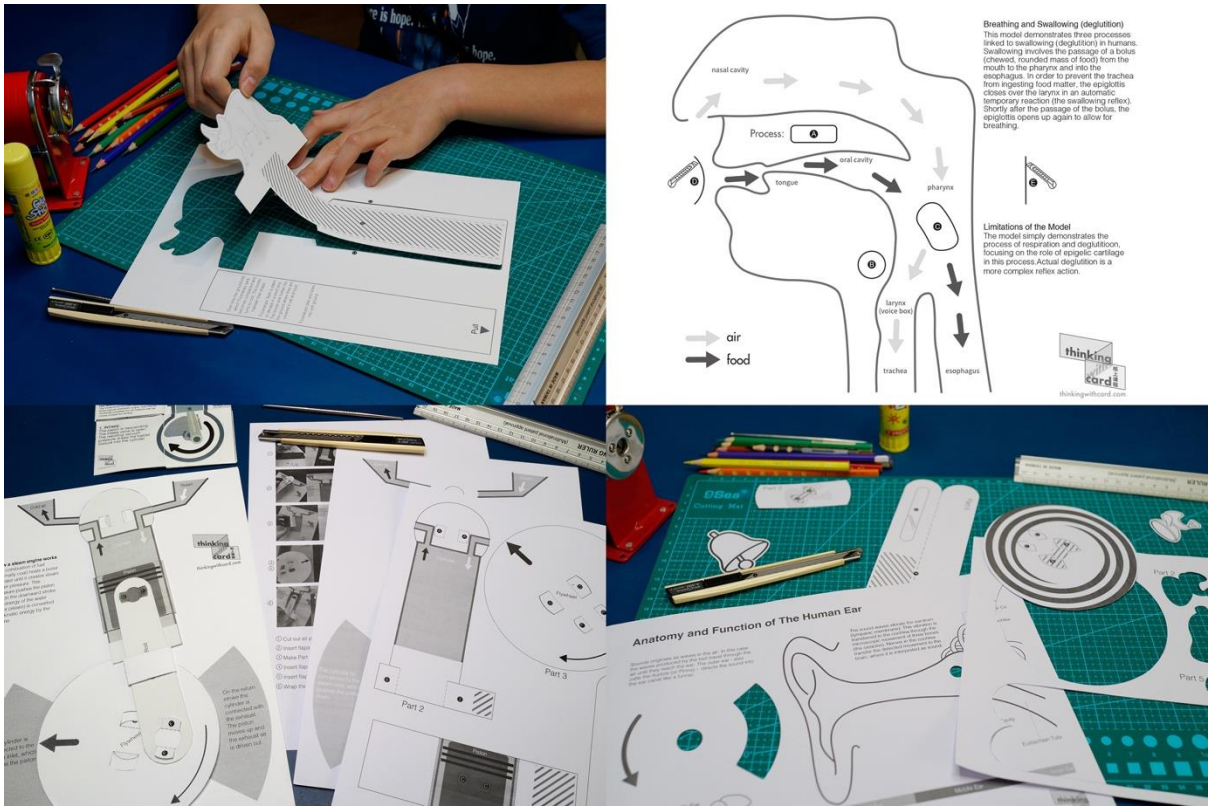

Figure 2. Some details of the resources, and instruction illustrations from the Thinking with Card resource.

Figure 3. Examples of the Thinking with Card resources and workshops run with students.

Testing and Conclusions

This project is in its early stages, but we have been successful in running several workshops to test the strategy on a local basis and obtain informal feedback from teachers. The workshops took the form of guided tuition in the building of the models held either in the design department or at a local school. Students attending were between 6-11. This is slightly lower than the target for the resources (7-14) but enabled us to gauge the level of interest amongst students, parents and teachers as well as to understand any difficulties experienced in making particular models. It was frustrating that the models of most interest to designers - those with the most complex and surprising mechanisms - were not always the most successful in terms of feedback from our teachers. The desire to create the kind of 'rich' learning experiences described in the introduction is a fun and challenging brief for most designers. Bringing life to static concepts and theories that might inspire a student is a great source of motivation. Without a comprehensive study to gauge students' reactions to the material, we only have some limited feedback from teachers. To date, some of the most positive feedback we received in this form was for a series of geographical study aids illustrating the different temperature and climate zones through the Chinese land mass. These are a complex series of maps with similar information that need to be memorised by each student. Perhaps the closest in form to existing standard textbook diagrams they are the least surprising models we created. Clearly the teachers recognised that the opportunity to not only draw the maps, but also to cut them out and be able to interact with them was an aid to comprehension and commitment to memory. It is exactly this kind of active learning that has been shown to enhance long-term memory retention, so it is encouraging to receive this feedback from teachers. There is a suspicion, however, that the teachers' enthusiasm was more down to the fact that the material might help students retain information needed to pass exams rather than fuel genuine interest and enquiry. This is indicative of the gap remaining in attitudes towards education in general. A fuller picture of the situation can only be found through production of further examples and more extensive testing. We still feel that there is a huge benefit to be gained from using card models to simulate and explain more complex phenomena particularly from the areas of life science and physical science. In relation to this, we are working with local teachers from the relevant subjects to advise on the format of the models.

Alternative Learning Styles, Card Models and Dyslexia

Dyslexia is not well recognised or diagnosed in China and discussion is generally limited to the effects in relation to the memorisation of Chinese characters rather than its wider impact on learning (Lin et al., 2020). Discussion with dyslexia specialists in the UK, however, suggests that the Thinking with Card strategy may be particularly helpful to dyslexic learners who respond well with visual and physical material. The models could help these students in the development of schema and visual memories that are more practical in relation to cognition and recall than text. These models of cognition are vital when it comes to the three stages of learning described by Mortimer (2008, p.124):

1. Getting the information in – modes of presentation
2. Processing the information – storing and retrieving
3. Getting the information out – modes of expression

This is an area that we intend to explore further in the future either by testing with dyslexic students and/or by taking advice from specialists in this area over the development of the resource.

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