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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** An Alternative Proposal for the

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V CRN European Organization for Nuclear Research, Geneva, Switzerland, and Auterian Educational Competence relay of Vienna. Autoria ле город, очиватор от честик линика Scha M. Schmeling, CERN, European Organization for Nuclear Research, Geneva, Switzerland and a second sec e nave uv vetopeu « cen ming umi totstu un tots Standard Model of particle physics, featuring nov. el typographic illustrations of elementary particles and particle systems. Since the unit includes antiparticles and and year total systems of antiparticles, a visualization of anticolor charge was systems on sample uses, a vanimetron or attraction states w required. We propose an alternative to the commonly used required, we propose an area native to the continuity used complementary color method, whereby antiparticles and compremensary coror methods, whereav antiparticles and antiparticle systems are identified through the use of stripes antipacticle systems are nonunied mough ine use or stripes instead of a change in color. We presented our proposal to high school students and physics teachers, who evaluated it to ingu x man susaens and purpose teneral a with commune to co be a more helpful way of distinguishing between color charge

an anucour cnarge. Education research shows that carefully designed images can improve students' learning.² However, in practice, ages can improve surveing reasoning, crowever, in practice, illustrations commonly contain elements limiting students? learning, as underlined by Cook?. "Visual representations are esential for communicating ideas in the science classroom: essential tox communicating areas in the actence cases com-however, the design of such representations is not always 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) Pographic representations used in our rearing unit (res. 1) hinder or promote learning, we tested and adapted them in nnuer ou promote tearring, we testeu uno auapteu unem tu the context of design-based research⁴ using lungs technique the context or design-based research using jungs technique of probing acceptance.⁵ In the course of developing our unit, or prooning acceptance. In the course or descripting our states, we also formulated this proposal regarding the graphical rep-Nentation or autoour cuarge. In the Standard Model of particle physics, elementary par-

the constance of particle physics, extraction year licles are sorted according to their various charges. A "charge" In this context is the property of a particle whereby it is influ-In two context is the property of a particle whereby it is more enced by a fundamental interaction. In quantum field theory, encer of a tunnamental micraction. In quantum view view of the electromagnetic, weak, and strong interactions are each increasing of the second standard stands and stand associated with a tunuamental citatise. The austract training of the strong interaction's associated charge as "color charge" or me survey unce actions associated charge as color charge originated in the work of Greenberge and Han & Nambu' in originateo in the work or creenoers, and the origination in the 1960s. They introduced red, green, and blue as the 'color harged" states of quarks and antired, antigreen, and only of the control charged. for antiquarks. According to this model, quarks have a color too autoquares, recording to this moure, quares maye a conn charge, whereas antiquarks are defined by having an anticolor charge. In addition, particle systems must be color neutral, strates in acountor, particle systems inset to constitution, i.e., "white" This includes mesons, composed of two quarks each, and baryons, made of three. In each case, the distribueach, and pay yons, made or three, the each take, the user too. the thouse the one of the one of the quarks. For mesons, this can only be achieved if a color charged quarks. For bound to an antiquark with the respective anticolor charge. In the case of baryons, all three (anti)color charge states must be THE PHYSICS TEACHER • Vol. 55, November 2017 DOI: 16.1119/1.508140



Fig. 3. Alternative illustrations of a proton and an Fig. 3. Alternative illustrations of a proton and an antiproton, using a stripe pattern to denote anticologic observe. This processitation clock the stress terms of the stress of the antiproton, using a stripe pattern to denote anticolor charge. This representation clearly shows corre-source of and anticolor charge these these charge. This representation clearly snows corre-sponding color and anticolor charge states while sponsong color and anticolor charge states while doing away with any requirement for prior knowledge of complementary colors

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Graphical Representation of Anticolor

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Fig. 2. Traditional illustrations of a proton and an

Fig. 2: Traditional Illustrations of a proton and an antiproton, relying on readers' prior knowledge of the antiproton, relying on readers' prior knowledge of the second seco

ant/proton, relying on readers' pror knowledge or the relevant color wheel. Obviously, using colors complerelevant color wheel. Upvously, using colors complex mentary to the quarks' red, green, and blue presents

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mentary to the quarks' red, green, and blue presents a challenge for identifying anticolor charges, e.g.,

Fig. 1. Typographic illustrations of a proton and a

"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



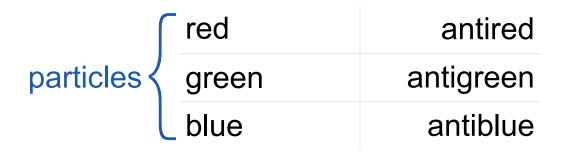
The Standard Model of Particle Physics

Electromagnetic interaction	Electric charge
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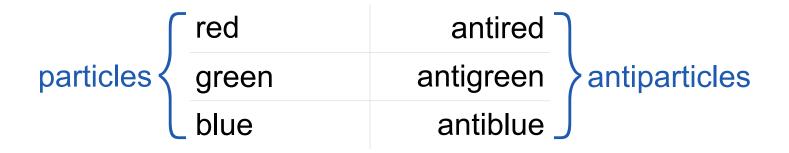


red	antired
green	antigreen
blue	antiblue

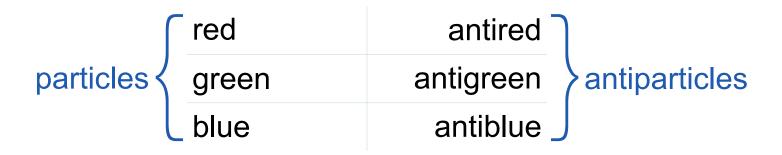










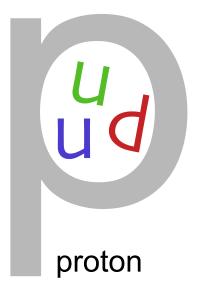


Greenberg, O. W. (**1964**). Spin and unitary-spin independence in a paraquark model of baryons and mesons. *Physical Review Letters*, 13(20), 598–602

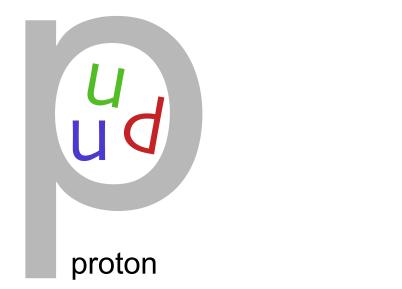
Han, M. Y. & Nambu, Y. (**1965**). Three-triplet model with double SU(3) symmetry. *Physical Review*, 139(4B), 1006–1010

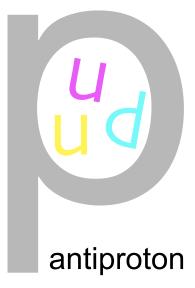












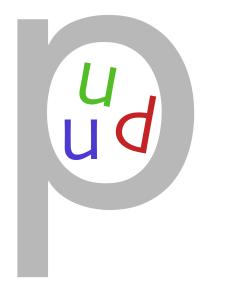


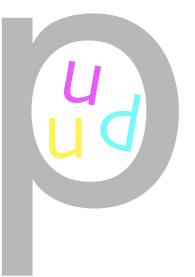
"Is not the complementary color of blue, orange, of green, red, and of yellow, pink?"

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



Alternative Proposal







Alternative Proposal







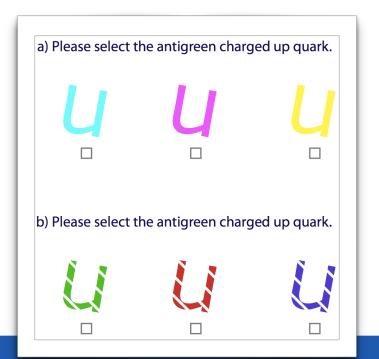
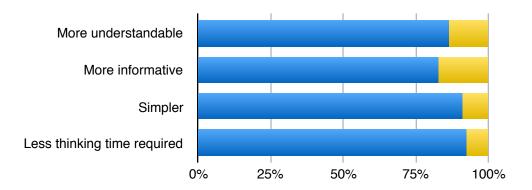




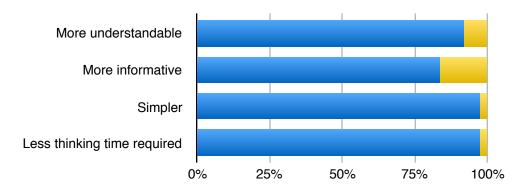
Illustration using stripe pattern Illustration using complementary colors



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



Illustration using stripe pattern Illustration using complementary colors



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



Merci bien!

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An Alternative Proposal for the Graphical Representation of Anticolor Charge

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e have developed a learning unit based on the Standard Model of particle physics, featuring nov-el 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 Cook3: "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 research4 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 Greenberg6 and Han & Nambu7 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

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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.

