Title
Choosing an Investigable Question Vignette

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This paper was written and produced by the developers of the Professional Development Program (PDP) at the Institute for Scientist & Engineer Educators (ISEE) at University of California, Santa Cruz. The PDP was a flexible, multi-year program which trained participants to teach STEM effectively and inclusively at the post-secondary level. Participants were primarily graduate students and postdocs pursuing a broad range of science and engineering careers. Participants received training through two in-person multi-day workshops, worked on a team to collaboratively design an authentic, inclusive STEM learning experience (an "inquiry" lab), and then put their new teaching skills into practice in programs or courses, mostly at the college level. Throughout their experience, PDP participants used an array of online tools and received coaching and feedback from PDP instructors. The overall PDP experience was approximately 90 hours and was framed around three major themes: inquiry, assessment, and equity & inclusion. Leadership emerged as a fourth theme to support PDP teams, which were each led by a participant returning to the PDP for a second or third time, who gained training and a practical experience in team leadership. ISEE ran the PDP from 2001-2020, and there are more than 600 alumni.

CONTEXT FOR THIS PAPER WITHIN THE PDP

The Choosing an Investigable Question Vignette was used in the PDP to prepare participants for "facilitating" the inquiry activity that they designed. The term facilitation was used in the PDP for the small, in-the-moment moves an instructor makes to accomplish specific goals. This vignette was read by participants and then discussed in a workshop setting, prior to their teaching. The vignette, and the characters within it are fictional.

The PDP was a national program led by the UC Santa Cruz Institute for Scientist & Engineer Educators. The PDP was originally developed by the Center for Adaptive Optics with funding from the National Science Foundation (NSF) (PI: J. Nelson: AST#9876783), and was further developed with funding from the NSF (PI: L. Hunter: AST#0836053, DUE#0816754, DUE#1226140, AST#1347767, AST#1643390, AST#1743117) and University of California, Santa Cruz through funding to ISEE.

Choosing an Investigable Question Vignette

Assignment Instructions

1. Read the "Choosing an Investigable Question Vignette" keeping the features of the **Facilitation Aims and Moves worksheet** in mind. Consider marking up and adding comments to the vignette transcript itself to remind yourself of things you notice.
2. Consider three major areas of facilitation as summarized on the **Facilitation Aims and Moves worksheet**. Follow the instructions on that worksheet to identify what the facilitator is doing (or not doing) to
   - make learners' thinking accessible
   - ensure that learners engage with hypothesizing or advancing their scientific knowledge of different forms of light sources, while maintaining ownership
   - create an equitable, collaborative and interactive social dynamic

This vignette is based on an ISEE inquiry activity. The goals of the activity in this vignette were focused on investigating the properties of different forms of electrical light sources, and testing hypotheses.

Just prior to the beginning of this vignette, students were socializing. The facilitator observing this group noticed that the students were socializing, then after letting that conversation unfold a bit, decided to bring over some new supplies as a prompt to help them refocus their discussion. The learners in this vignette are **very early in their investigation,** they have yet to pose, select or decide on the "investigable question" that they will subsequently be responsible for developing into a hypothesis and then pursuing. Thus, the overarching facilitation goal for this interaction is to help them identify a particular question that supports a testable hypothesis.

01. FACILITATOR (FAC): [*Arrives at the workstation with an assortment of light bulbs*] Okay I've got the goods for you! I've got a bunch of different stuff.

02. FEMALE STUDENT (FS): [immediately responsive to arrival of facilitator] Oh cool. Doin' it up.

03. FAC: [*Handing bulbs over to each of the student investigators while speaking*] I've got 40, 60, 75, and 100 watt [incandescent] bulbs. And I've got a fluorescent.

As background, incandescent light bulbs of various wattages work by passing electrical current through a filament, heating the filament so much that it glows. They emit broad-spectrum light across a range of wavelengths. Wattage refers to the bulb's power when run at a standard voltage, and is directly proportional to its brightness.

04. FS: [*handling different individual bulbs to inspect them visually*] So these are all… like would you say….

05. MALE STUDENT (MS): [*interjects, addressing facilitator rather than responding to FS*] So like, what's in this fluorescent bulb? [*indicates fluorescent bulb with spiral tubular shape*]

06. FS: Is it like a metallic filling? Or like mirrors? I don't know… Those are just like energy saving bulbs right?

Fluorescent bulbs work differently than incandescent bulbs. Fluorescent bulbs produce light by passing a small current through a cathode to liberate electrons, which then collide with the tenuous gas in the tube. These collisions cause quantum transitions in the gas, and typically release UV light, which then excites fluorescence in the phosphor coating on the tube. This fluorescence produces light at visible wavelengths. Unlike incandescent bulbs (which must be hot to emit light) fluorescent bulbs maintain a more stable temperature.

07. FAC: [*Responds first to MS assertion that this is a fluorescent (CFL) bulb, not ostensibly to FS questions about composition of these bulbs*] Yes that's a compact fluorescent. It's a florescent bulb and it's like a kind of gas. I don't know exactly what gas is in there, inside fluorescent bulbs. [*FAC shifts stance and tone of speech*] But why would that matter?

08. FS: I don't know what's in there. Isn't it like neon? Or is it argon? Or a noble gas…

09. MS: [*interjects with his supposition*] Yeah, I think depending on the gas it is going to change the spectrum. That's my understanding. So I guess if it is… it's like white though, so I don't know how they get that coating.

10. FAC: Yeah [*nodding in agreement*] good point. We've actually got the uncoated tubes next door. Have you ever seen those tubes that have like hydrogen or whatever?

Here the facilitator is referring to gas-filled emission tubes. These are similar to the fluorescent bulbs, but without the phosphor coatings. High voltage ionizes and excites particular transitions in the gas, emitting photons at particular wavelengths that differ for every gas. An uncoated neon sign is an example.

11. FS: Yeah, yeah totally. Yeah, it seems like a coating has been added to the [compact fluorescent] bulb; why do they do that?

12. FAC: How might you make use of the uncoated tubes to answer that?

13. MS: [*bypasses logic of FS question/FAC lead to interject with his observation while still visually inspecting the compact fluorescent bulb*] I think, I think it's neon inside.

14. FAC: What makes you think that?

15. MS: Oh yeah - neon is like pink though.

16. FAC: Yeah but it seems hard to tell anything about the color associated with the gas inside because, like you both noticed, it has that white coating…

17. [*conversation dies off, group pauses, students appear to be considering what the FAC just said and/or their options*]

18. MS: [*picks up an incandescent bulb, apparently with the intention to insert it into a power source, but there are no more sockets available*] These sockets are already all used.

19. FAC: Okay so you need some more sockets then, we can use the extras available on the supply table over there [*gestures towards a table across the room*]. But okay, so… I mean, now you have all these bulbs - and - well so I'm not quite sure, what the goal is here?

20. FS: [*addresses FAC*] What I am still not quite sure about, is how we're going to be able to tell if the voltage changes the spectrum. But we are going to need to use the same bulb right?

21. FAC: Yeah, yeah or you could change the wattage [*glances towards the assortment of bulbs he carried over*]

22. FS: But how are we doing that, I don't know.

23. MS: Yeah, this is changing the voltage right? [*fiddles with a dial on a variable power supply a.k.a "dimmer switch"]*

The "dial" referred to above is a power supply that can take ordinary 110V electricity from an outlet and step it down to a lower voltage. Depending on the properties of what's plugged in to the power supply, this lower voltage will also affect the electrical current.

24. FAC: [*leans in to see what is being indicated*]. Yeah that's right. So it's basically-

25. FS: So this goes to 120 right [*indicating the dial*]? After 120 is it [*i.e. the bulb*] going to explode?

26. [*Laughter*]

27. FAC: I think all that we have is like 110 volts right? [*indicating the outlet*] Because that is what regular outlets are.

28. FS: Well so that says 120 right? So then what does this do [indicating the dial]. She [*referring to another facilitator who had stopped by earlier*] said it changes the voltage.

29. FAC: Yes, it should change the voltage.

30. FS: So it doesn't change the spectrum. Right? [*tone she uses here suggests she is seeking confirmation of this assertion*]

Here it is worth noting that students were also provided with color filters and simple look-through spectrographs. These devices offer simple ways for learners to break up the light from the light sources into separate wavelengths, to examine the spectra of the various bulbs or the same bulbs illuminated at different intensities.

31. MS: So that's what we will find right? No matter how you change the brightness, you are not changing the wavelength.

This assertion is partially inaccurate. As an incandescent bulb gets hotter the light will get brighter and also bluer. An increase or reduction in current/voltage will result in a change in temperature which changes brightness and the "color temperature" of the light emitted from the bulb.

32. FAC: Yeah, well maybe, maybe but I don't know. Well so, that's an interesting question right? So - what is happening when you reduce the voltage allowed to power the light bulb?

33. MS: You are increasing or decreasing the number of photons, you are not changing the wavelength. The photons are increasing, some more of them are coming.

This is also partially inaccurate. These changes represent an increase in electron collisions which transfer more energy to the filament.

34. FS: But the wavelength is not changing. [*equivocating on her own assertion*] That is weird to think about.

35. FAC: [with enthusiasm] You should test that – you should try to figure out a way to test that hypothesis if that's your hypothesis. And yeah - that's a good

hypothesis. Now you just need to figure out a way that you can test it. Make some observations and see if it holds up.

36. MS: So we should just turn it up [*indicating the dial again*]? This is how we turn it up? [*starts to screw in a CFL bulb into an open socket*]

37. FAC: Well so, you might notice that the fluorescent bulbs behave differently than incandescent when you are turning up the dial. And keep in mind that different kinds of bulbs might be useful for testing one kind of hypothesis but not another…

38. MS: This is how we are going to test a hypothesis - I don't know if I am right correct me if I am wrong -I think the brighter that it goes, it means more photons.

39. FAC: Well that would be a good thing to investigate, although we don't really have the equipment for you to investigate that directly. But there might be some way for you to investigate that *in*directly.

40. {laughter}

41. FAC: But you also had another hypothesis, something to do with the spectra, right? And that could be something you might be able to test more directly with the equipment we have. So anyway, I'm going to let you guys check out some of these different bulbs.