Two Polarization-based Games

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1 Introduction

For pupils and students, polarization is a rather difficult topic lacking the vividness of most other optical phenomena. Direct observation of polarization is not really possible[1] and, therefore, motivation to understand polarization is often not very high.

It is intimating to try to raise motivation by surprising demonstrations. Apart from the well known experiments (two or three polarizers in series, strain measurement by birefringence, polarizers in photography, just to name a few) I tried raising interest by using polarization-based games.

In the following, I shortly introduce two games and then give a conclusion about their value as educational tools.

2 Four-in-a-row: The polarization version

I assume you are familiar with the old game "Four-in-a-row", also known as "Connect Four". It is a two-player board game[2] in which the objective is to be the first to get four of one's own pieces in a horizontal, vertical, or diagonal (45 degrees) line.

For the polarization-based version we use different polarizations instead of different colors for the two players. That way, the players do not see which fields are occupied by their pieces. Rather they have to remember where they have put them. Only if they look through a polarizer they see their pieces.

During the game each player is allowed to peek only three times through the polarizer but he can at least decide *when* he wants to use the polarizer. By this approach, we introduce a memorization and a tactical component into the classic "Four-in-a-row".

Fig. 1 shows the board when looking at it without and with a polarizer. Dependent on the rotation of the polarizer one sees the pieces of player one or player two. To make the game more visually pleasing the polarizers are mounted on top of birefringent (polyethylene) material so that we see nice colors due to the strain in the material.

Schematically, the optical setup is shown in Fig. 2. I used small square plastic boxes for the board. The caps of the boxes, where the main polarizers are attached, therefore, can be rotated in two different ways, corresponding to the two players.

As in the original "Four-in-a-row", the basic board layout uses seven columns. One might think that other layouts work equally well, but this is not true. An uneven number of columns is necessary. The central column has a strategic advantage, so that (experienced) players try to control that column.

I only want to point out two of the many possible variations:

- Better players might be forced to play with a reduced number of possibilities to peek through the polarizers.
- Other, more complicated patterns might have to be realized (e.g., 4-in-a-block, some specific binary numbers).

Playtesting, first in the family and then with children and teenagers at an open house day of the university, lead to the following results:

1.) It turned out that putting the "pieces" (the caps of the boxes) the correct way onto the plastic boxes is a little bit difficult because you have to use them in the right orientation. Small kids (below an age of about 10) need help.

2.) The usability might be further improved, if the polarizers would have been mounted differently so that one would see (without rotating the polarizer) black (player 1), white (player 2), and grey (not occupied).

3.) Also it turned out (not really surprising) that people were able to memorize the board for quite a long time. But at a certain moment, when enough pieces had been used, they would need the polarizer for nearly every or every second move.

My personal impression is that the game is not that much fun. Somehow the combination of memorization and "Four-in-a-row" is not really convincing. The

[1] neglecting the not very spectacular Haidinger brush phenomenon
[2] It can be played also with pencil and paper.

(a) without polarizer (b) polarizer under 0° (c) polarizer under 90°

Fig. 1: Polarization version of "Four-in-a-row": Only by looking through a polarizer the pieces of players One and Two can be discerned.

colorful (birefringence) appearance makes the game an interesting eye-catcher for events like open house day. But for such occasions the game is a little bit too long, too complicated, needs too much concentration and explanation.

3 Polarization-based puzzle

Fig. 3 shows a birefringence-based puzzle. Again, we use the same caps of plastic boxes. The playing area is just a glass plate illuminated with polarized light[3].

The birefringent plastic is illuminated with polarized light. After passage through plastic and the second polarizer (the analyzer) this leads to a colorful pattern. Of course, the pattern depends on the strain and the thickness of the plastic between the polarizers.

The aim of the game is to align 9 (or 16) pieces correctly so that they resemble the "solution pattern" which has been printed out before and is given to the player. This, at first, sounds simple because it is a puzzle with only 9 pieces. But the pieces change as you rotate them. In practice children need about five minutes to solve the 9 pieces problem.

The fascinating thing really is the experience that the pieces change as you rotate them. Also the game can be easily explained (even to small children) and it can be played alone (with only one visitor). Therefore, it is indeed very much suited for occasions like trade-shows or open house days.

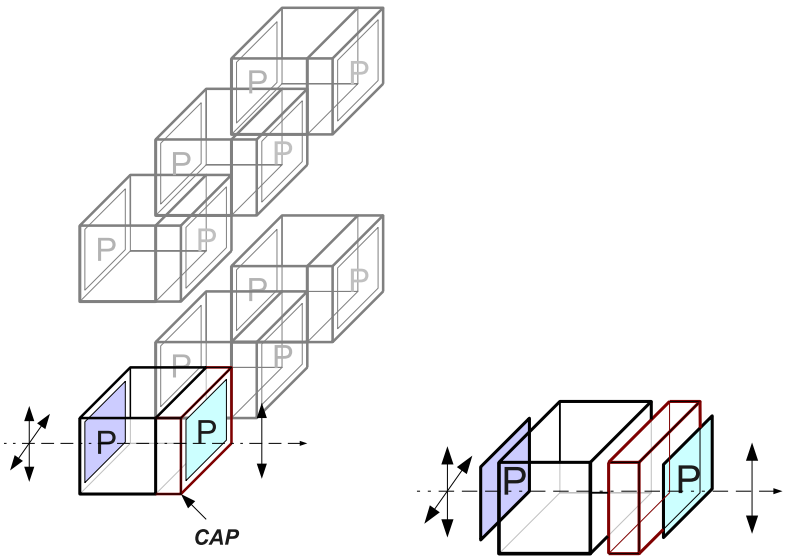
4 Does all this help for teaching?

Both games are eye-catchers and at least the polarization puzzle makes sense for special events. But both games are not really useful for the purpose of optics education. The colorful birefringence phenomenon is unfortunately quite complicated. You have to know at least something about waves and interference to understand how the colors arise. Therefore, it might be only used in education for students studying optics. For children it is way too complicated.

For students studying optics on the other hand, I think the phenomenon alone is interesting and motivating enough so that you do not need a puzzle to keep their motivation high.

So in conclusion, the "Four-in-a-row" game is a very nice eye-catcher but not a very good game and I cannot see a real application for it. The "polarization-puzzle" is also visually interesting and it can be used for trade-shows, other special events, or science parks.

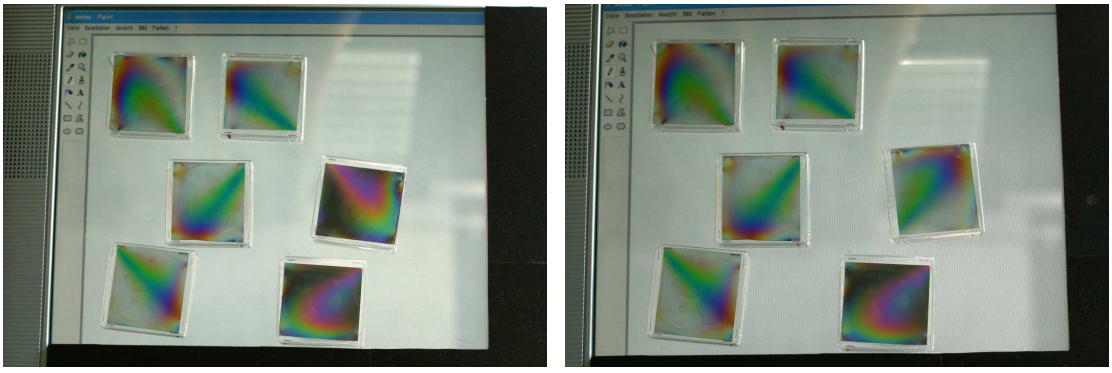
[3] The easiest way of implementation is to use an LCD screen.



(a) some of the boxes

(b) explosion view of one box with cap

Fig. 2: Polarization version of “Four-in-a-row”: Optics



(a) Original setup

(b) Same setup with one piece rotated

Fig. 3: Polarization Puzzle: The pieces have to positioned and orientated so that a given pattern becomes visible. The pieces change their color if they are rotated because of the birefringence of the plastic.