Learning Particle Physics with DIY Play Dough Model

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Abstract. The scientists once believed an atom was the smallest particle, nothing was smaller than this tiny particle. Later, they discovered an atom which consists of protons, neutrons and electrons, and they believed that these particles cannot be broken into the smaller particles. According to advanced technology, the scientists have discovered these particles are consisted of a smaller particles. The new particles are called quarks leptons and bosons which we called fundamental particle. Atomic structure cannot be observed directly, so it is complicated for studying these particles. To help the students get more understanding of its properties, so the researcher develops the learning pattern of fundamental particles from Play Dough Model for high school to graduate students. Four step of learning are 1) to introduces the concept of the fundamental particles discovery 2) to play the Happy Families game by using fundamental particles cards 3) to design and make their particle in a way that reflects its properties 4) to represents their particles from Play Dough Model. After doing activities, the students had more conceptual understanding and better memorability on fundamental particles. In addition, the students gained collaborative working experience among their friends also.

1. Introduction

The scientists discovered an atom was the smallest particle, nothing was smaller than this one. But later, in 1895, J.J. Thomson found the electron, and it is the structure of each atom. Later in 1911, Ernest Rutherford found that atoms have their charge concentrated in a very small nucleus and named proton. The atom was believed to be composed of a positively charged nucleus surrounded by negatively charged electrons. Until in 1932, James Chadwick found the neutral electrical charge and the approximate mass of a proton. This particle became known as the neutron. With the discovery of the neutron, so an atom model structure consisted of proton, neutron and electron, which called fundamental particles.

Since 1932, through continued experimentation, many additional particles have been discovered in the atom. The atomic theory has been further enhanced by the concept that protons and neutrons are made of even smaller particles called quarks and gluon. The currently standard model of fundamental particles were 3 groups of particles, quarks leptons and bosons. Each group consists of six particles. Six of quarks are paired in the three generations, the “up quark” and the “down quark” form the first generation, followed by the “charm quark” and “strange quark”, and then the “top quark” and “bottom (beauty) quark”. The six leptons are similarly arranged in three generations, the “electron” and the “electron neutrino”, the “muon” and the “muon neutrino”, and the “tau” and the “tau neutrino”.

Quarks and lepton have the same identical but only differ of charge, which called anti-quark and anti-lepton. Boson is the force-carrier particles, “gluon”, “photon”, “W+” , “ W-” and “Z bosons” , and “Higgs” is the last boson [1].

From above data, more number of fundamental particles made difficulty to learn for students. According to the result of conceptual mapping, which indicated that many students were confused to group the particles [2]. The methods from the research to solves them such as The Particle Physics Workshop helps students gaining the comprehension of particles in physics[1] The second method was using disk magnetic which represented as quark then student compose three neodymium disc magnets into models of proton and neutron [3].

This study, to get more understanding of the fundamental particles by apply The Happy Families Games [4], [5] and made particles model from “Play Dough” to develop creativity in students with imagination and collaborative of them in a fun way. Previous paper reported that game made enjoinment in class [6], [7]. Other reported its made more ability of their memory and activity to for learning of students [8].

2. Methods

In this study, the researchers to implemented with the undergraduate students in science program. First, the instructor introduces the concept of the fundamental particles. The scientists have discovered that atoms are made out of smaller particles, which we call protons and neutrons, and these in turn are made out of even smaller particles called quarks and gluons, and they found other particles which are the currently standard model of fundamental particles. Then the instructor explains about the accelerator particles (Large Hadron Collider - LHC) at CERN.

After, the students play the Happy Families game[4], using cards to familiarize themselves with the names of the fundamental particles and their characteristics. One pack of 30 cards per group, the maximum number of student per group was five. The set contains one card for each fundamental particle, with the name, symbol, group of particles , its mass (very light, light, heavy and very heavy) and its charge (Figure 1). One card set consists of the thirty fundamental particles of matter and antimatter shown in table 1.

After playing the Happy Families game students, each student is assigned to one card particle. Students are asked to use their imagination and creativity to design for their particle in a way that it reflects its properties. Pairs of students work together on matter and antimatter because their particles have same identity but different charge.

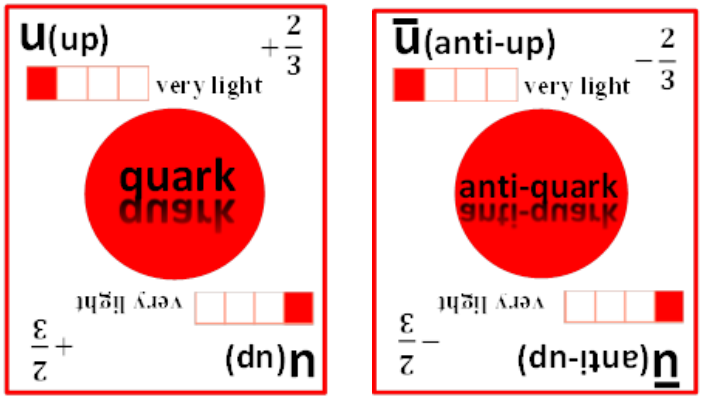

Figure 1. the example of card which consists of the name of particle, symbol, group of particles, mass (very light, light, heavy and very heavy) and charge

The instructor prepares tools for making Play Dough models.

- There are three color of dough; the first color represents quark and anti-quark; the second color represents lepton and anti-lepton; the last color represents boson.
- Thin wire for stringing plastic beads and colorful plastic beads
- Scissor, marker pen, glue and white paper
- Other accessories for decoration
- The table of fundamental particles (table 1)

Table 1. The table of fundamental particles

Quark	Anti-quark	Lepton	Anti-lepton	Boson
up (u)	anti-up ($\bar{u}$)	electron (e^{-1})	anti-electron (e^{+1})	gluon (g)
down (d)	anti-down ($\bar{d}$)	electron neutrino (ν_e)	electron anti-neutrino ($\bar{\nu}_e$)	photon (γ)
charm (c)	anti-charm ($\bar{c}$)	muon (μ^{-1})	anti-muon (e^{+1})	Z boson (Z)
strange (s)	anti-strange ($\bar{s}$)	muon neutrino (ν_μ)	muon anti-neutrino ($\bar{\nu}_\mu$)	W plus (W^+)
top (t)	anti-top ($\bar{t}$)	tau (τ^{-1})	anti-tau (τ^{+1})	W minus (W^-)
beauty (b)	anti-beauty ($\bar{b}$)	tau neutrino (ν_τ)	tau anti-neutrino ($\bar{\nu}_\tau$)	Higgs (H)

The significant characteristic of particles is mass, The agreement between instructor and students is that stringing beads representing mass. The mass is relatively to the particles level of mass very light (one beads), light (two beads), heavy (3 beads) and very heavy (4 beads)

Another vital characteristic of particles is charge, the agreement between instructor and students is that upper teeth represent positive charges and the lowers represent negative charges. Students use marker pen to paint each tooth. Furthermore the agreement of instructor and students is that they can design independently depending on their imagination.

After every student has design the model of particles and anti-particles yet. Each pair of models represents particles from Play Dough.(Fig.2, Fig 3) The models utilize the understanding of students and to increase memorability among them.

Figure 2. Quark model from students' Play Dough models, left handed dough is strange has -1/3 of charge (three lower teeth but painted only one lower tooth). The right handed dough is anti- strange has + 1/3 of charge (three upper teeth but painted only one upper tooth). Both of them have light mass, so each of them has got two plastic beads on the top.

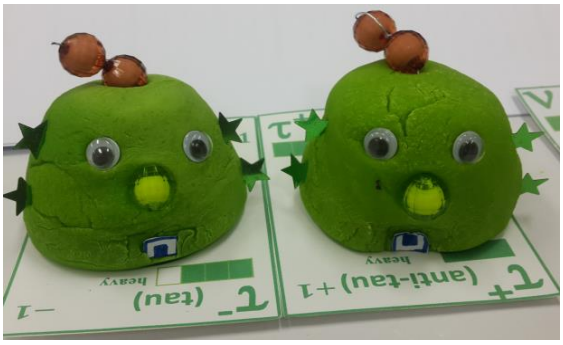

Figure 3. Lepton model from students' Play Dough models - left handed dough is tau has -1 of charge (one lower teeth and painted its). The right handed dough is anti- tau has +1 of charge (one upper teeth and painted its).Both of them have heavy mass, so each of them has got tree plastic beads (two on the top and one at the front)

3. Results

The result of testing students after doing activities, the result shown that students had more conceptual understanding and better memorability on fundamental particles. Including the characteristics of these particles and during the activities, students had enjoyed because they were allowed to think independently for designing fundamental particle models by using their idea. Moreover students gained collaborative working experience among their friends.

After students presented models of each particles in class instructor may let students to combining particles of hadron which can be classified into 2 types are 1. Meson which the combination of two quarks or anti-quarks such as Pion plus (π^+) which comes from the blending of up and anti-down has total charge equals +1, 2. Baryon is the combination of three quarks or anti-quarks such as proton (p) comes from the composing of up, up and down, has total charge equals to +1[9]. In the future the researchers would design the combination of particles models from Play Dough for helping students conceptualize the fundamental particles in next level.

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