Using educational theory and advanced technology in colour education

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ABSTRACT

This paper begins with an educational problem: the defects in how colour is often taught. It then uses educational theory to suggest an analysis of the problem in terms of a failure to connect learners' personal experiences of colour to the theories being taught. It then describes the development of a promising method for colour theory. Observations from a comparative study between this activity-centered learning method and learning from text are then discussed. Finally we exploit the impact of advanced 3D technology in color education after testing a preliminary version.

1. INTRODUCTION

This paper describes what was learned from the first stage of a project to develop an improved method of teaching colour theory that will eventually involve the application of advanced computer technology. We have developed initial versions of the method and run a trial of them on learners. Further related information, including photographs and illustrations, which there is not room to include in this paper, are available at http://www.psy.gla.ac.uk/~steve/patera/

2. THE PRE-EXISTING EDUCATIONAL PROBLEM

Colour is frequently not taught as a separate course but integrated into other subjects.[1] Occasionally it is not taught at all, even in programmes where it is important to students' subsequent professional practice e.g. art and design and architecture.

Too often a course may consist mainly of lectures and notes presenting highly abstract concepts, such as hue, value, saturation and colour-order systems. Didactic lectures on colour theory, with no visual teaching aids or practical activities, can lead to shallow learning, where students do not connect the theoretical concepts to real life situations. Black and white textbooks can be ineffective for building connections between symbols and visual recollection of the colours. In such cases, learners find it difficult to master the concepts, and hard to get motivated to learn.

On the other hand, some courses on colour are based on practical activities, excluding entirely the theoretical aspect. When practical assignments are not linked to any theory, they can also lead to limited learning that does not transfer or generalise well. Students tend to concentrate more on how to mix paints accurately and to cut out colour samples from magazines than actually reflecting on the purpose of the exercise.

We selected the small topic of the hue, value and saturation colour space as our first target for several reasons. We needed something conveniently concise for our initial work, partly in order to try out our overall strategy. Secondly, several studies[2] have shown that 3D virtual environments are particularly appropriate for teaching complex and abstract concepts and since colour space has an inherently three-dimensional nature, this could offer a significant advantage.

3. ANALYSIS OF THE PROBLEM USING EDUCATIONAL THEORY

Educational theory suggests that a better balance between theory and practice should result in a learning experience that is both more effective and more enjoyable. The most frequently mentioned educational concept is constructivism.[3] According to this theory, people do not just receive or reproduce, but actively (re)construct, new knowledge and understanding founded on what they already know and believe. This is also expressed in Laurillard's model[4] of the teaching and learning process, which asserts that all well-designed teaching will attend equally to both the public, abstract, conceptual aspects and to the private, concrete and experiential aspects of a topic, and also to creating connections between them.

In fact it is desirable to connect new ideas being taught to three things. Firstly, to the prior concepts (whether right or wrong) the learner may have embraced e.g. that the colours of the spectrum form a linear sequence and not a circle of hues, or that black and white are colours and thus should be included in the spectrum. Secondly, to their prior experiences of colour and using colour, especially since people experience colour from a very early age: it is not sensible to try to teach even a simplified theory that cannot deal with facts that the learner already knows. Thirdly to their present experiences: although some learning occurs without any actions being performed, it is also clear that important learning occurs through attempting tasks. Since colour is a perceptual experience, this is both important and relatively easy to arrange.

Educators need to build on these personal conceptions and experiences in ways that assist learners to achieve a deeper understanding of the subject. Thus in general, the design of learning materials should be preceded by an investigation into what the target learners typically think, rightly or wrongly, about the topic. It should also include practical activities where possible, partly because people learn by exercising the ideas they are trying to learn, but even more in order to link the theory to practical experience.

4. TUTORING METHOD

We therefore developed a teaching method for our chosen topic that consisted of a set of exercises in arranging colour samples guided by a set of prompts by a human tutor in the spirit of Socratic dialogue. This evolved into our design for effective teaching, satisfying the theoretical criteria discussed above and containing a balance of theory (the concept of three-dimensional colour-order systems) and practical experience (arranging and placing colour samples in relation to each other). However it also was valuable as a research method, because it gave prolonged opportunities for observing how participants arranged colours, the reasons they gave for their actions and what this revealed about the different ways people think of colour. We report on this in the next section.

The method we used was to give participants a pile of coloured squares (for instance 10 samples ranging from white through pink to fully saturated red) and then ask them to arrange them in any way they think is right. After they completed it, we asked them why they chose the arrangement they did. They would then be asked a few other probe questions: e.g. where they would now insert one or two more squares (handed to them) in their current arrangements. The sequence of tasks was generally:

- Arrange a set of squares coloured white through grey to black.
- Arrange a set of squares coloured white through pink to red.
- Arrange a set of squares coloured black through dark red to red.
- Combine the two previous sets (white-black, red-black) of squares into a single scheme.
- Combine all three sets (white-black, red-black, red-white).
- Arrange a set of squares of fully saturated hues.
- Combine these (the hues) with the red to white set.
- Combine these two sets with the red to black set.
- Combine these three sets with the black to white set.
- Next, a cardboard skeleton of a sphere, with the vertical axis already marked as the gradient from black to white, and with Velcro tabs on, was put on the table; and they were asked to attach all the squares they had on it.
- Finally a set of test questions might be asked, including pointing to where a new probe colour should be placed within the 3D sphere; and what shade of colour should correspond to a point within the sphere pointed to by the tutor.

We also implemented an alternative digital way of presenting this, using 3D digital models built in the Maya software package on a desktop computer to replace the material cardboard squares and sphere (but still with a human tutor presenting the tasks and asking probe questions) and tested this too on a set of participants.

5. THE STUDY

We compared learning using the cardboard equipment, the computer models and a text (compiled from passages from several textbooks). We also compared performance on immediate post-tests i.e. at the end of the learning phase, with performance on delayed post-tests i.e. about a week later. We used participants, about 50 in total, who were mostly but not all in their early twenties, from a variety of backgrounds. Some had art and design backgrounds, others had not. All those given the computer models had current experience on using the same computer modelling software, so that familiarity with the user interface conventions would not be an issue.

While the participants were performing the tasks, notes, photographs and some video were taken in order to record the process. In this paper we report the observations made in this way.

6. OBSERVATIONS

The first strong impression is that those performing the material version of the learning tasks found it enjoyable and indeed absorbing. Even those who took over an hour to complete them all, were surprised at how the time had passed and never showed any signs of fatigue or boredom. These participants often used the word “play”, while the ones who performed the digital version considered it more like a problem-solving task. None of this could be said of those with the textbook version.

Every person arranged the coloured tiles in a different way. As regards spatial relations, the patterns the participants formed varied from straight lines, circles and triangles to squares, spirals, stars and zigzag diagonal patterns. Particularly in early trials, the fact that our samples were themselves square in shape (whereas we could have made them circular, say) often seemed to influence people to use square or rectangular layouts. They also tended to reason in terms of the number of tiles in the current problem e.g. if there were eight, then a three by three square layout might be attractive.

One of the reasons for developing the digital version was to provide the participants with the option to utilize the third dimension, which a flat tabletop might prevent them from considering. They were told at the beginning of the test that they were free to use all the views available in the software -orthographic or perspective- and switch between them. Yet, most "digital" participants performed the task using the top view and did not consider using the third dimension.

As regards the properties they were expressing in their spatial layouts, some participants were organising the colours according to their intensity or hue, while others were dividing them as cool and warm and many said they were arranging them by lightness, even in cases where the samples they were working on had been intended by us to show equal brightness, although limitations in the colour printing used to generate the tiles meant this was imperfect. Only a couple of them argued that colours should be randomly scattered and one claimed that colours are like music notes.

In the early development of our tutoring method, it emerged that the number of samples in a set was a significant issue. From the point of view of rapidly sorting samples on a given dimension, a small number seemed most convenient. However for getting learners to see a set as a smooth sequence of a single varying property, a powerful intervention or question was to offer another intermediate value and ask where it could be inserted into an arrangement. Introducing more and more fine distinctions seems important in dislodging people from the opposite tendency of seeing colour in terms of a small handful of landmark primary colours with no particular relationship to each other. This is in fact a form of a very general educational tactic that can be important in quite different areas, is sometimes known as "bridging"[5,6,7] and which consists essentially of suggesting the learner to consider an intermediate case midway between two cases they regard as poles apart and unrelated, in order to see a connection between them.

The great variety of ways of arranging the squares, both spatially and in terms of the colour properties expressed, was true for both those from an Art school background and from a computing background. It shows, however, that this kind of approach is effective at eliciting from each learner the properties of colour they are already aware of and which ideally they need to relate to any abstract theory or organising principle. This remains true that colour-order systems only express some properties of colour. A full appreciation of the theory should also include a definite realisation of the properties it does not capture e.g. the cool/warm dimension or the emotional connotations of different colours, as well as of the satisfactory integration of the properties it does address.

The majority of the participants did not have a clear mental model of how all possible colours could be related before the 3D sphere model was presented to them; however after arranging the tiles in each task, most of them provided good reasons to support their schemes. When the 3D sphere model was presented to them, most of them agreed that it related colours in a coherent way and tried to revise their conceptions. A literal interpretation of the notion of constructivism and of Socratic dialogue, is that each learner should construct the target concept for themselves, perhaps under the impact of experiences and questions arranged by the teacher. This was what we aimed for, but in most cases did not achieve in this version of tutoring method. However, our impression from our observations is that this may not matter. It may be that all that is important is first to get learners thinking of their own notions of colour, whether explicit or implicit and to address the question of how to organise colours, and so to grasp, both practically and intellectually, that this is a problem that is not trivial, but which perhaps could be solved. In contrast, texts describing the specific colour-order system do not prompt readers to discuss whether a cylinder for example would or would not be just as good as a sphere or why the axis must progress from black to white.

7. DIGITAL VERSUS MATERIAL VERSIONS

As noted above, we tested our tutoring method on both a cardboard and a computer version. The preliminary data and the researchers' observations do not suggest any great difference in the effectiveness or enjoyableness between these two implementations. However, the digital version proved more flexible since it could be updated and altered much more rapidly and easily by a programmer than the cardboard materials. It is also portable and can run on most computer systems. The physical model needs a large carrier bag to carry around and it requires plenty of space, usually a big tabletop (about 1by .5 meters), larger than most desks. After a number of tests, the cardboard began to bend and crush unlike the digital version, which of course does not wear out.

In the future, we will explore the automation of the human tutor. Furthermore, participants reported enjoying “playing” with the cardboard squares because they could touch them, so colour education may also be able to benefit from the use of haptics and other advanced technology.

8. CONCLUSIONS

Preliminary inspection of results from these early trials suggest that there is no great difference between digital and material implementations of our tutoring method and so that further development of digital versions is worthwhile to gain the advantages of robustness and ease of distribution. Participants seemed to retain their knowledge longer from our tutoring methods than did those who were given a passage from a textbook on the same theory. This is consistent with our analysis based on educational theory. However still more benefit may be obtainable if we are able to improve our tutoring method further in the light of our observations. The challenge is to refine it so that participants gain a fuller appreciation of the concept of colour-order systems (a way of organising all possible colours into three dimensions) and what aspects of their ways of thinking it does not directly accommodate, even though they are valid, such as express divisions of colours into "warm" and "cool".

References

1. Bergstrom, B., “Creative Colour Education”, AIC Colour 01, Rochester, USA, (2001).
2. Winn, W., “The Impact of Three-Dimensional Immersive Virtual Environments on Modern Pedagogy”, HITL Technical Report R-97-15, Human Interface Technology Laboratory, University of Washington, Seattle, WA, USA, (1997).
3. Larochelle, M., Bednarz, N., Garrison, J., *Constructivism and education,* (Cambridge University Press, Cambridge, 1998).
4. Laurillard, D., *Rethinking university teaching: a framework for the effective use of educational technolog, (*Routledge, London, 1993).
5. Brown, D., and J. Clement, “Classroom teaching experiments in mechanics” in Research in Physics Learning: Theoretical Issues and Empirical Studies, R. Duit, F. Goldberg, and H. Niedderer, eds. (San Diego, Calif.: San Diego State University, 1991).
6. Brown, D., and Clement, J., “Overcoming misconceptions via analogical reasoning: Factors influencing understanding in a teaching experiment.” in *Instructional Science*, 18: 237-261, (1989).
7. Brown, D.E., “Using examples and analogies to remediate misconceptions in physics: Factors influencing conceptual change.” In the *Journal of Research in Science Teaching*, 29, 17-34, (1992).