Response to reviewers

Transforming school students' aspirations into destinations through extended interaction with cutting-edge research: `Physics Research in School Environments'
M.O. Archer et al.

We thank the editor and the reviewers for their comments. We have revised the manuscript in response to these, which we detail here. Line numbers refer to the tracked changes version of the manuscript.

EC1

Thank you for your comment. I have looked at your comments, the submitted paper, and the two companion papers you have submitted, alongside the reviewer comments. Your proposal at the moment still reads, to me at least, as a broad and sweeping outline and discussion of PRiSE, rather than a clearly focussed piece. I still find it hard to discern the specific academic purpose of the paper, which will allow you to simplify and clarify it. To this end, I have taken the liberty of attempting to re-write the abstract and make a few suggestions. I realise that it is difficult to step back, view with fresh eyes, and substantially modify a paper with a substantial history, but I encourage you to attempt this.

The abstract I suggest is shorter, and gives you space to firstly describe PRiSE, then after this set-up get onto the research that is the core of the paper. Currently the introductory description of PRiSE is 18 pages, and all of the research (methods/results etc ...) is 10 pages. Although this paper can be to some extent a vehicle for a description of PRiSE, this balance may explain some of the reviewer reactions. The clear description of the paper's content I suggest may mitigate this partially, but some re-balancing is probably also necessary, using appendices if you must. In terms of what should be cut, the 10 pages of research seems to be a reasonable length.

Title: Evaluating participants' experience of an initiative (PRiSE) to inspire school students to continue studying physics by extended interaction with cutting-edge research.

Abstract: Physics in schools is distinctly different from university, research-level work, which may hinder participation in science at higher education. Initiatives wherein students engage in independent research linked to cutting-edge research within their school over several months may mitigate this. However, how this is best done remains unclear. This paper evaluates the PRiSE initiative through participants' experience of the scalable framework used. First, the PRiSE initiative and the theory of change used to break down its aims into a series of realistic intended outcomes for 14–18-year-old students are described. Then, the framework used is evaluated using survey data from participating students, teachers, and university collaborators. Overall, PRiSE appears to provide highly positive experiences that schools cannot provide internally, and the intensive support offered is deemed necessary with all elements appearing equally important. We suggest that the framework could be adopted at other institutions and applied to their own areas of scientific research, something which has already started to occur.

We now understand the editor's position much more clearly following these helpful comments. We have largely used the editor's suggested title and abstract and have dramatically reduced the length of the description of PRiSE in the article, taking the editor's broad comments in mind.

Please find below a non-exhaustive list of comments that I hope might help. Please also respond to all of the reviewers' comments, although because you are seeking to focus and shorten the piece this may be given as a valid reason for not acting upon some of them.

• "Developing" in the title. Developing, implies a narrative description of the process of development, which is difficult to reconcile with a research article.

We have used wording more aligned with the editor's suggestion in the title.

• "PRiSE is a positive experience", but for a research article there is a need to focus on whether this is better or worse than other frameworks/initiatives.

We now emphasise that our evaluation shows PRiSE gives a more positive experience to participants than typical schools engagement programmes, as demonstrated by comparing to benchmark data.

• Scalability, if emphasized, needs to be evaluated. If there is no empirical evidence to assess this, I suggest you downplay it; including, for example a paragraph describing how the framework might be scaled up.

Scalability has been downplayed more than in the previous version. We now provide a brief discussion in section 2.3, demonstrating how the PRiSE model through its efficient use of researchers' time has allowed more schools to be involved per institution than other formats. Section 5 also presents data from independent researchers and engagement professionals, with one of the resultant overall themes being that approaches like PRiSE are deemed achievable by them.

• Please seek to state your work concisely e.g. the abstract is now 160 words down from 264. You may be assisted in making the paper concise once the purpose of the paper is clearly identified. An illustration of this is Section 2.5 in version 1 of the manuscript ("Current Projects"). This probably needs no more than a relatively short paragraph and a single line for each project. Please ask yourselves for each section: How is this critical to either (i) a clear concise description of the framework or (ii) its evaluation. Other material should be removed please, although appendices can be used if needed. I also suggest keeping descriptions of parts of the framework that are uncontroversial or not evaluated short, allowing some more space for the elements of interest to the research into participants' experience you present.

We have removed all parts that we feel are not critical based on the editor's comments.

• I changed the text to "schools cannot provide internally" as the experiences could be possible through other frameworks / initiatives.

We have taken this into account in the abstract.

• I removed inverted commas and jargon from the first sentences of the abstract for clarity of communication.

We have inverted commas and jargon from the abstract.

Editor comments to author

Three reviewers found the work interesting, well presented, and with a good grasp of best practice. One reviewer [RC5], however, suggested some major revisions. These relate to the presentation and focus of the material, rather than the quality and detail of the content. Please give these concerns serious attention. Overall, I think it has the potential to be an excellent paper, and very much encourage you to undertake the revisions necessary.

I note that you have been in touch with the editorial team of GC more generally about the suite of papers submitted about the PRiSE project. Thus, an overarching consideration for the paper is an understanding that you will sharpen the focus of each paper.

We clarify that the executive editor contacted us in the first instance and we responded.

In terms of an overview on how to approach the revision, given my initial reaction (see below) I find it hard to express it better than in RC5

"Building on the other reviewer's comments, I think there is ample opportunity to streamline the text, and clarify the presentation to only those details most salient to communicating to the reader the design and implementation elements of the program, while being much more explicit about how the data they have collected demonstrate if/how (or not) the program 'meets' their Theory of Change. This is essential to demonstrate a) how the program is scalable and b) the documented value and impact and therefore, why it is a model that should be scaled to other schools/locations/programs."

In my words: The purpose of the paper should be clearly laid out, and it should be readily apparent why material retained is directly related to this - if not, remove it. Illustratively, in the first line of the abstract you say "We introduce a scalable framework .... " Why do you introduce it? In the second sentence you say what PRiSE's aim is, but you do not clearly state what the aim of this paper is in the abstract. Clarity here might help both writer and reader.

Following EC1 we now better understand the editor's position and have throughout attempted to clarify the purpose of the paper and why its contents are included. Much material has been removed in the revision to keep the description of PRiSE concise.

• Creating a paper that is readable, focussed and concise, incorporating the reviewers'comments that are most relevant.

We have attempted to refocus the content and reduce its length, while also addressing the reviewer comments relevant to the purpose of the paper.

Focus on how the distinct added value and purpose of this paper, as opposed to the other papers.

All cross-references to other papers have been removed from the body of the article.

Attempt to briefly consider international initiatives.

We have briefly added to the introduction some relevant international initiatives (lines 67-75) as well as expanding discussion of the HiSPARC programme to include the other countries in which it runs (lines 93-95).

1. Please attempt to make the manuscript more concise. It seems quite long for thematerial presented.

We have reduced the length of the manuscript.

2. I am aware of, and have participated in the Nuffield STEM initiative that has been running for at least 10 years (https://www.nuffieldfoundation.org/contact). By linking school students to active research, placing them in universities it performs a similar role, and includes physics within its remit (i.e. one of my students investigated an element of geophysics, winning an award).

While this is a different format to `research in schools', we now highlight on lines 67-71 some initiatives that make use of dedicated out-of-school events including Nuffield placements.

3. The paper is currently very UK-centric for an international journal. Please make an attempt to identify and acknowledge other initiatives globally. It is difficult to believe that these do not exist, but if they do not, then please argue this case explicitly.

• RISE programme at Stanford - summer internship programme.

https://oso.stanford.edu/programs/disciplines/20-physics

• https://www.sas.upenn.edu/summer/programs/high-school/experimentalphysics

• 'ANU extension' https://physics.anu.edu.au/engage/outreach/

We have included relevant examples of international programmes on lines 67-75. Our discussion of the HiSPARC programme now also includes the other countries in which it runs (lines 93-95).

4. If PRiSE is scalable, can you provide a simplified diagram that others could use to set up similar programmes, perhaps in other countries or other scientific fields? If it is purely physics (excluding physics in related disciplines) and only in the UK, state limitations on scope at the start. [see RC3 point 3]

We have created a figure (Figure 2 in the tracked changes version) to summarise the framework.

L106 - "complete lack"? It would be good to see a review of other papers investigating schemes that use research in school as a method; these might be academic papers, but internal evaluations of these schemes or grey-literature they have published would be beneficial here. Please add a paragraph.

We have undertaken a comprehensive literature review of both academic and published grey-literature surrounding both independent research projects and `research in schools' specifically. This has all been included in the introduction in the preceding paragraphs. Unfortunately very little material surrounding `research in schools' style initiatives have been made public, highlighting the need for this paper.

L575-580 ..... discussion of causes of this expected later.

The qualitative research starting on line 691 investigates the causes of these positive quantitative results. We have now made this clearer.

L593 ... how were the categories / themes defined? Add reference for analysis method please.

This was outlined in our Methods section on lines 654-660.

L806 - some formatting issues with references.

So readers do not confuse papers by L. Archer with the first author we have disambiguated the two by including initials. This has been checked with Copernicus staff.

RC1

The article submitted about the PRiSE project is very interesting. The quality of the presentation is excellent ... the implementation and results of the project are clearly presented. Nevertheless, I would have liked to have seen more details for the teachers involved in the project. What strategy is actually implemented for teacher training during the PRiSE project?

line 172 > 'Therefore, opportunities for teachers' development are integrated within the programme rather than being a separate offering to schools'

We have added a paragraph on lines 266-271 about teacher development.

RC3

Many thanks to authors for all of their efforts in putting together this interesting piece of research. I am sure that many of those working in Outreach and Public Engagement in HE could use some elements of this article for their own benefit. That said there are few elements I ask to authors to review. These comments should be seen as constructive and should really enhance the current structure of the article

1. The Theory of Change (ToC) presented reads well and it follows very closely the Theory of Change published by Davenport et al 2020., in terms of identified audiences, causal paths and terminology. I recommend a more explicit acknowledgement by the authors to Davenport et al 2020. Where I think there is room for improvement is to explain or summarise and assumptions and barriers that often accompany a ToC, as throughout the paper some of these emerge (e.g - researchers or institutional buy-in a barrier to your ToC). Finally the ToC description needs a bit more details. For instance what is the meaning of the different shades of the same colour

Upon the editor's request to refocus the article, we have removed the Theory of Change.

2. The framework as well described by the authors, feels disconnected from the ToC and more references throughout the text should be made to the ToC especially in section 2.3 and 2.4 For example line 230 to 245 , removal of barriers, involvement of teachers etc, really highlight that these are aspects of your ToC.

Upon the editor's request to refocus the article, we have removed the Theory of Change.

3. Even though the PRISE framework has been presented as scalable, what are the lessons learnt by the authors? what are the recommendations to other practitioners in the field? Adding a few paragraphs in the conclusions, or even some bullet points, would address not only the scalability of PRISE but the transferability of PRISE to another subject or institution (e.g. - produce a detailed guide for students and teachers, etc)

We have added sentences highlighting the recommendations to practitioners based on the results of the evaluation. These can be found on lines 908-915.

RC4

General comments

This paper makes a valuable contribution to the available literature on undertaking projects that involve school students in research. It is generally well-constructed and well written, leading the reader through the premise, structure and success of the programme. The detailed exposition of the workings of PRiSE is especially welcome as it facilitates the successful replication of such a programme without a duplication of the evidently extensive effort and multiple trials that have been required to bring the programme to its current level.

There are some points in the paper (as will be addressed in the specific comments below) that would benefit from further consideration; however, these comments are mostly fairly minor, and

are noted in a spirit of bringing the level of every part of the paper to the high standard it exhibits overall.

The authors give a thorough depiction of the landscape in which this work sits, taking care to give details of other similar projects distinct from PRiSE. Nevertheless, as noted below, these other projects are not always considered in a positive light. It might be wise not to be over-critical at the risk of sounding petty rather than constructive. However, proper credit is given where appropriate, both to work outside this project and to the researchers and other staff involved in PRiSE, which was heartening to see.

We have adjusted the tone slightly in places when discussing other projects to mitigate any perceived negativity. The points raised summarise the information available about these projects, highlighting the need for more publications detailing the provision within this area, and also to be able to compare/contrast to PRiSE's approach.

The title seems fair, although there is an emphasis on 'destinations' that is less apparent within the body of the paper. Although this is mentioned within the section on the Theory of Change, there seems to be little further discussion or evidence of the destinations of students that take part in PRiSE. Nevertheless, the abstract provides a concise, complete and clear summary of the contents of the paper.

Upon the editor's request to refocus the article, we have changed the title.

The language is largely fluent and precise. On occasion, some of the sentence structures are a little hard to follow on a first reading. In particular, there is substantial use of possessive apostrophes that on occasion impede initial comprehension. It may be worth reconsidering some of these to aid the flow of the text (as opposed to the text's flow).

We have attempted to improve the language throughout.

The paper is well-referenced throughout, with many recent publications cited, demonstrating a laudable grasp of current best practice and educational research. This is to be highly commended.

Specific comments

The specific comments are given with line references relating to the pre-print (pdf) of the paper.

- Line 9: 'with all elements appearing equally important.' – it would be useful (perhaps later in the article) to have a simple list of all the elements that are being encompassed by this phrase.

The added figure (Figure 2 in tracked changes version) attempts to make the elements of the PRiSE programme clearer.

- Line 66 on: The discussions of other similar projects, while not obviously straying from factual, nevertheless read as ungenerous. E.g. line 73: 'other memberships are seemingly justified to ensure that schools make a commitment to working with the university'; line 88: 'While some researchers/academics have designed or consulted on some IRIS projects, they appear in general to have little involvement supporting students or teachers'. This could perhaps be construed as criticism of the other projects (with the aim of elevating PRiSE) which may or may not be considered constructive at this juncture.

As mentioned earlier, we have adjusted the tone of these statements. See lines 101 and 117-118.

- I understand that the Theory of Change as presented here is discussed in more detail in another publication. Nevertheless, I would query a couple of aspects that are here presented without substantial examination (though I recognise this review comment may not be the best home for this remark and the authors may feel that no response or alteration is merited.) ** Figure 1: The implication that 'Know other people interested in physics' leads to 'See themselves as equals in physics to those from different backgrounds'. I don't know that this follows. I think you can quite easily know other people interested in physics and *not* see yourself as "equal in physics" to those other people. ** Line 163: 'By interacting first-hand with "real physics" through the projects and working with active researchers, students (especially those from underrepresented groups) should feel included'. I think it is perfectly possible to do physics research and yet feel excluded. I am not convinced that under-represented students will automatically feel included, simply by virtue of doing "real physics", especially if they do not recognise themselves in the active researchers they are connected with or are a minority in the group taking on a project in their school.

Upon the editor's request to refocus the article, we have removed the Theory of Change.

- Line 201 -205. How do the other IRIS physics projects compare here? As it stands, it reads like a cherry-picked list of worst performers, highlighted to make PRiSE look good. If further data on the numbers of researchers / schools is not available for other IRIS projects, then this is worth noting here to avoid this impression.

We now note that information on the other IRIS projects has not been made available (line 596).

- Line 196: It becomes apparent here that some schools have taken part but then dropped out. It might be worth pointing this out explicitly, and possibly signposting the later short discussion of this (e.g. around line 806)

This is now explicitly pointed out on lines 249 and 587-590.

- Line 240 – 242: teachers decide who to offer the PRiSE projects to. Do you have any thoughts on how successful teachers are at selecting students who excel on the projects?

Unfortunately, we don't have any specific information on how teachers go about selecting students, which we now raise in the manuscript on lines 258-261.

- Line 248: 'We allow teachers to determine how best to integrate the projects within their school, though provide advice on this.' From the perspective of an outreach practitioner hoping to replicate the success of PRiSE, it would be interesting and useful to see this advice – perhaps included in an appendix?

As this had been done informally, unfortunately we cannot include this material.

- Line 286 on: How much drop-off do you typically see between teachers applying for projects and then not taking up an offer come the new academic year?

There is a 33±5% drop-off between application/assignment and the initial kick-off meeting in the new academic year. Retention within the programme is outside the scope of this paper and is addressed in another publication.

- Line 309: 'though this latter approach often proves unsuccessful' – thank you for including this kind of helpful detail

- Line 463: What is 'the UK coding agenda'? This phrase needs further explication and / or a reference

Upon the editor's request to refocus the article this is no longer referenced.

- Line 534: Feedback from the university sector. This is a bit confusing – it's a little unclear what the university sector is being asked or why, and how that connects with the previous discussion of participant feedback. Although there will be further detail given later, it might be worth clarifying some of it at this stage. Maybe it's simply the mention of "the workshop" (line 535) without context that is disconcerting.

The content of the workshop is now clarified on lines 631-633 and 851-852.

- Line 589: I enjoyed the inclusion of the negative words in the word cloud, and appreciated that they were highlighted here.

It is important that the entirety of the collected data are presented and discussed in a balanced and appropriate way, which we have aimed to do throughout.

- Line 791: 'The ethos behind PRiSE is to transform current scientific research methods' This could be read as though you are trying to alter the way the scientists undertake their research. Perhaps consider re-phrasing this, if that is not your intention.

This sentence is no longer included.

Technical corrections

- Line 143: 'with standard one-off (or even short-series of) intervention(s)' – this doesn't quite read right to me

Upon the editor's request to refocus the article this is no longer included.

- Line 169: 'Experience from physics outreach officers . . . have shown' – grammar error. Should either be 'Experiences . . . have shown' or 'Experience . . . has shown'

Upon the editor's request to refocus the article this is no longer included.

- Line 174: 'the impacts of PRiSE can be felt much wider' – grammar. Suggest 'can be felt much more widely'.

Upon the editor's request to refocus the article this is no longer included.

- Line 183: 'another major influence on young people's aspirations are family' – grammar error. Should be 'another major influence . . . is family'.

Upon the editor's request to refocus the article this is no longer included.

- Line 213: 'One might think it is feasible that students' work on PRiSE projects contribute to novel research.' - Grammar: contributes - This sentence is generally hard to follow – consider revising

This has been rephrased, see lines 298-299.

- Line 423: 'organic semiconducters' – typo: semiconductors

Upon the editor's request to refocus the article this is no longer included.

- Line 502: 'and responsibilities have remained largely been falling to only a few people per PRiSE project' – grammar. Remove 'remained'?

Upon the editor's request to refocus the article this is no longer included.

- Line 803: 'and have relished the challenge of working differently to in their regular school experience' – grammar. Remove 'in'?

This correction has been made, see line 908.

RC5

Thank you to the authors for working to summarize their program and research as part of the PRiSE program. It is clear that this group has taken the task of creating and evaluating their educational program seriously and I commend them on identifying many different facets of the program to document and share with the broader community. The paper is generally well presented but as a reader first learning about this program I have some major revisions to suggest.

Major Considerations for Revision: While I see the clear value and need to share this work with the broader community, especially given the authors' goal to "introduce a scalable framework for protracted research-based engagement with schools", I have some questions about how this and the other papers submitted simultaneously in review in Geoscience Communication about the same program differ from one another and how they each meet the journal requirement of making "a substantial contribution to scientific progress within the scope of Geoscience Communication (substantial new concepts, ideas, methods, or data)"

The three papers concern separate areas:

- This paper: A process evaluation of participants' experience within our provision framework.
- Impact evaluation exploring the actual benefits for students and teachers that might have resulted from the programme.
- Audience evaluation assessing the diversity, accessibility and equity within the programme for the schools we work with.

Each paper contains clear and separate conclusions. Other published papers in this field by other authors, for example the various papers cited on IRIS's programme, also split the content and focus up in similar ways thus we feel this is appropriate. Upon discussion with the executive editorial team at Geoscience Communication they are satisfied with our response that three papers are required.

Further, based on the references cited in this manuscript, the lead author also has another paper in review at another journal that seems to align with a similar premise being presented here.

Upon the editor's request to refocus the article this is no longer referenced.

As a reader (who hasn't read all of these manuscripts to know exactly how they differ), I'm left wondering why someone would need to read four papers about a program to understand the structure and impact.

The programme is significantly more extended, consisting of several different parts, than typical one-off engagement approaches published in this journal and others, thus it is not surprising that a full exploration of its structure and impact is lengthy.

While I fully appreciate the appropriateness of evaluating and interpreting results from a program like this in multiple ways, the current structure of the arguments suggests that they might be able

to present their work in one well-structured and concise paper (or two) that really uses the data to substantiate the claims being made and demonstrates how they are meeting their Theory of Change which states: "The intended impact of PRiSE is to contribute towards the increased uptake and diversity of physics at higher education."

We initially aimed to combine the current framework paper with the papers on impact and diversity. However, including sufficient information for clarity and to support our points made the paper exceedingly long, and awkwardly structured. Consequently, for clarity, we split the manuscript into three papers. Each paper stands alone and does not rely upon the results of the others. The papers have been reframed to make their independence clearer and unnecessary cross references have been removed. Upon the editor's request to refocus the article, we have removed the Theory of Change. Impact is not within the scope of this paper.

As a reader new to the program, and taking the abstract at face value, I found myself asking fundamental questions about the structure, resources, personnel and design of the program. This is touched on in brief in various parts of the paper but some challenges about the program structure are mentioned starting in line 500 that seem to warrant further comment, especially in the context of thinking about scalability of this program.

We have attempted to clarify the structure, resources, personnel and design of the program of the programme throughout the revised section 2. Challenges are also more explicitly highlighted.

Other details like the core resources or research that undergird the program are mentioned in the latter part of the paper and seem a bit out of place. Perhaps some of the text could be instead captured in visuals or a diagram?

We have summarised the specific projects in Table 1 and added a figure (Figure 2 in tracked changes) to outline the framework.

Overall, while the Theory of Change and surrounding literature review are helpful for framing the need and context of the PRiSE program, the body of the text and data presented don't seem to directly align with or support the premise of the paper as articulated in the abstract and conclusions.

Upon the editor's request to refocus the article, we have removed the Theory of Change.

To concretely illustrate this, in the abstract the authors state "This illustrates that the model appears to provide highly positive experiences that are otherwise not accessible to schools and that the extraordinary level of support offered is deemed necessary with all elements appearing equally important. Researchers and public engagement professionals seem receptive to the PRiSE framework of schools engagement and it has started to spread to other institutions." While the authors present some data to demonstrate their programmatic success, for their most critical claims, they point the reader to a different paper (as above) and don't really touch on the focal point of their theory of change.

Upon the editor's request to refocus the article, we have removed the Theory of Change.

Further, they mention on several occasions in the paper the "extraordinary level of support" needed and offered through this program by the researchers but do not elaborate on how this might be a barrier to the scalability of their program. It would be helpful to the readers if the authors were more explicit about how much time is required from researchers to support this type of programming, how researchers are recruited and rewarded/acknowledged for their

participation and how the program itself is funded or supported, especially in light of the acknowledged barriers to sustaining engagement by researchers. These types of structural and programmatic details are key to seeing how the program supports their ToC and offers valuable insights for those seeking to recreate this type of 'research in schools' program.

The added figure (Figure 2 in tracked changes) now explicitly highlights time commitments of each stage of the framework. Scalability is now briefly discussed in section 2.3 and acknowledges the barriers to sustained engagement by researchers. Views from independent researchers are presented in section 5.

Building on the other reviewer's comments, I think there is ample opportunity to streamline the text, and clarify the presentation to only those details most salient to communicating to the reader the design and implementation elements of the program, while being much more explicit about how the data they have collected demonstrate if/how (or not) the program 'meets' their Theory of Change.

Upon the editor's request to refocus the article, we have removed the Theory of Change from the article and streamlined the text.

This is essential to demonstrate a) how the program is scalable and b) the documented value and impact and therefore, why it is a model that should be scaled to other schools/locations/programs.

Scalability is now briefly discussed in section 2.3. The impact of the programme is explored in another publication.

I would encourage the authors to significantly revise this manuscript and to think about how to present the details about how the program works and the data they have that indicates that the program is successful (and why) together in one paper.

As noted, one single paper was not sufficient to fully explore all the aspects of the PRiSE programme and its evaluation to the level of rigour required by the journal.

Based on the review criteria, this article falls short in demonstrating (in relation to the other papers submitted for review at the same time) how each makes a unique and substantial contribution that warrants publication, and as currently written, this paper does not really provide sufficient evidence to support the interpretations and conclusions.

The evidence and conclusions in this paper concern the experiences of participating students and teachers and their feedback on the level of support offered, as well as perceptions of researchers at other institutions.

I have no doubt that through some more careful writing, streamlining of the text and analysis of the data alongside the programmatic structure, that readers would see the substantial contribution being made through this program and its structure and the value it offers as a model that could be replicated elsewhere.

While there is work to do, I really do commend the authors on their thoughtful approach, clear investment in data collection and analysis, and for developing and iterating on a program that seeks to make a novel contribution for bringing research to schools. They certainly have invested an enormous amount of time and dedication to the PRiSE program and I really hope to see this work shared with the science communication and education communities.