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An Alternative Proposal for the Graphical Representation of Anticolor Charge

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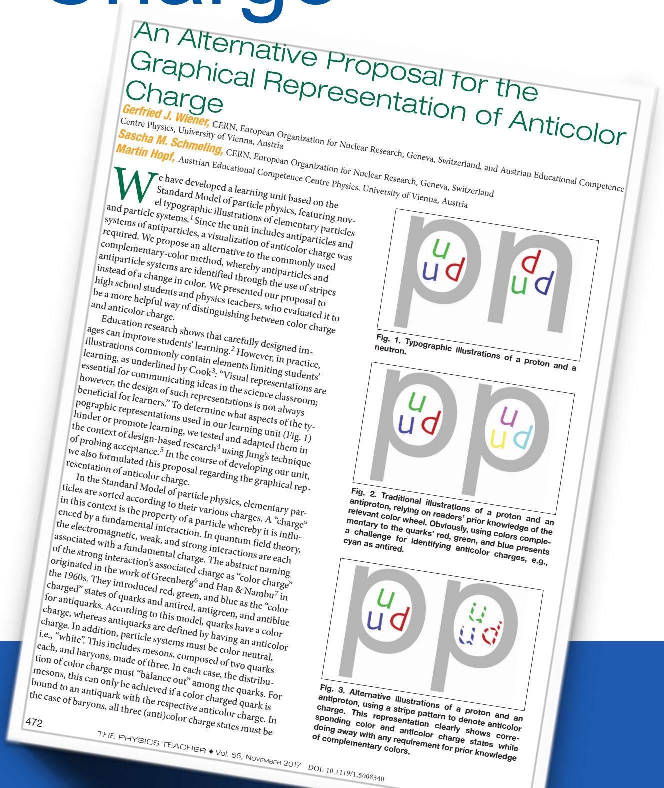

An Alternative Proposal for the Graphical Representation of Anticolor Charge

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Sascha M. Schmeling, CERN, European Organization for Nuclear Research, Geneva, Switzerland
Martin Hopf, Austrian Educational Competence Centre Physics, University of Vienna, Austria

We have developed a learning unit based on the Standard Model of particle physics, featuring novel typographic illustrations of elementary particles and particle systems.[1] Since the unit includes antiparticles and systems of antiparticles, a visualization of anticolor charge was required. We propose an alternative to the commonly used complementary-color method, whereby antiparticles and antiparticle systems are identified through the use of stripes instead of a change in color. We presented our proposal to high school students and physics teachers, who evaluated it to be a more helpful way of distinguishing between color charge and anticolor charge.

Education research shows that carefully designed images can improve students' learning.[2] However, in practice, illustrations commonly contain elements limiting students' learning, as underlined by Cook[3]: "Visual representations are essential for communicating ideas in the science classroom; however, the design of such representations is not always beneficial for learners." To determine what aspects of the typographic representations used in our learning unit (Fig. 1) hinder or promote learning, we tested and adapted them in the context of design-based research[4] using Jung's technique of probing acceptance.[5] In the course of developing our unit, we also formulated this proposal regarding the graphical representation of anticolor charge.

In the Standard Model of particle physics, elementary particles are sorted according to their various charges. A "charge" in this context is the property of a particle whereby it is influenced by a fundamental interaction. In quantum field theory, the electromagnetic, weak, and strong interactions are each associated with a fundamental charge. The abstract naming of the strong interaction's associated charge as "color charge" originated in the work of Greenberg[6] and Han & Nambu[7] in the 1960s. They introduced red, green, and blue as the "color charged" states of quarks and antired, antigreen, and antiblue for antiquarks. According to this model, quarks have a color charge, whereas antiquarks are defined by having an anticolor charge. In addition, particle systems must be color neutral, i.e., "white". This includes mesons, composed of two quarks each, and baryons, made of three. In each case, the distribution of color charge must "balance out" among the quarks. For mesons, this can only be achieved if a color charged quark is bound to an antiquark with the respective anticolor charge. In the case of baryons, all three (anti)color charge states must be

Fig. 1. Typographic illustrations of a proton and a neutron.

Fig. 2. Traditional illustrations of a proton and an antiproton, relying on readers' prior knowledge of the relevant color wheel. Obviously, using colors complementary to the quarks' red, green, and blue presents a challenge for identifying anticolor charges, e.g., cyan as antired.

Fig. 3. Alternative illustrations of a proton and an antiproton, using a stripe pattern to denote anticolor charge. This representation clearly shows corresponding color and anticolor charge states while doing away with any requirement for prior knowledge of complementary colors.

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“Visual representations are essential for communicating ideas in the science classroom; however, the design of such representations is not always beneficial for learners.”

Cook, M. P. (**2006**). Visual representations in science education: the influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education*, 90, 1073–1091

The Standard Model of Particle Physics

Electromagnetic interaction	Electric charge
Weak interaction	Weak charge
Strong interaction	Color charge

The Standard Model of Particle Physics

Electromagnetic interaction	Electric charge
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Strong interaction	Color charge

The Model of Color Charge

red	antired
green	antigreen
blue	antiblue

The Model of Color Charge

particles	red	antired
	green	antigreen
	blue	antiblue

The Model of Color Charge

particles			antiparticles
	red	antired	
	green	antigreen	
	blue	antiblue	

The Model of Color Charge

	red	antired	
particles	green	antigreen	antiparticles
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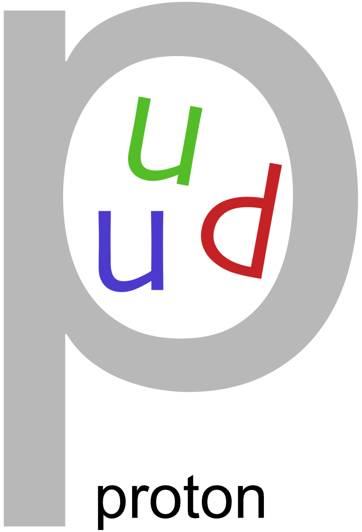
Greenberg, O. W. (**1964**). Spin and unitary-spin independence in a paraquark model of baryons and mesons. *Physical Review Letters*, 13(20), 598–602

Han, M. Y. & Nambu, Y. (**1965**). Three-triplet model with double SU(3) symmetry. *Physical Review*, 139(4B), 1006–1010

The Model of Color Charge

The Model of Color Charge

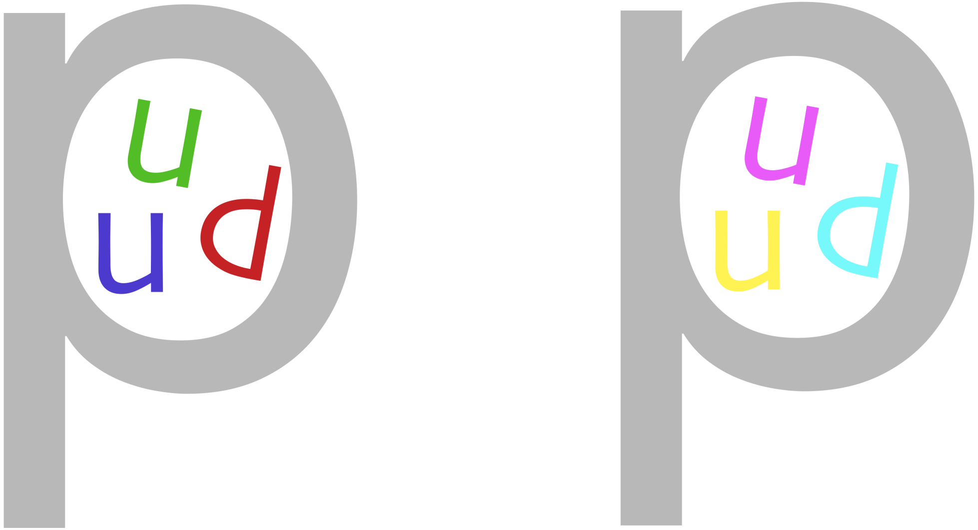


The Model of Color Charge

“Is not the complementary color of blue, orange, of green, red, and of yellow, pink?”

[student, age 17; translated from the original German]

Alternative Proposal



Alternative Proposal

Evaluation of the Alternative Proposal

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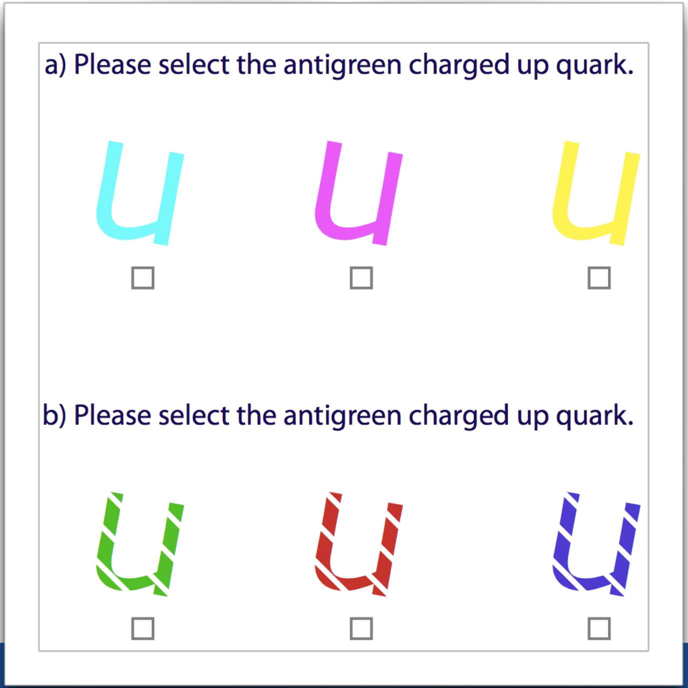

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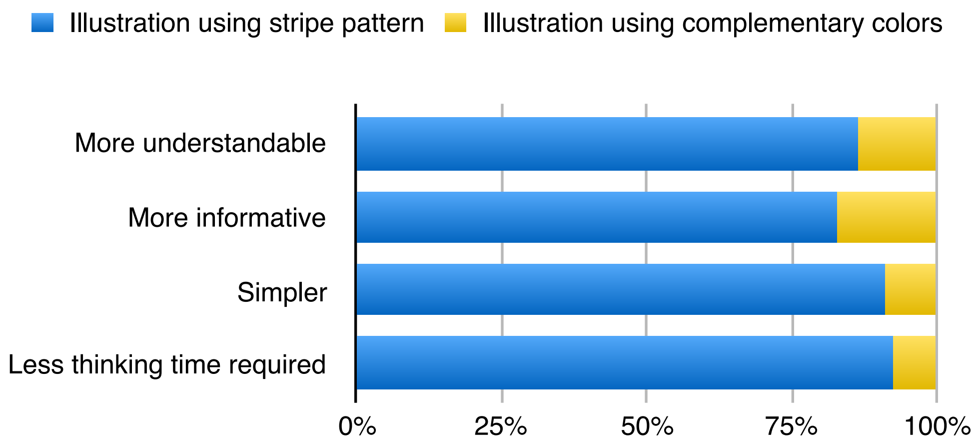

Students' assessments of the two illustration methods (ages 16-17, n=78)

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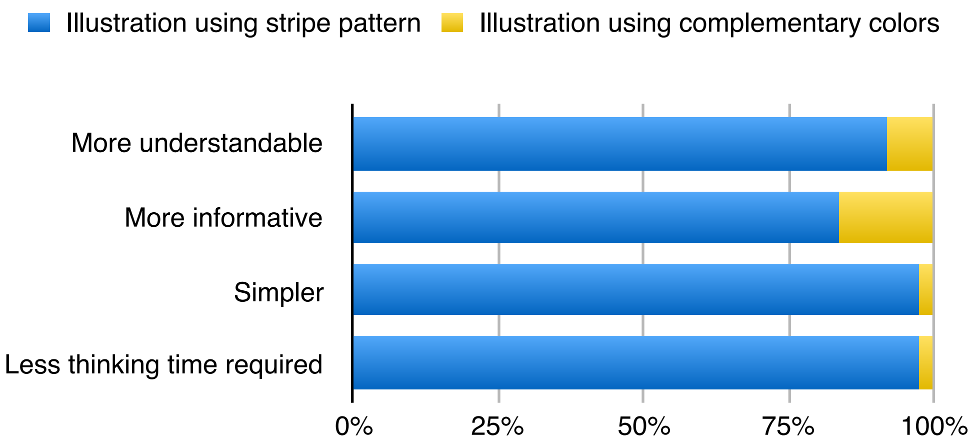

Teachers' assessments of the two illustration methods (n=45)

Merci bien!

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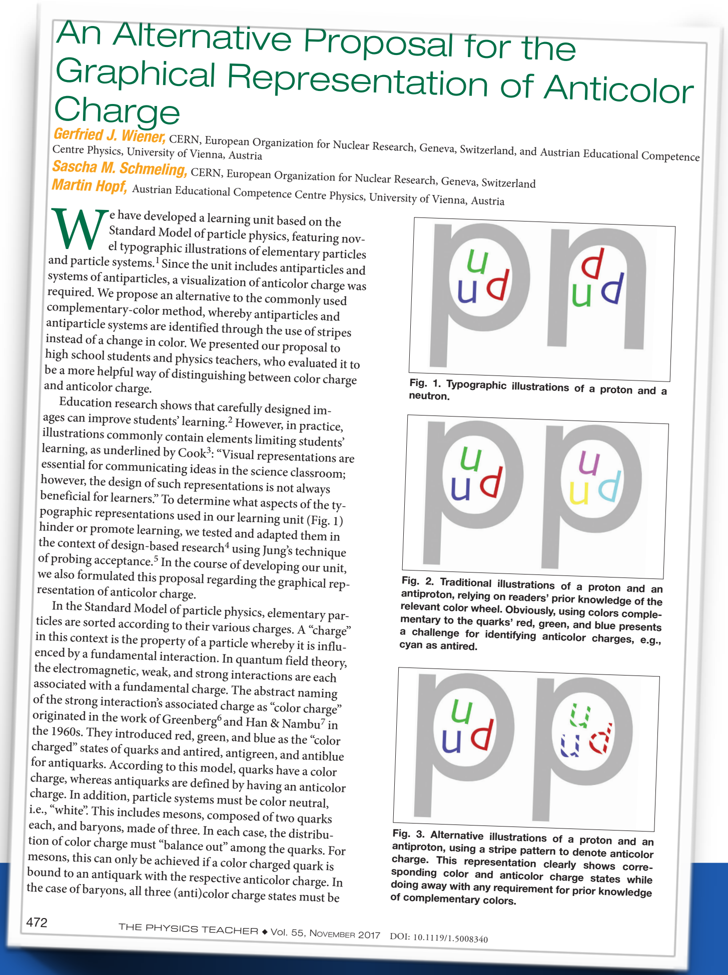

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