Supporting Collaborative Curriculum Customizations Using the Knowledge Integration Framework

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Abstract: Teachers are currently facing a major instructional challenge, namely, supporting students to meet the three dimensional learning goals of the Next Generation Science Standards without adequate curriculum materials to do so. In this paper, we report the design and outcomes of professional development activities that support teachers and researchers to collaboratively customize Web-based Inquiry Science Environment (WISE) units to help students develop coherent science knowledge. The WISE units and professional development activities were developed using the Knowledge Integration (KI) Framework. We show that the KI framework functioned as an effective scaffold to support teachers in modifying their teaching practice to make curriculum customizations that are evidence-based and aligned with a theory of learning. We discuss how our study results informed the design of an online curriculum customization and implementation interface and offer the principles of the KI framework as design principles for the development of other collaborative professional development endeavors.

Keywords: curriculum customization, professional development workshop, teacher-researcher collaborative learning, NGSS, knowledge integration

Introduction

We report on the design and impact of a professional development workshop that positions teachers and researchers as collaborative partners in customizing Web-based Inquiry Science Environment (WISE) units to align with the Next Generation Science Standards (NGSS, 2013). To the workshop, teachers brought their teaching expertise and used their experience implementing the units and logged student data to improve the unit. Researchers brought their expertise in designing the units following the Knowledge Integration (KI) pedagogical framework and used the framework to guide the professional development activities. We hypothesized that, if aligned with curriculum activities, the four steps of the KI process (i.e. eliciting ideas, adding ideas, distinguishing ideas, and reflecting on ideas) would serve as instructional strategies and scaffold teachers' application of the underlying constructivist theory of learning. We further hypothesized that, if aligned with the workshop activities, the four KI steps would give teachers and researchers an experiential knowledge of the process, facilitate the integration of their respective knowledge, and foster the collaborative customization of WISE units for NGSS-alignment and variegated classroom implementation. We discuss how the results from this study informed the design of an online interface on the WISE platform to support teachers to customize and implement NGSS-aligned curricula in ways that helps students develop coherent, three-dimensional science knowledge.

Background

Since its publication in 2013, the NGSS (NGSS, 2013) has been widely adopted by U.S. states, often without accompanying curriculum materials. During initial implementation of WISE units, many teachers reported interest in better aligning their instruction with NGSS, motivating this study. Given the new, three-dimensional learning goals of the NGSS, developing curricula de novo that can support students to meet these ambitious standards is a formidable task, even for the most adept teacher. In their instructional comparison study, Penuel and Gallagher (2009) showed that when teachers assume the role of curriculum customizer rather than designer, they produce higher quality curriculum, as measured by its ability to support inquiry and promote student science understanding. Building on these findings, we designed a knowledge integration workshop to build teachers' capacity to customize existing curricula rather than design new curricula.

A review of professional development supporting teachers to use technology-enhanced science inquiry curricula found a significant effect for programs that followed the KI framework (Gerard et al, 2011). Successful professional development efforts elicited teachers' ideas, added new ideas to their existing repertoire, and encouraged teachers to distinguish among their ideas, reflect upon their experiences, and develop an

integrated, coherent view of instruction (Linn & Eylon, 2011). The KI framework draws on extensive research supporting a socio-constructivist view of learning.

A key tenet of socio-constructivist learning and knowledge integration is sustained collegial collaboration. In successful professional development efforts, this collaboration involves teachers from multiple schools along with university mentors (Penuel et al., 2007). As teachers collaborate with other education community members in activities such as customization, they negotiate meaning (Lave, 1996), which is a critical aspect of learning.

Research questions

Research suggests the value of focusing on the customization of existing curriculum materials. However, supporting teachers to incorporate the NGSS into their teaching practices calls for new models of professional development. The KI framework as a professional development model offers promise, especially for the customization of WISE units, since they were designed using the KI framework. Thus, we investigated the following research questions:

1. Can the KI framework guide the design of both curriculum customization and professional development?
2. Which professional development activities:
   o Enable teachers to use pedagogical principles to align existing curriculum materials with NGSS?
   o Support teachers and researchers to collaborate to develop curriculum that enables students to meet the three-dimensional learning goals of the NGSS?

Methods and materials

We designed and tested professional development activities consisting of a 1.5 day workshop to review and customize WISE units, in-class support during implementation of the customized unit, and post-implementation interviews. The professional development activities followed the KI pedagogy of eliciting ideas about teaching the unit, adding new ideas to customize the unit, distinguishing among ideas during implementation of the customized unit, and reflecting on the experience.

Participants

The workshop participants included 21 middle school science teachers and 15 researchers. The teachers came from 8 schools across 6 districts and the researchers came from 2 universities. All teachers had implemented at least one WISE curriculum unit prior to attending the workshop.

WISE curriculum units

WISE units are developed using the KI Framework. They elicit student ideas from their own experiences; engage students in gathering new ideas using embedded models and simulations and hands-on activities; encourage students to distinguish among these ideas by building models, testing alternative views, or critiquing ideas of others; and request reflections in reports or presentations. The WISE units used by teachers in this study are: Photosynthesis, Global Climate Change, Plate Tectonics, and Self-Propelled Vehicles. Each unit features embedded assessments, logs student responses, and captures student activities (e.g. click-stream data). Teachers and researchers can access all logged, de-identified student data via the data export interface in the Grading Tool.

Customization materials and activities

Before the workshop, in preparation for the customization process, we analyzed the WISE units to identify the NGSS performance expectations addressed in each. Then, we restructured the units into lesson series such that each lesson in the unit targeted a single NGSS performance expectation. To support coherent knowledge building for the target performance expectation, we also structured each lesson in the unit to engage students in each step of the KI process (i.e. one lesson corresponds to engagement in a complete KI cycle). The lessons were designed such that they could be taught in sequence as a unit or as independent lessons.

In addition, we created a diagrammed version of each unit consisting of a 5" x 7" notecard for each lesson with each activity in the lesson briefly described on 3" x 3" sticky notes, color-coded by each KI step (pink: Elicit Ideas; orange: Add Ideas; green: Distinguish Ideas; blue: Reflect On/Revise Ideas, see Figure 2C). On the 5" x 7" notecards was the following lesson information: unit title, lesson title, recommended grade

levels, targeted performance expectation, and a brief description of the learning goals. These tangible, diagrammed versions of the WISE units were the objects of customization and were designed to pilot a prototype version of a unit customization interface on the WISE platform.

After the workshop, the researchers incorporated the customizations of the diagrammed version of each unit into a complete digital version for subsequent post-workshop classroom implementation.

Data sources and data analysis

To address our research questions, we gathered data corresponding to each of the KI-aligned professional development activities. During the 1.5 day workshop, we documented the customized units for comparison to their previously implemented counterparts. Throughout the workshop, the researchers captured audio recordings and photographs of the workshop activities, and collected teachers' written responses to the following prompts:

- What are some things you learned or have taken away from engaging in this customization process and sharing with other teachers?

- Was this customization process and reflecting on the KI cycle helpful for you in thinking about how to achieve your NGSS and other curricular goals?

- Do you think you could use this customization process for another unit you'd like to run?

- Please share any other reflections or feedback you have from the workshop.

To analyze the customization of the WISE units, we counted the number and type of interleaved KI-aligned, non-WISE activities that teachers added to the diagrammed units. Our analysis of teachers' written reflection consisted of identifying themes related to the customization and collaboration process. For this paper, we analyze the implementation of the customized WISE Photosynthesis unit as carried out by two, 7th grade teachers, Mr. Vega and Mr. Harrison. We took field notes during classroom observations and conducted post-implementation interviews to discuss their customization decisions and their overall implementation experiences. We evaluated our observation notes and interview data in terms of their implementation of the workshop customizations and the type of customizations they made during implementation.

Results

Knowledge-integrating and experiential activities

The activities of the 1.5 day workshop aligned with the four steps of the KI process (see Table 1) and positioned teachers as experts on their teaching practice and researchers as experts on their curriculum designs. To begin the workshop, the researchers facilitated a whole group discussion to elicit ideas about the function of each dimension of the NGSS performance expectations in terms of lesson development (e.g. disciplinary core ideas provide the lesson content). During this discussion, the researchers introduced the KI framework and invited teachers to share activities they used or could KI process. This activity was designed to highlight the similarities between how the teachers and researchers conceptualize and support the knowledge building process. Each group activity of the workshop (whole group and small group) was designed to highlight the expertise of both teachers and researchers and to create opportunities for expertise sharing.

Table 1: A summary of the professional development activities, their alignment with the KI process, and sample teacher reflections.

Professional Development Activity	Knowledge Integration Alignment	Sample Teacher Reflections
KI Framework for NGSS Lesson Development	Eliciting & Adding Ideas	"*I enjoyed looking at the KI. It is very similar to how we plan our lessons and it was cool to see we were aligned in our thinking.*"
Identifying KI-supporting Activities	Eliciting & Adding Ideas	"*[KI] allowed [me] to better think about the learning process. Breaking it down into components and deciding what kind of activities and scaffolding will go into that part of the project*"
WISE Unit Analysis Using	Adding & Distinguishing	"*This is something I will use in the future with other lessons*

Student Data	Ideas	*to make sure it is really meeting all areas[, if] students [are] really understanding a lesson.*"
Interleaving KI-supporting Activities into WISE Units (Customizing)	Adding & Distinguishing Ideas	"*The customization process and reflecting on the KI cycle are definitely helpful for me. I understand better how each unit is built and how I can interact with it. I can pull different components together to fit the needs of the curriculum or the time constraints*"
Reviewing Unit Customizations	Distinguishing & Reflecting On Ideas	"*It was really interesting to hear other teachers' reflections on their units. It gave me the chance to think about how I might want to use some similar ideas in the units I plan to run in my classroom.*"
Actualizing Customizations Using the WISE Platform	Adding Ideas	"*I added new labs to the WISE project, learning how to use the authoring tool was great to be able to add our new ideas into the project.*"
Implementation of Customized Unit	Distinguishing & Reflecting On Ideas	"*I deployed instruction in similar fashion to the Knowledge Integration process through a unit designed and planned by [another curriculum provided] for 6th graders learning from instruction that is 3-D and that conforms to the NGSS. I generally follow the same process throughout each unit of instruction.*"
Post-Implementation Interviews	Reflecting On Ideas	"*The [KI] labels on each step [of the customized WISE unit] were useful to me in identifying the stage of learning the students were in; to which, I targeted my instruction or interactions with small groups. I loved how the unit was divided into distinct but incremental lesson[s] for that exact reason, they demarcated conceptual bubbles that can exist on their own but are still a part of something larger, the bigger picture, the overarching idea.*"

The sharing and integration of expertise was evident in the customization activity. For the unit customization activity, teachers were assigned to a small group corresponding to a unit they recently implemented and with researchers who had developed the units. Teachers were asked to think of and write on colored 3 x 3 sticky notes as many activities as they could think of for each step of the KI process (Pink: elicit ideas; Orange: add ideas; Green: distinguish ideas; Blue: reflect on/revise ideas). Teachers were invited to share their KI activity ideas with other workshop participants by placing the sticky notes on a long table centrally located in the meeting room (see Figure 1). The goal of this activity was to further elicit and add ideas regarding topic-specific activities that were accessible to teachers and would support the KI process.

Figure 1. Shared interleaved teacher activities.

To further add ideas regarding unit customization, the researchers provided teachers with evidence of their students' learning. Specifically, researchers gave the teachers a random sampling of 30 of their students' responses to a post test assessment item that targeted at least one dimension of an NGSS performance expectation addressed in the unit. Teachers were asked to evaluate the responses to identify areas of strength and weakness in their students' understanding.

The researchers then invited the teachers to customize the unit by interleaving the activities they previously wrote on the color-coded sticky notes with those on the lesson notecards. The goal of this activity

was to customize the unit in ways that would better support students in developing an integrated understanding of the targeted NGSS performance expectation, using evidence of previous student learning as a point of reference. Teachers were given full license to eliminate, substitute, or add any KI-supporting activity by rearranging the sticky notes on the lesson notecards. In this way, teachers could distinguish their ideas about how to customize the unit in ways that would support their students in the KI process and function within their classroom constraints and resources (see Figure 2A, 2B).

Figure 2. WISE unit customization process: Identifying non-WISE, KI-aligned activities (a); Identifying relevant activities to customize the unit (b); Integrating their activities into the diagrammed WISE unit (c).

Teachers worked collaboratively within and across their small groups to exchange ideas and activities to customize their unit. Of all the customizations that teachers made across all the units, 33% (31/94) would elicit students' ideas, 33% (31/94) would add to students' ideas, 10% (9/94) would support students in distinguishing their ideas, and 24% (23/94) would help students reflect on or revise their ideas (see Figure 3).
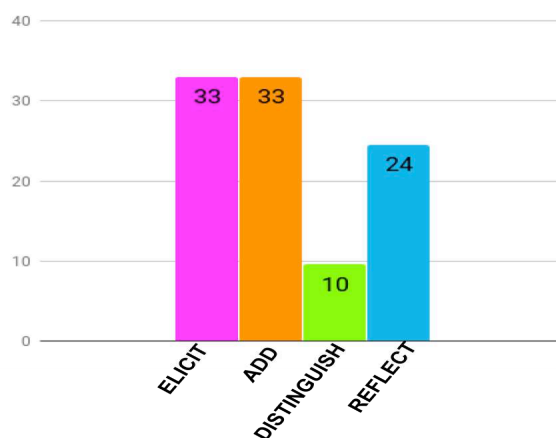
Figure 3. Percentage of unit customizations aligned to each Knowledge Integration step.

In another group workshop activity, teachers were asked to evaluate whether their customized unit would support their students in developing an integrated understanding of the disciplinary core ideas, cross cutting concepts, and science or engineering practices targeted in the unit lessons. After teachers made their final customizations, they were invited to share their customized units with other teachers who were interested in implementing the unit. During this unit exchange activity, teachers were able to get feedback from other workshop participants about their customization decisions.

In the final group workshop activity, the researchers demonstrated and helped teachers use the unit authoring tools currently built-in into the WISE platform. During these small workgroup sessions, teachers chose 1-2 customizations to reify in the digital version of the unit on the WISE platform.

To conclude the workshop, teachers were asked to provide their reflections on their workshop experiences (see Table 1). Of the 21 teacher participants, 15 (71%) provided responses to the reflection quetsions. As for whether the KI framework was a productive lens through which to evaluate and customize a unit, 80% of teachers (12/15) answered in the affirmative. In response to the question, "Do you think you could use this process again to customize another unit you'd like to run?", 87% of teachers (13/15) answered in the affirmative. Additionally, many teachers (87%, 13/15) shared that the lesson series format of the WISE units provide great affordances for customization using their own activities.

Reflection on and implementation of a customized unit: The cases of Mr. Vega and Mr. Harrison

To continue exchanging expertise after the workshop and to extend the collaborative customization efforts, the first author provided in-class support during implementation of the customized unit. The following are the results of the implementation of the customized Photosynthesis WISE unit (https://wise.berkeley.edu/project/24548) in the fall term after the summer workshop by two teachers, Mr Vega and Mr. Harrison. Mr. Harrison worked in the small group that customized the Photosynthesis unit during the summer workshop, however Mr. Vega worked in the small group that customized the Global Climate Change unit. Over the course of implementation of the customized Photosynthesis unit, the first author noticed how both teachers interleaved non-WISE activities, most of which were designed to provide students with additional ideas to supplement their limited prior knowledge about certain topics, like chemical reactions. This observation supports the analysis of the unit customizations made during the workshop where 33% of the total customizations aligned with the Adding Ideas step of the KI process (see Figure 3). In both cases, the teachers used a molecular modeling kit to provide their students with ideas about atoms, molecules, and the nature of chemical reactions related to photosynthesis. Additionally, Mr. Harrison incorporated a multi-modal activity on the conservation of matter during the photosynthesis reaction as a transition from Lesson 1 (Plant Growth Needs) to Lesson 2 (Photosynthesis and Cellular Respiration Reactions). During the post-implementation interview he commented that he used the WISE concept mapping activities to support his students in distinguishing their ideas about energy and matter cycling, the targeted cross-cutting concept in the unit. Mr. Harrison's use of WISE activities over his own activities to help students distinguish their ideas correlates with the result from the customization activity, namely the low levels (10%) of customization activities aligning with the distinguishing step (see Figure 3). This finding also parallels Mr. Vega's reflection comment that he plans to "*[s]trengthen the role WISE plays during the Distinguishing...phase*".

Mr. Harrison: A deeper look

During the workshop, Mr. Harrison expressed reticence regarding the customization partnership. His past experiences with the units led him to feel like they were "*adapted to fit the need of each researcher*", additionally he could not see how the digital version of the WISE unit could be restructured into related but independent lessons aligned to specific NGSS performance expectations. However, when asked how he thought the customized, digital Photosynthesis unit aligned with the NGSS he remarked, "*It's definitely aligned, it fits right in with our [other curriculum materials] because we go from Photosynthesis right into ecosystems*" (which is Lesson 4 of the customized Photosynthesis unit). This comment highlights the way that Mr. Harrison interleaved the WISE Photosynthesis unit with his existing curriculum to better support his students in meeting the targeted NGSS performance expectations. Specifically, Mr. Harrison commented that his existing curriculum, although nominally aligned with the NGSS, did not actually provide his students with sufficient opportunities to develop a robust and coherent understanding of the targeted ideas, concepts, and practices. He, therefore, used the customized WISE unit to provide his students with these opportunities. Mr. Harrison further discussed the difficulty and discomfort he experienced when implementing curriculum that he did not develop and therefore greatly appreciated the ability to customize the WISE unit with his own activities to make the unit "his own". When the first author asked Mr. Harrison how the researchers could further collaborate to address his curriculum customization challenges, he offered the idea of incorporating specific WISE lessons and activities into the Google Classroom that he used to plan and organize his instruction. He stated that doing so would solve the notoriously difficult problem of trying to re-synchronize students who progress at different speeds through the WISE activities. (We elaborate upon this idea in the Conclusion section.)

Mr. Vega: A deeper look

Mr. Vega also engaged in extensive customization during implementation to assume greater "authorship" of the unit. During the implementation, he commented to the first author, "*I was motivated to Edit Content to the unit...Take a look*", referring to his use of the unit authoring tools on the WISE platform, a feature historically used only by researchers. In these edits, Mr. Vega customized the prompts for the concept maps to align with the topics and terminology used in his non-WISE activities. In this way, he created greater continuity between WISE and his other curriculum materials. Mr. Vega's customization of the Photosynthesis unit during implementation is of particular note since during the workshop customization activity he was not part of the Photosynthesis small group. Therefore, Mr. Vega's customization of the Photosynthesis unit demonstrates that he was able to transfer and apply the knowledge he gained during the workshop to another unit, actions that substantiated his "*YES*" to the reflection question of whether he could customize another unit. Beyond making edits to provide greater continuity between the WISE unit and his existing curriculum materials, Mr. Vega also

applied his understanding of the KI process to all his instruction. During the post-implementation interview he stated that he used the steps of the KI process to keep track of the stage of learning in which his students were engaged and thus provide them with targeted support.

Discussion

Design principles for Knowledge Integration customization

In this paper, we described professional development activities that were aligned with the KI framework and showed how the framework helped teachers customize their existing curriculum to better support their students in meeting the three dimensional learning goals of the NGSS. The workshop reveals three design principles that we recommend for teacher-researcher professional development: support teachers and researchers to learn from each other; make thinking about customization visible; and support sustainable customization practices. In the sections below, we highlight the value of each design principle in supporting collaborative learning amongst researchers and teachers. We conclude the section with a discussion of how the insights gained during the customization activity inform the design of an online curriculum customization interface.

Supporting teachers and researchers to learn from each other

The workshop facilitated the integration of teachers' and researchers' knowledge and expertise. Throughout the workshop activities, researchers used the KI framework as a mediating tool to share their insights into the learning process, and teachers shared their insights into the instructional constraints and resources of their teaching contexts. Transitioning from whole to small group activities allowed workshop participants to learn from each other and consider new strategies and activities to help students meet the learning goals of the NGSS. Teachers expressed that having opportunities throughout the workshop to learn from researchers and other teachers within and outside their school was invaluable, as they do not regularly have such opportunities. The final customized WISE units reflected the integration of the ideas and expertise of researchers and teachers. Thus, the workshop embedded research-based pedagogical insights into teachers' curriculum customization practices and expanded researchers' understanding of teachers' instructional constraints and resources.

Making thinking about customization visible

To customize the WISE units, we designed workshop activities that made the customization process visible. The diagrammed WISE units made the researchers' thinking visible to teachers by highlighting the units' salient features and the researchers' design rationale. The diagrammed units facilitated productive conversation about the feasibility of unit implementation and theories of learning, specifically the KI framework. Writing their ideas for lesson activities on sticky notes color-coded according to the steps of the KI process provided teachers tangible artifacts with which to organize their current curriculum materials in ways that would support constructivist-grounded pedagogy. Having the content of the sticky notes at the grain-size of lesson activity supported experimentation with lesson structure and sequence. Teachers could place and replace the notes on the lesson notecards. Thus, the customization activity helped participants make their thinking visible by moving their ideas from conceptualization to paper, making their ideas available for evaluation and revision by themselves and others. The activities also helped make learning the KI framework accessible to teachers, thereby providing teachers and researchers with a common pedagogical lens with which to evaluate and customize curriculum.

Supporting sustainable customization practices

After the workshop, teachers and researchers partnered to implement the customized WISE units. The two cases presented in this paper, highlight the power of the professional development activities to promote sustainable curriculum customization practices. In one case, the teacher (Mr. Vega) implemented a customized Photosynthesis WISE unit which he did not work on during the workshop. During implementation he applied the KI framework to effectively interleave his existing curriculum activities into the digital WISE Photosynthesis unit to support his primarily English Language Learner students in developing a coherent understanding of the targeted performance expectations. Similarly, the other teacher (Mr. Harrison) customized the WISE Photosynthesis unit to supplement his existing curriculum. He recognized that his existing curriculum did not support students to distinguish their ideas, a critical step in the KI process. He used WISE activities to do so. Both teachers noted that the structure of the WISE units, namely a series of related yet independent lessons targeted to specific NGSS performance expectations that engage students in each step of the KI process, made customization feasible and effective. Rather than viewing the WISE units as a product of research efforts

that needed to remain unedited, both teachers viewed the units as their own and acted accordingly. The workshop developed teacher agency around curriculum customization thereby allowing the customized WISE unit to be the product of a partnership between education experts, experts of theory and experts of practice.

Conclusion

The outcomes and associated principles presented in this paper illustrate the promise of the KI professional development activities to support the alignment of existing curriculum with NGSS. Analysis of the activities suggest three design principles that echo the KI tenets: learning from others, making thinking visible, making learning accessible, and promoting autonomous learning (Linn & Eylon, 2011). The principles were developed in the context of STEM curriculum customization; however, they should also be tested in other contexts, such as developing culturally-relevant curricula. The findings also illustrate the value of logging student activities and using student work to support customization. Incorporating learning analytics into the WISE units could potentially allow teachers to use evidence of student learning in real-time to make curriculum customization that support the KI process. This is an application of these findings that we are actively investigating.

Make customization accessible

The diagrammed version of the WISE units and the workshop activities provided a prototype for an online customization and implementation interface. This interface makes the customization process accessible to teachers. Teachers commented that the diagrammed WISE unit provided the ideal amount and type of information they needed to gain a working knowledge of a unit. They also valued the intuitiveness of customizing units with activity-level sticky notes color-coded for the KI process. Using these experiences, the researchers and WISE technology team designed a customization and implementation interface on the WISE platform. When teachers view a WISE unit from the interface they will see a pop-out window with the same information that was on the notecards. Upon selecting the unit for implementation, the unit will be displayed at the activity level with each activity tagged for the KI step that it targets. Teachers can add specific activities from other WISE units or from their own resources. In the future, we anticipate integrating with Google Classroom so that teachers can seamlessly combine their existing curriculum with WISE lessons or activities. Additional analysis of the final customized unit will help ensure that teachers have a customized curriculum that engages their students in compete KI cycles. The interface will allow teachers and researchers to continually benefit from each other's respective expertise and sustain their curriculum customization partnership.

Next steps

Based on the successful implementation of the customized WISE Photosynthesis unit, we will study the implementation of all the customized WISE units. These findings will allow us to refine the online customization and implementation interface and the workshop design.

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