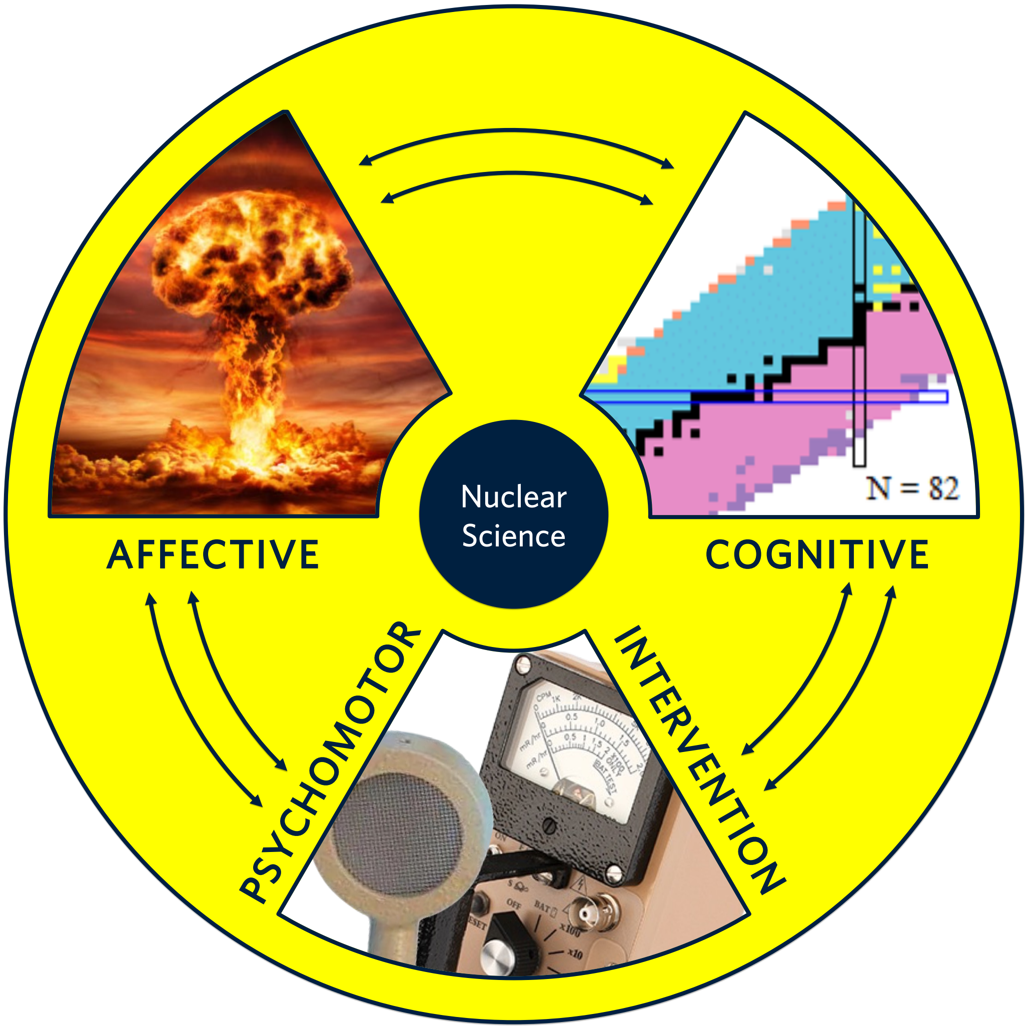
Supplemental Information

For *Combating fear of nuclear science by measuring radioactivity* by Antonio A. W. L. Wong



Literature Review

Radioactivity is a natural phenomenon where an unstable atom decays to form a more stable atom through emission of radiation. It is fundamental to current society in aspects of energy, medicine, fire safety, archeology, industry and research. A Geiger-Müller counter can be used to measure radioactivity. The understanding of radioactivity and radiation is broadly known as nuclear science. The teaching of the radioactive phenomenon serves as an important stepping stone to development of critical thinking skills in, not only in secondary, but also higher education science curriculum (Morales López & Tuzón Marco, 2022). However, misconception around radiation and radioactive contamination is common due to social, historical, ethical, economical, and political implications of nuclear applications. A study studied the attitude of 56 prospective physics teachers of post-graduate age towards radiation; 100% of the participants confused radioactive irradiation and contamination (Taşoğlu et al., 2017). 27% believes that radiation is hazardous, and they fear of exposure to radiation, with little to no justification of the dose (quantity) received. In another study of with 191 secondary school students and 27 trainee-teachers found out that radiation is often classified with "destructive", "damaging" and "dangerous" (Morales López & Tuzón Marco, 2022).

Tension and controversy around nuclear science is common due to its societal and political implications. Easing such tension is necessary to develop a welcoming atmosphere for learners to critically assess the dangers and benefits of radiation and its impacts in scientific discovery and medical care. For example, adoption of radiation is necessary for effective treatment of cancer, but the lack of scientific literacy and communication around benefits and risks are negatively impacting patients likelihood to seek radiological treatment (Dauer et al., 2012). The Society of Nuclear Medicine and Molecular Imaging also mentioned challenges around recruiting prospective trainees, while the need for more technicians is only intensifying with the aging population. While intervention exists in clinical settings, one may design first-year level undergraduate curriculum to open discussion around radiation early to dismantle misconception around nuclear medicine.

Intervention and Research Question

- Iteration 1: What is a more preferred way to introduce a controversial topic to students?
  - This question was rejected due to an unrealistically broad scope.
- [Two tailed] How does the use of instrumentation change perception in radiological education?
  - This question was rejected since radiation is commonly perceived as harmful; a focus to relieve this perception is warranted. A two tailed study is not appropriate.
- [One tailed] How does the use of instrumentation reduce fear in radiological education?

The author proposes an intervention for this phenomenon by using instrumentation available in nuclear physics and medicine – a Geiger-Müller counter ("GM counter"). The author hypothesized that using tangible measurements of household and naturally occurring items, learners can distinguish different levels of natural radioactivity and radioactive hazards. The author sees radioactivity as a unique opportunity inflict in all three domains of learning (cognitive, affective, psychomotor), making the series an impactful learning experience.

Methodology

Both qualitative and quantitative research methods were used to study how the use of a GM counter change perception around nuclear science in a 3-day course on natural radioactivity taught by the author. Discussion group with open and close ended questions were used. However, the over-reaching research question was obfuscated from the participants to prevent observation bias.

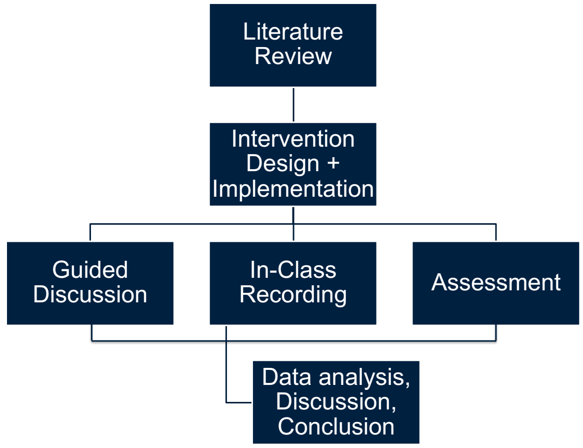


Figure 2. Research work flow chart.

Results

I feel comfortable about radioactivity (*N* = 3). Frequency is normalized to the number of participants.

Time	Frequency	Typical response
Before Day 1	33%	I think of nuclear contamination/ warfare
After Day 1	66%	It's surprising that radioactivity is around us
After Day 2	100%	Wow. I did not expect household items can be radioactive

The use of the instrument enhanced your comfort level with radioactivity (*N* = 3). Frequency is normalized to the number of participants.

Response	Frequency	Typical response
Yes	100%	I can finally measure it
No	0%	-

How does the instrument help you understand radioactivity?

- It contextualizes radioactivity as a tangible phenomenon
- It resolves conflicting misconception
- It confirms my learning of radioactivity
- It increases the number of sensory inputs (visual, tactile, aural)

What techniques does your field use to introduce new abstract concepts?

Field	Technique
Microbiology	Analogy (not an instrument)
Engineering	Scale model
Mathematics	Computer model

Discussion

Student responses were positive over the use of the GM counter, siting benefits of contextualization of scale. Some students pointed out that radioactivity was presented to them in an abstract manner without a tangible demonstration, the measurements reconciled the learning memory as concrete experience (Kolb et al., 2014). Student comfort improved from day 1 to end of day 2 as subject familiarity increases. This is expected since human psychology tends to fear of the unknown (Dauer et al., 2012). Instrumentation is also generalizable to teaching other subject matters; the author anticipates virtual reality will transform active learning as the technology matures.

Limitations

Small sample size (*N* = 3) limits the validity of the research. The author must also note that the participants are all graduate students in STEM fields (microbiology, engineering and mathematics), which is not representative of the perception of young adults in university. The research is also only conducted over 3 days, and hence long term change in perception is impossible to establish. Future work shall 1) expand the cohort to more students from a wide range of faculties and different year levels, and 2) extend the course to a semester and cover more topics on not only the benefits of radiation to the society (e.g. nuclear energy, nuclear medicine) but also frank discussions on nuclear demobilization, nuclear (de)contamination and nuclear ethics.

Bibliography

Dauer, L. T., Thornton, R. H., Hay, J. L., Balter, R., Williamson, M. J., & Germain, J. S. (2012). Fears, Feelings, and Facts: Interactively Communicating Benefits and Risks of Medical Radiation With Patients. *Http://Dx.Doi.Org/10.2214/AJR.10.5956*, *196*(4), 756–761. https://doi.org/10.2214/AJR.10.5956

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2014). Experiential learning theory: Previous research and new directions. In *Perspectives on thinking, learning, and cognitive styles* (pp. 227–248). Routledge.

Morales López, A. I., & Tuzón Marco, P. (2022). Misconceptions, Knowledge, and Attitudes Towards the Phenomenon of Radioactivity. *Science and Education*, *31*(2), 405–426. https://doi.org/10.1007/S11191-021-00251-W/FIGURES/5

Taşoğlu, A. K., Ates, O., & Bakac, M. (2017). Prospective Physics Teachers' Awareness of Radiation and Radioactivity. *European Journal of Physics Education*, *6*(1), 1–14. http://31.220.4.173/index.php/EJPE/article/view/51