Tweaks and Tensions:
What can we learn from the process of adapting a teacher workshop over time?

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1. Context for the Study and Scope of this Report

Purdue University's *Research Goes to School* (RGS) professional development program uses a problem-based learning (PBL) approach to help K-12 teachers understand and teach STEM-related topics to high school students. The goal was to recruit teachers who work in rural schools where students may be less likely to pursue a STEM degree in college and help these teachers better engage and motivate their students through PBL applied to interdisciplinary STEM topics. This combination of topical and pedagogical approaches is thought to offer a clear picture of how STEM is used in real-world situations, making the subject more appealing for students and encouraging them to engage in STEM fields. For years 1-3 of the project, the interdisciplinary topic was drawn from work by scientists and engineers in Purdue's C3Bio research team, a Department of Energy-funded effort to develop alternative liquid biofuels from non-food crops or waste products. In years 4-5, the STEM team came from Purdue's nanoscience institute; we do not address the nanoscience-related workshops in this report.

Teachers who participated in the workshop were in-service teachers (ISTs) from Indiana high schools and pre-service teachers (PSTs) from the *STEM Goes Rural* (SGR) program. In-service teachers were already experienced at planning courses and working with students, while pre-service teachers did not have much prior exposure to everyday classroom work because they were just starting their teaching careers. The teachers were in residence for two full-time weeks, participating in lectures, labs and discussions on PBL and the interdisciplinary STEM topic, and working in groups to develop a PBL unit that could be applied in their own school settings.

The first version of the two-week intensive workshop was based on extensive planning by the Purdue team. As for any new activity, the first year was challenging both to the Purdue team and the K-12 teachers going through the workshop, and there were many learning points for everyone. After Year 1, the team identified some issues that required changes to the workshop to bring the K-12 teachers to an understanding of how to connect PBL with STEM topics, and in each subsequent year, the team tried to improve the quality of the workshop. For example, they were aware of teachers' different backgrounds and took into consideration what changes might foster a better outcome and improve the teachers' gains. In the interviews, team members agreed that the workshop had improved since Year 1. Others noted that making the workshop inclusive to all teachers with different STEM backgrounds was going to be very challenging. The issues that arose as the team diagnosed the issues, and then addressed them in later versions of the

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workshop, highlight differences in various stakeholders' needs or expectations, some of which had not been explicit until the workshop actually took place.

For this report, we focus on the issues encountered and changes made to the workshop, as a way of understanding key elements of the workshop model and their function. We analyzed interviews with members of the Purdue project team who held a variety of roles: education and science specialists who planned and led the workshop, PI team members and staff who worked with the teachers or were familiar with the project in other ways. These interviews were conducted before and after the first three annual workshops. We focus on interviewees' descriptions of changes made to the workshops in the first three years of the five-year project. Indeed, all the interviews included significant discussion of observations and analysis of what worked and what did not, descriptions of the changes made in response to these observations, and the rationale for these. All interviewees expressed a sincere desire for feedback and improvement to optimize the teachers' learning experience.

Overall, we find that some of the changes made to the workshop did indeed resolve some of the issues that were identified. These solvable problems and their solutions are the "tweaks" referenced in the title, which include optimizing and adjusting the conceptualization, planning or implementation of the workshop. In some cases, there was high consensus that a particular change had been an improvement, while in other cases, the change solved one problem but generated another. These latter situations often point to built-in challenges that may arise from differences in the needs of different groups or from tensions among different goals. These may not be solvable in ways that meet all the needs or goals, thus we suggest they reveal "tensions" that are built into the workshop model. We will analyze these model elements and tensions in a future report that will incorporate data from project Years 4-5.

2. Adjusting the Schedule

The most straightforward changes addressed the flow of the day and responded to teachers' reports of the course as very intensive. Instructors made the class time more interactive, and allowed teachers to have a free lunch hour so they could talk to each other or have time for themselves or to handle personal business.

> We wanted to decrease the amount of time that they spent being talked to, if you will. …[Now] we designate that last hour for group work. …And then also not having them work over lunch…. Almost every lunch last time had a guest speaker. So we've changed that [so] they are actually, quote, 'free' for lunch, 45 minutes, and they can completely ignore the course or they can work with their group or whatever they want, but it's their time….

A second and especially important set of changes focused on the amount of material to be covered. One change was providing a "big picture" by framing the course with some introductory material before the workshop started.

> One of the things we did is, we had a lot more introductory information on the website that teaches to that extent, ahead of the workshop itself. Then as they came in, what we did was give them an overview of the energy picture in the US, covering all of the sectors of energy, so that they could see the place that biofuels fit within that picture.

This change was also intended to enable the K-12 teachers to get more out of the workshop from the start, instead of catching them up on introductory material on the first days. This let them take full advantage of the two weeks since it is a short period of time to learn so much material.

In addition to getting teachers started with some pre-reading, the team streamlined the content. The team not only wanted the K-12 teachers to be able to connect PBL with their STEM topic, they also wanted teachers to have time to think through the PBL unit and to reflect and focus more on the material of most importance. "You're asking them to digest so much," noted one speaker. Thus this change also addressed teachers' feelings that the pace was too fast and allowed them to go into more depth.

> [The first year] we spent the whole first week [in] what we thought was modeling the [PBL] process using a topic that was related but not identical, or not [included] directly into their required project on biomass to biofuel [conversion]. We spent a week immersed in the PBL unit about sustainable energy… wind, water, solar as alternative energy.
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> *(continues)* But we didn't talk about biomass to biofuels, and so students didn't see the connection—so [now] we've eliminated that completely. [Now] we start off, I mean right off the bat, investigating biomass to biofuels, and so that gives us basically two weeks for them to complete their units as opposed to one week. So that spreads out the assignments, the time in between the assignments so that they can get the feedback before the next component is due. And they find that more relevant as well because we made it [fit] to what they need to produce for the course.

The team saw being able to provide more targeted course content to the K-12 teachers as a very positive change, as the teachers knew better what material they would be covering and were more aware of what they need in developing their own PBL unit.

> One of the major differences this year was the order in which we presented information and material, and also the scope of things—the whole program for the two weeks. We had decided to narrow the focus, because trying to cover all areas of energy research was just too broad to give a sense of what is involved in research, in scientific research, and in the grand challenge. I think by narrowing it to really focus on to the biofuels and bioenergy and the issues within that, there's just a range of disciplines, we got more focus. We were more directed, and I think we were able to show a much greater relevance to what the teachers needed and to the individual lesson plans and so forth. I think focus was a big thing.

Overall, allowing more ease in the schedule was seen as a successful change that was responsive to teachers' feedback and provided the opportunity to concentrate more on key material.

3. Responding to the Differing Needs of In-Service and Pre-Service Teachers

One of the main problems that the interviews highlighted was the different needs of in-service and pre-service teachers when coming to the workshop. Since the in-service teachers are teachers from Indiana rural high schools, they had prior exposure to high school students and knew what to expect in a classroom setting. The pre-service teachers had different goals because they were still graduate students in Purdue's STEM Goes Rural program. The in-service teachers were ready to learn about PBL and how to connect the method to their classroom, while the pre-service teachers were interested in finding a job, learning how classrooms function, and being able to build a class agenda.

While interviewees noted that in-service and pre-service teachers had different goals and different gains from the workshop, they also mentioned ways in which the differences in teachers' experience meant they could help one another positively, as in the following quotation.

> From what I have observed, having the in-service teachers work with the pre-service teachers has been beneficial. I think it is probably more beneficial for the pre-service teachers, but there may be benefits to the in-service teachers as well…. But certainly the pre-service teachers are getting to interact and network, which is one of the things that we want to do, but they are also getting to hear the kinds of concerns and realities and questions and perspectives that the in-service teachers bring to this.

Even though Indiana has many rural and small town teachers, the state is not geographically huge. So they are isolated in their daily work but it is possible to bring them together physically for this kind of workshop. When two teachers came from the same school, they could support each other while practicing PBL in their classrooms. To address this issue, the project tried to recruit teachers from the same school, yet did not want to require teachers to come in teams, so as to keep the workshop open to all who were interested.

> We intentionally tried to recruit teachers from the same school to get teams of teachers—preferably in different content areas. [When that happened,] that was nice. The two biology teachers that were from the same school, we put in different groups, so they were each able to build [something] and they have two units when they go back.

Some expressed that pre-service teachers were slowing down the in-service teachers' learning because the PSTs were still learning how to design a curriculum, worried about getting a good grade for the course because they were getting credit for the workshop, or looking for a job. It was difficult for them to be job-hunting while in the workshop, as this speaker noted:

> This can't be the only thing [the PSTs] do, they've got to be putting out applications, they've got to get jobs, and this is just really problematic. You miss a day in a two-week course, then you miss a lot of content. …And that immediately started to frustrate me. Before this course even started, getting e-mails from students saying 'I'm going to be gone,' 'Is it okay if I miss the first day?' I had the sense that they were just saying 'yes' if someone says, 'Can you come for an interview Monday?' I don't know that that's true,

> but that's how it felt to me. They could be saying 'Well, I have a class, but can I come in after 3:30? Or can I come Friday?' And of course they're anxious to get interviews, so they probably are just saying 'Sure.' And I'll say okay. But I just found it really hard. I don't know how we get around that.

Some interviewees worried somewhat about the mixed group impeding ISTs' outcomes from the program. This could be a problem if in-service teachers are not learning or fully comprehending how to teach PBL to their students. That is, instead of learning how to connect STEM with PBL, in-service teachers are teaching pre-service teachers what to expect in their classrooms.

4. Building Connections to the Interdisciplinary Topic

Team leaders gave a great deal of thought to ways of making the workshop's central interdisciplinary STEM topic more relatable for teachers. The team wanted teachers to appreciate the richness of interdisciplinary topics as a natural fit with the PBL pedagogy, and their inherent interest and relevance as ways to help students make conceptual connections among STEM disciplines and from school to the real world.

> We've picked bioenergy because we have this [C3Bio] grant, and because [this topic is] a sort of entry point for working out the bugs and the details of how to do this. But you could pick climate change, you could pick global food security, you could pick issues around water. I mean, there's a whole range of societal issues where you think, 'Okay, let's get the students thinking and engaged about this and how science and technology could help you solve that problem.'

Yet, in most high schools, teachers are assigned to teach courses on particular science disciplines—biology, chemistry, physics, Earth science, mathematics, or technology. So they also needed to be able to connect the material to their own disciplinary area of teaching focus. The team wanted the workshop to include K-12 teachers across STEM fields and still demonstrate to teachers how a successful PBL unit is done and how to incorporate PBL into their own classrooms. This means it is very important that the workshop demonstrate how PBL fits into each subject that the K-12 teachers are teaching. Some interviewees wanted to be able to build a PBL model incorporating different STEM topics to demonstrate that PBL can be practiced throughout different fields, or for topics that are inherently interdisciplinary.

Interviewees felt that even the first version of the workshop communicated this goal, although perhaps not until the end of the workshop did this message come through strongly to the teacher participants:

> I do feel like some of that understanding came out of it. …When they gave their presentations that first week, when they were examining, the solar energy makes sense, the wind energy makes sense, they found that, well gee, not [only] one makes sense, but look, this makes sense perhaps in combination with this. So it wasn't that we were going to switch entirely to just one [energy source], and …that was gonna be the perfect solution to everyone, everywhere—it wasn't that. I think in a sense, from looking at the

> presentations, they recognized, it's more a portfolio of energy solutions for sustainable energy. So it did provide that.

Moreover, the relevance of the PBL approach across multiple, interdisciplinary topics was seen to be a general strength of this workshop model. This premise could be tested by applying it to a different topic in later years (as in fact the team did in Years 4-5).

> We might think about bioenergy again, or we might think, 'Okay, what is another topic that we can take the lessons that we've learned from doing this for bioenergy and apply it to another area of grand challenge research?' For example, food security, right? So security for food for a growing world population is a critical issue. We actually have a center here at Purdue that's focused on global food security and there are many scientists in the College of Agriculture here that work on different aspects of that. You could imagine thinking about that in an interdisciplinary fashion and pulling together all kinds of different aspects that impact food security, from sustainable growth crops to agronomic considerations to economics and policy and so forth. …I think it might depend on how well we've done. If we feel we've done very well this year in terms of achieving just the standards that we want from this workshop, it may be time to move on. It may be time to see if we can generalize this science.

However, the team soon came to understand that the interdisciplinary content area was exciting but also challenging for teachers. It was unfamiliar and did not fit squarely within any of their traditional areas of content expertise. Teachers were being asked to absorb not only PBL as an approach to teaching that might be new to them, but also a great deal of new science content. "It's a lot, to ask those teachers to learn a totally different pedagogy and very different content," noted one interviewee. Commented another,

> I think there's always gonna be a struggle…. I can't imagine trying to envision a place where I haven't been yet, and trying to really get outside my comfort zone like that. I think it's a pretty difficult task that we're asking for those teachers.
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> A number of them were asking very specific questions, "Okay, if I'm gonna do this with my students, here's where what you just presented might not work as well. So how do I explain it to them in a way that I can help them make the connection?"

This challenge may have been particularly significant for pre-service teachers, respondents suggested, because they did not have much classroom experience to draw upon when thinking about either applying PBL or using the interdisciplinary STEM content.

> Some of them, I think, have a difficult time because of the subject matter. They haven't been in a classroom yet, so I think they kind of have ideals, or an ideal kind of picture in their head, of what's gonna happen when they get in the classroom. We're trying to stretch them a little bit by picking a different content than what would be normal for them to pick. …It's just my impression, [but] because they don't have that classroom experience, I think they really struggle.

Yet the challenges of connecting the broad interdisciplinary content to their own teaching assignments were apparent for all the teachers, in-service and pre-service alike. Connections and implications that felt natural and obvious to workshop presenters or scientists experienced working in the interdisciplinary field were not obvious to the teachers.

> One of the big issues—what I was hearing this morning, and kind of as feedback from the teachers, is the level at which we try and communicate. So the teachers are saying, 'Well look, the mass spec— it's really nice, and we think we understand it (*laughing*), how the hell are we going to take it back to our students? How are we gonna package this up and do something that is relevant to them?' So I think there is a real disconnect that we have to try and work out. What level and content of material is really appropriate here?

Over time the team learned to make these connections much more explicit, and continued to streamline and focus the science content, make learning goals more explicit, and better align the learning goals, activities, and assignments. The scientists developed a joint plan for key points that they wanted to cover and divided up responsibility to cover different areas. That work continued into Years 4-5 and we will report further on those changes in a future report.

5. Accommodating Different Disciplines of K-12 Teachers

Another set of adjustments addressed having K-12 teachers from different backgrounds. This was seen as a positive feature because having teachers from different STEM backgrounds allows for the workshop to incorporate a variety of perspectives and ideas of how to build PBL into different STEM courses. If teachers could see how difficult science problems require different disciplines to work together, it was thought, they could better show their students how pursuit of a wide variety of subjects can help to solve a real-world challenge. PBL is not about looking at a STEM subject through one lens; it is more about incorporating different subjects to work on a hard problem together, as these two speakers described:

> What I'm really hoping that [the teachers will] get out of this that they'll better be able to introduce students to the idea that science, technology, engineering is something that you do, not something that you memorize. Right? It's not a list of facts that you just know. It's a way of thinking, and a way of doing. While the facts are important or what's been already discovered or learned prior to you doing what you're doing is important, that's only the beginning. It's not the end. There's an element of doing, an element of critical thinking involved. That's what I'm hoping that that they can move the teaching of science, technology, engineering, mathematics from beyond just a set of facts to something that you do, and a way that you think.
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> I think it has a lot of potential. I do think that [PBL is] going to be, not only a sustainable, but an effective way of immersing students in some of these bigger questions of science in ways that will engage them, and motivate them, and excite them.

Because of this emphasis, the mix of K-12 teachers from various areas of expertise was seen as very helpful for many teachers, analogous to doing interdisciplinary research in science.

> Dealing with information that is not cut and dried, that guides you in a particular direction so that there's much more uncertainty in high-risk, high-reward research than you might get in a laboratory experiment that's very carefully controlled, because it has to work in a classroom. I think that's something that we wanted to convey. That we're kind of thinking on the fly here, I guess—to see you're constantly in a state of response and you constantly value the input from your colleagues and from their very disciplinary perspectives.

However, speakers widely recognized that the math teachers felt frustration because they did not see how they would be able to connect the PBL with their classroom curriculum.

> I think there is still work to be done on how to present the content to the math people, in a way that they see the importance of what is, to them, science topics, and how it can be used in their classroom in a very powerful way to engage their students. (Y2, s15)

Speakers suggested that the math teachers did not easily recognize how mathematics might be used to address an interdisciplinary topic, or that the math teachers felt more highly constrained by their course curriculum and the need to prepare students for high-stakes tests. Others suggested that the math teachers are used to learning math in a traditional form, for instance:

> *Interviewer*: Have you noticed… is there anything about math teachers or future math teachers that is different from the science teachers? One thing that struck me in that wrap-up conversation a couple of weeks ago, at the end of the class, was that the science teachers kept saying things like, "Gosh, we want our students to transfer knowledge and to apply." The math teachers had sort of a different take of the important roles and importance of that….
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> *Respondent*: My experience with the [pre-service] math students has been that they typically have struggled a little bit more with some of these ideas of, just in general, more student-centered classrooms, more different ways of teaching it. …The two SGR math students this year seem to be much more open to inquiry-type learning. They seem to feel more comfortable with that than our math teachers in the previous [workshop], or than our students in the past had been, which was very exciting. I still think there's a disconnect in the idea of learning math content for the sake of math content, no outside application. You know, 'We need to just kinda keep it math, for the sake of math'….

In this workshop, math teachers are not only being exposed to a new way to teach math to their students, but they are also learning how to connect math to PBL themselves. Speakers suggested that math teachers had a harder time seeing how their subject can be delivered using PBL; it seemed easier to see how science could be applied in a real-world situation.

> [The pre-service teachers] come from a lot of backgrounds—some come from an engineering background, some come out of industry where they've been doing something quantitative, and some of course are straight out of undergrad…. The way math is traditionally taught, you know, and with science you traditionally do at least some

> demonstrations, right? And you have labs. And so there is sort of a culture that we should be doing something hands-on. That culture doesn't exist in mathematics…. Right, and they've never seen any other way of learning mathematics, they don't see it when they go out to work in the schools. …Most math teachers in Indiana are pretty traditional, so even when we place them clinically… they're not seeing those things, they're not being mentored in those things. So I think it is more of a stretch for them.

In response, adjustments to the workshop were applied to make it more inclusive to teachers with every STEM background. A main strategy was the addition of content-focused coaches or master teachers, who could work with the discipline-based groups on developing their PBL units. The master teachers took on roles such as facilitating group process, clarifying expectations and requirements, and providing many teaching ideas from their own experience. Their positive and encouraging attitude had general benefits in boosting participants' buy-in and reducing participants' anxiety.

> [Having a master teacher to coach each group] works really well, because those teachers have been through it, so they know the intensity. They know what those teachers are experiencing. They're able to say, "It's horrible right now, but it's gonna be much better in two days," kinda stuff. Plus, they have so much credibility, because they're out there doing the same thing everyday, whereas we don't have quite so much credibility, in terms of a lot of things with teachers.

The most successful master teachers proved to be experienced in-service teachers who had previously experienced this workshop and implemented a PBL unit. It was harder to find a master teacher with math PBL experience, and the attitude of the person in that role was crucial in shaping the attitude of the math teacher working group.

> I guess as I look at changes, I have math teachers that I work with on other projects that have a lot of classroom experience and are very receptive to trying to build connections with science content, so that students can help see the applications of what they're learning in the math classroom. I think I would be more inclined to see, for next year, if one of those teachers actually had time [to take part].

Overall, the inclusion of master teachers as coaches was a positive adjustment, but it did not entirely solve the challenge of meeting the needs of the math teachers.

6. Integrating Interdisciplinary Content with Problem-Based Learning

Finally, the team made constant adjustments to the way in which the workshop was taught. They wanted the K-12 teachers to be able to see connections between PBL and STEM topics, but initially they did not teach the workshop entirely in a PBL form themselves. Yet if teachers experience PBL themselves, they are more likely to learn how PBL and STEM can be practiced and how to teach it in a more efficient way to their students. For example, one interviewee noted,

> It's difficult for people to learn both things at the same time. Like the [pre-service] teachers that we're trying to train, they're all scientists, or they're trained as mathematicians or scientists, and yet trying to engage them in the pedagogy, that's really different. They want answers. They're used to teaching differently. And so it's a challenge for us, as advocators [of PBL], to get them to wrap their heads around PBL, and how to make it work for their students. It would be interesting to see how they implement it…. I'm not a purist, it's not like it has to be exactly like this or it's not PBL. But it will be interesting to see the variations, and how that actually gets implemented when they end up having to deal with all the logistics of a classroom, with the differences in students. And I don't know how strong their knowledge base is, either. Of course, my knowledge base wasn't very strong, and if you can be a good facilitator, again, I believe it can happen, but that's asking a lot of these teachers. And I think they'll need support.

This issue manifested in a variety of ways, including choices about modeling PBL in teaching the science content of the workshop, but also in decisions about assignments and assessments. The compressed time frame for the workshop meant that it was easy for instructors to become impatient with the time participants needed to figure things out for themselves, and thus to fall back on traditional teaching methods themselves.

> Let's say we use a daily quiz just as an example, and the teacher are creating their assessment measures and they put in daily quizzes. You know, we don't want to say, "Well, we did it for you but we don't want you to do it for your students" (*laughs*)—you know, that doesn't fit very well. So again, as much as possible, [we need to] model, and this is kind of based on Prensky's approach, as much as possible the students are finding out the information. Like, I'm not going to do a overview PowerPoint about the driving question! It's kind of like, 'Well, what does make a good driving question?' Then the next half hour, see what you can find out—let's create, you know, a list of criteria, or something like that. I mean, that's what I hope to do.
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> (*continues*) Last year we did a lot more introductory PowerPoint, and to some extent that's fine too… we call them mini lectures, you know, where you just kind of introduce the topic. But I'd like to forward that to the students. And I think there will probably be some bumps along the way, because you want to revert to what you're comfortable with, and it will be uncomfortable for everybody and myself included (*laughs*) you know—but that's the hope. And if I read the Prensky book again before that class starts, I'll be motivated—I'll have the vision front and center, you know (*chuckles*)—but it's easy for [any of us] to say, "Oh well, you know, we don't have much time" or whatever.

This quotation highlights how these tensions over the choice of instructional strategies and the integration of pedagogy and content show up in the everyday decisions that instructors make in planning and leading a workshop like this. Compromises among laudable goals must be made, but they may still feel like compromises to the project designers, as this speaker noted: "Yeah,

integrating the pedagogy with the content, I thought that was presented more cohesively than it had been the year before. I thought that was better. I don't think it's ever gonna be perfect."

7. Conclusions

Overall the team took a proactive stance in making adjustments and used the data that were available as well as their own observations and conversation. They recognized that this was important as well as time-consuming, and they recognized that each year they made progress in identifying the core issues and refining the model.

> Less planning had to go into it this year. Year 1, of course it was very intense. Year 2, since we changed so many things, it was very intense. This year we were just building on what we had done last year. The planning and the preparation was much less stressful, which was nice.

At the same time, they recognized the challenges of connecting existing programs, each with its own goals and strategies, into a single program offered through a common framework.

> I understand the goal of trying to build off things that are already in existence and trying to get synergy that way, but I also think it's very, very, very difficult. I don't know that—I just think that it brings a whole 'nother set of baggage to it, because you have a really difficult time with communication across entities that were already kind of involved in projects that had different goals and objectives. I don't know if it—it's a lot, to ask those teachers to learn a totally different pedagogy and very different content.

Analysis of the changes made in the final two years, and the participants' overall assessment of the final model, will help us understand in greater detail which tensions remain fundamental to the model, and why, in contrast with issues that can be tweaked and resolved.

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