Powering Up Nuclear Skills: a novel card game to support teaching of nuclear skills

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SUMMARY

- Improving teaching of 'nuclear' skills necessary to meet growing sector and retiring workforce
- Can we use games to enhance teaching of nuclear science to 11-18 year olds?
- Yes: "RAD ratings", tested with and positive feedback from >1000 students in 13 UK schools
- Resource freely available to everyone – we want people to use it! – to improve STEM outcomes

1. INTRODUCTION

Improving the teaching of nuclear skills is crucial to address the global skills shortage, and to help inspire the next generation to pursue careers in the sector. To this end, we have developed RAD Ratings, an open-source educational game to make nuclear science more engaging and accessible for students aged 11 to 18. We have already received positive feedback from 1,000+ students and teachers across 13 UK schools and other STEM events, with further events planned.

We recently published these results in the Journal of Chemical Education. In this *Nuclear Future* paper, we wish to show the game to new stakeholders – including industry and charities – who we hope may find it useful to dovetail with community engagement and social value activities. Included in this article is a link to download printable versions of the game cards.

2. MAIN PART OF THE PAPER

The nuclear sector faces a growing demand for workforce expansion to address aging infrastructure and meet 'net zero' targets.[1, 2, 3] To tackle the skills shortage, a multifaceted approach involving apprenticeships, undergraduate programs, and industry collaboration[3] is needed, to engage students early.

However, and despite its importance, nuclear science receives minimal curriculum time [3, 4]. Outreach is limited by safety concerns [5, 6] and could benefit from emphasizing real-world applications and career prospects.[5-7] Teaching issues are further exacerbated by staff shortages in the core science subjects, and as well as ongoing difficulties from the pandemic.[4, 8] New approaches to address these issues are therefore required.

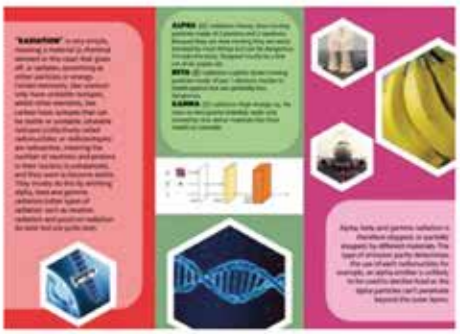
Gamification – using games to improve learning outcomes – is not a new technique, but has only recently been applied to the teaching of nuclear skills to teenagers, and mostly focused on an American audience.[5, 6] We were not aware of examples developed for British students. Accordingly, we developed *RAD Ratings*, a multiplayer card game to support the gamification of teaching in both school lessons and social and community engagement events across the UK. The game features 30 colourful radionuclide cards (Figure 1), each with details like half-life, cost, danger rating, decay type, uses, and environmental impact.

The game is designed to be delivered with a short PowerPoint file, can be integrated into a 50–60-minute school lesson, or shorter outreach activity.

RAD Ratings is two games in one, Figure 1. Game 1 is a 'Top Trumps'® style game where two to five students select and compare characteristics (half-life, danger rating, etc.); the highest wins the round and collects the card. The player with the most cards wins the game. This game is designed for players 11+, focusing on simplicity and ease of use, and typically taking no more than 20 minutes. The objective for this game is teach students about the basic concepts of radioactivity, such as half-life.

Game 2 builds on game 1, using questions about the basics and combining this with a scenario (*"which radionuclide could be used to make food sterile to increase its shelf life?"*, Figure 2) to guide discussion about how and why radionuclides may be useful. The target age is 14+, and involves three to six players, with players justifying their choice for each scenario. Players then vote on the winner, and the most votes wins the card. The player with the most cards wins.

30 Radionuclide Cards



Supporting Materials

Game 1 applies & reinforces examined components of KS3/4 (11-16) science

Each card gives a brief description of the radionuclide with correct chemical notation

Game 2 uses real-world examples to support more complex open-ended, discussion questions

Card example: Radium-226

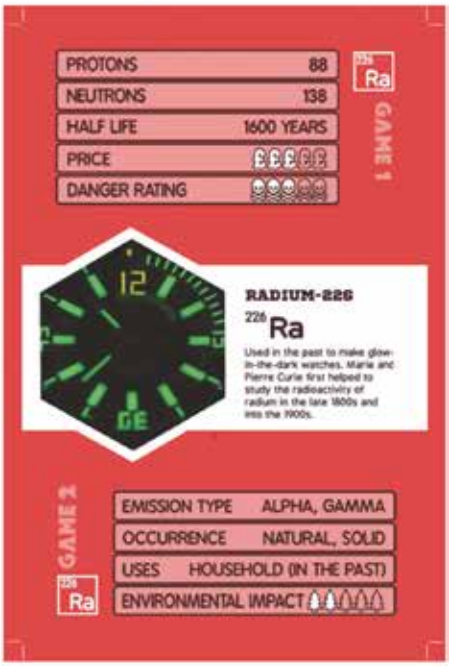


Figure 1. Left, examples of the complete card set and supporting materials, and right, example card (Ra-226). Cards are colour-coordinated depending on position in the periodic table: radionuclides from group 1 are yellow, group 2 are red, main group are green, transition metals and actinides are pink, and lanthanides are purple.

Figure 2. Example of a question that may be used in Game 2, here, on radionuclides that may be used for food sterilisation.

In this example, Cs-137 or Co-60 are good choices (and, indeed, actually used), whereas Pu-238 or Po-210 would be very bad, because of their toxicity (probably poisoning the food or killing the diner!).

This work features in a recent contribution to the *Journal of Chemical Education*.[9] Our intention in this paper to not to re-detail these findings, but, rather, summarise these results, to stakeholders who may not read the Journal of Chemical Education. We hope readers of this paper may find *RAD Ratings* useful in their own social value or community engagement activities and we would be delighted if *RAD Ratings* helps in these. To this end, all resources discussed in this paper are freely available for everyone to download and use, at https://pubs.acs.org/doi/suppl/10.1021/acs.jchemed.4c00603/suppl_file/ed4c00603_si_001.pdf, or in scannable QR codes below in Figure 3.

To read our paper, use this QR code

To access our card materials, use this QR code

Figure 3. Left, a QR code linking to *Journal of Chemical Education* paper, and, right, QR code linking to downloadable version of the cards we used. To scan, hold a camera (on a mobile device with an internet connection) up to the picture and follow the link.

2.1. Teacher and Student Feedback

To collect feedback on the effectiveness of *RAD Ratings*, we anonymously sampled 98 students (ages 14 – 16) and 9 teachers via Microsoft Forms surveys, before and after playing in schools across the UK. We also conducted classroom interviews to collect more detailed responses. Questions assessed student enjoyment, understanding of radioactivity, and its applications, as well as interest in further learning. Teacher surveys evaluated overall engagement and benefits. To date more than 400 card packs (more than 12,000 cards) have been distributed to 13 schools across the UK, with more provided to STEM (Science Technology Engineering and Maths) Ambassadors; more than 1,000 players took part across 12 months over 2022 and 2023. A full description on our methods can be found in Lu et al.[9]

Key findings include:

- **Increased interest in radioactivity:** Both students and teachers reported being more enthusiastic to learn about radioactivity and its applications, with the game effectively capturing and maintaining student engagement.
- **Easy implementation of Game 1:** Teachers found Game 1 simple and effective, aligning well with Key Stages 3 (ages 11-14) and 4 (ages 14-16) curricula, and supporting existing lesson plans. However, its simplicity limited deeper exploration of key curriculum topics.
- **Suitability for novices:** Game 1 was ideal for students with limited prior knowledge of radioactivity.
- **Game 2 enhancements:** Based on teacher feedback, Game 2 was adapted with a PowerPoint presentation, making it a more engaging, teacher-led, whole-class activity. This format helped teachers identify knowledge gaps and adjust teaching accordingly. Game 2 was considered more engaging than Game 1.
- **Competitive aspect of Game 2:** Introducing voting into Game 2 was found to make it more competitive, enhancing participation. Teachers noted that this was particularly true for students who are harder to engage.
- **Survey specific results:** Post-activity student sampling suggested that nearly 80% of those surveyed 'agreed', 'strongly agreed', or were 'neutral' on that it "improved understanding of isotopes and what they may be used for". Also, 64% of those surveyed enjoyed the game, and 58% of those surveyed were interested in playing again. Teacher sampling correlated, with the majority (83%) of those surveyed feeling it increased student interest in the topic in a way that is easily understandable.

While this study is predominantly classroom based and still ongoing, we believe our results demonstrate that the gamifying the teaching of the basic principles of nuclear science can improve both the learning outcomes and the teaching of industry-relevant skills.[5, 6, 9]

3. CONCLUDING REMARKS

RAD Ratings, a card game developed to address the nuclear skills gap, was distributed to 13 schools across the UK, reaching over 1,000 students in its first year. Additionally, 160 packs were provided to industry-linked STEM Ambassadors, extending its impact beyond the classroom. Student feedback indicated an improvement in interest and understanding of radioactivity and radionuclides, comparing results before and after playing the game, supported by positive teacher feedback and classroom observations. Teachers highlighted the ease of implementation and the game's effectiveness as a learning tool.

Game 2 proved more effective with whole-class participation, guided by a PowerPoint presentation, compared to small group play in Game 1. Survey results from both students and teachers suggest the structured approach improved understanding of radioactivity and its real-world applications. Pre-prepared packs and PowerPoint resources also streamlined preparation for STEM Ambassadors, making the outreach process more efficient and engaging.

3.1. Future Opportunities

What we present here, in *Rad Ratings*, is one of an increasing number of tools that educators can use to improve teaching of STEM subjects, both in and out the classroom. Indeed, one of the reviewers for this paper identified – in a comment we fully agree with – that combining these resources (games, tools, lesson plans, etc.) into a coherent plan to teach nuclear skills specifically to 11–16-year-olds could be of substantial benefit to the industry. Templates as to how this may be achieved already exist – for example, the GAIN course from the National Skills Academy for Nuclear (NSAN), or the Young Generation Network (YGN) from the Nuclear Institute – but these are tailored to graduates and apprentices, not students, and would need to be carefully transposed to school lessons to address the unique challenges of a classroom, such as the formidable demands on teaching time.

Additionally, the teaching of 'nuclear' skills is often fragmented, and there does not appear to be a coherent plan for the teaching of 'nuclear' to students of school age at the industry or strategy level. For example, the National Nuclear Strategic Plan for Skills mentions 'schools' only once,[10] and there is no specific commitment in the Nuclear Skills Delivery Group (NSDG) Nuclear Charter to improving teaching of nuclear skills to students of school age.[11] We suggest that this is an easily addressable gap, and that making a specific commitment to include schools in NSDG (or related) Strategy, and actively engaging with educators to develop specific resources to align with this commitment, would be helpful to address the 'skills gap' we discuss in the introduction.

We also recognise that a variety of game formats are available for the teaching of nuclear skills. We chose a Top Trumps® style card game as our format for simplicity and because it slots nicely into a 50–60-minute lesson plan. Most of our evidence is therefore focused on classrooms. While we have some evidence to suggest that *RAD Ratings* is useful in non-classroom settings, this is circumstantial (such as colloquial feedback from STEM Ambassadors using the game in outreach sessions), and further work could establish this relationship more formally.

For broader appeal outside the classroom, board games or other game mechanics may be more useful than the Top Trumps® style we employ here. Our intention in this paper is to raise the standard for the teaching of nuclear skills to all relevant ages, and we would love to see *RAD Ratings*, and concepts raised by it, available as a not-for-profit board game to help teach nuclear skills outside the classroom.

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SHAUN HEMMING

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