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Impact and Importance of Teaching Nuclear Processes, History, and Contemporary Issues in the Middle Grades

Peter Knutson[1]

Abstract

Out of the scientific discoveries of the 20th Century, the harnessing of the power of the atom stands above all else in its impact on our world. Despite its global impact, nuclear processes are all but ignored in the middle grades. The world's use of this technology provides rife opportunities for students to explore the impact of science on the global stage, politics, energy, environment, and humanity (in both its personal and existential forms). We go deeply into all components of the science behind these processes. Beyond the science we delve into the impact of nuclear weapons on the geopolitics of the 20th Century and the social mindset they caused, nuclear contamination from testing, industry, and nuclear power. This provides ample discussion points for students to explore, with debate frequently utilized in class. The confidence and academic strength gained by these students was large. Beyond the Cold War, we also focus on contemporary nuclear issues including current Trump/Putin nuclear comments and North Korea's nuclear program and claims. After this unit, students exhibit expanded mindset to the impact of this science and gain confidence in their own scientific competencies and analytical abilities. This paper will focus on these approaches, outcomes from this unit, and the argument that nuclear issues must play a larger role in middle grade science curricula.

1. Introduction

Although it is not commensurate to the role radioactivity and nuclear processes played in the 20th Century, only a brief section of the topic is allocated in the middle school science curriculum. As an effort to better connect the role of scientific discoveries to historical geopolitics and society at-large, I move beyond the minimum prescribed curriculum and expand it to introduce students to the myriad of implications that the discovery of the atom's power had on our world [E]. Through exposure to higher-level nuclear processes, nuclear weapons, and nuclear power, students attain a baseline knowledge of the science which they can connect to environmental issues, post-World War II and contemporary geopolitics, and ethical implications [A,B]. This paper chronicles activities, based on pedagogical frameworks, in my classroom regarding nuclear processes and societal connections. I also address my perceived impact on students' understanding of impact of science on the world, the nature of nuclear weapons and testing in the context of the Cold War, and contemporary issues nuclear weapons and nuclear power [G]. The explored activities and perceptions are from the school years spanning 2014-2017 and are from 8th grade physical science course.

2. Multimodal Approaches and Activities

Research has found that taking students, of all ages, out of the classroom and beyond the textbook to connect their learning to real-world applications or contexts increases their engagement in the subject, retention of the material, and ability to apply and synthesize the knowledge [B,D,E]. Directing activities and learning opportunities in this manner also contributes to the middle school student's ability to think critically [D,H]. Students at this level are cognitively making a transition between concrete and abstract thinking, and much of the nuclear processes explored are abstract, requiring concrete examples for student comprehension [C,D]. Modeling is an excellent way to represent the abstract, concretely, for the

[1] *Dubuque Community Schools, United States*

middle school student [M,N]. Throughout this unit I utilize the following modeling methods: analogies (visual, kinesthetic, and verbal) [M], mathematical, simulation, cartographical, and predictive [N].
Lectures are limited and intended to be avenues for analogous explanations and contextual anecdotes but mainly designed to catalyze critical thinking and discussion [G,H]. Narratives are also used in this unit to humanize the historical and personal context of the material [C,K,L].

2.1 Student prior knowledge

Students enter into this unit with a working knowledge of the atom, its structure and parts, the Periodic Table, ions, isotopes, ionic and covalent bonding, basic gas laws, temperature's effect on particle movement and chemical/physical properties and changes.

2.2 Nuclear processes activities

In the early days of the unit students are introduced to the radiation emissions of alpha, beta, and gamma decay, via a kinesthetic demonstration of particle size and penetration. Calling upon their prior knowledge, students develop a visual model of U-235 fission, U-238 alpha decay, and deuterium/tritium fusion, a ZAX notation to accompany the model, and teacher explanation to clarify nuances [N]. For example, to illustrate the binding energy involved in radioactive decay and fission, objects are placed in a student's arms until the items become too many and begin to fall (alpha decay) or another student bumps into them causing half of the items to fall (fission) [M]. Once students possess a working understanding of the processes of decay, fission, and notation, decay chains for U-238 and Np-237 were completed by students. Nuclear power plant structures are also modeled visually, emphasizing the neutron control, energy transfer from fission to water, creating steam, and generating energy [B]. Half-life is explored through a physical and a computer simulation of randomly decaying atoms. In both experiments students execute multiple trials and data from all classes are compiled on one Excel spreadsheet and utilized by students to create a decay model for half-life from the averaged data [N].

2.3 Nuclear history exposure

Beginning with the necessity and creation of the Manhattan project, students are exposed the history of the Atomic Age via discussions, guided research, and video. Topics covered include: the history of nuclear proliferation, weapon types and functionality, atmospheric and underground testing, cultural and geopolitical impact of nuclear weapons and the Cold War, the Military Industrial Complex, and non-proliferation efforts. Throughout this portion of the unit, the previously outlined nuclear processes are connected to the events as appropriate. This encompasses nuclear weapons' power from fission and the subsequent use for fusion weapons, the effect of fallout and fission products, plutonium dispersal from industry and 'safety tests', half-life, and the basic physics of the nuclear blast and cloud [E]. Activities include reading the Leo Szilard et al. letter to Truman and debating dropping of the atomic bombs on Japan [A], discussion groups [H] and reflective essays regarding atmospheric testing, the effect of nuclear testing on the environment, military personnel, and local populations, the arms race, nuclear deterrence, total nuclear war, and analysis of movie clips regarding the public fears of nuclear annihilation [C,G]. Discussions surrounding nuclear power, waste, and accidents are also integrated [B]. Each student is asked to interview a family member about memories from the Cold War era and write a narrative surrounding their stories [K,L]. A culminating research project concludes the unit, where students provide an overview, cultural impact analysis, and a modeling of the scientific process of a specific topic [D,G].

2.4 Contemporary nuclear issues and activities

Integrated into the unit is a general overview of non-U.S./U.S.S.R. nuclear powers, including North Korea. Many of the activities are added with spontaneity as a world event happens. Students are asked to call upon their background knowledge to analyze the event and synthesize a conclusion with supported facts. My class has also reached out to multiple professionals in the area of nuclear security, non-proliferation, and history. North Korea's claim of a hydrogen bomb development and a nuclear missile that could reach Washington D.C. were analyzed and both successfully debunked by my students, and the conclusions with supporting evidence were sent to the National Nuclear Security Agency and the Stanford Center. Both agencies responded laudatory critiques of student work including senior NNSA officials and William J. Perry, Sect. of Defense under Bill Clinton. Students also participated in a webcast session with a U.S. associate professor in nuclear history, where students developed highly critical and in-depth questions and received in-depth verbal discussion surrounding them [D, H].

3. Discussion and Conclusions

The unit was marked by a perceived increase in student engagement. Prior to the nuclear unit, the predominant focus is traditional chemistry and the structure of atoms and molecules, which appeared, at times, to be much less engaging. Once transitioned into nuclear chemistry student interest seemed piqued and there was a perceived change in attention level of the students and student participation. Nuclear physics is a highly complex science, but the basic tenets are not, and the students quickly grasped the structural concepts of decay, fission, and fusion.

When a full ZAX notated decay chain is presented to the students, their reaction is that of overwhelmed defeat, but once I walk them through the decay chain, calling on their prior knowledge of the Periodic Table (including atomic number and mass) and the decay particles, they exclaim at the ease of it and within a class period are independently and mathematically modeling decay chains [N]. The realization of their capacity to apply their previous knowledge to do this initially overwhelming task is empowering. Through the sections regarding nuclear testing we discuss TNT equivalence, and it is connected to Einstein's to $E=mc^2$, showing the massive energy that can be gleaned from small amounts of matter. This 'blows their minds', in the words of many students, on two levels: one, that they, mere 8th grade science students just used and understood the most famous equation in history [G], and two, the reality of the sheer magnitude of power held within the atom itself.

The reality and implications of nuclear weaponry opens their eyes to the real horrors of these devices and that this stems from scientific discovery. They are horrified at the possibility of war with these weapons, but then juxtapose this with the need to deter the Soviet Union, during the Cold War, from humanity's annihilation. Discussions on this, as well as the dropping of the atomic weapons on Japan, are robust and powerful [A]. They connect the broader implications of a few drawings in a text book to a discovery that drove the geopolitics of the latter 20th Century. I see them no longer bound by a text book but now free to analyze scientific and political choices that are not mutually exclusive. However, when exposed to the ill effects of the U.S. atmospheric nuclear tests, they can see the wanton disregard of people such as the Marshallese and the 'downwinders' in Nevada, even in the name of balancing the Cold War deterrence.

In analyzing contemporary issues students are able to apply knowledge learned during the nuclear unit. Students are astounded that experts in the field of nuclear security reviewed their work, and their conclusions were accurate and based on the appropriate facts. From this feedback student confidence grew in regards to their ability for knowledge application from multiple disciplines of science. This was not a test they needed to memorize facts for, this was real-life analysis [C]. The narrative exercise is also a powerful tool for some to hear the oral history of the Cold War from family members, bringing a personal touch to a global story. [K,L]

Despite their young age, these middle schoolers have shown me their capacity in connecting scientific discoveries to society and the world at large. This seemed much more powerful than a unit on pH or endothermic reactions. The broader spectrum of the nuclear needs to hold a higher place in middle school science curriculums, if we are to lay the seed of scientifically literate citizens that hopefully will push for a world free from the nuclear sins and fears of the 20th Century.

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