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Scaffolding learner autonomy in a wiki-supported knowledge building community and its implications for mindset change

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Abstract
Prior research has revealed resistance against wiki collaboration in higher education classrooms. Compared with small-group projects, whole-class knowledge building (KB) on a wiki is difficult, given students' lack of similar experiences, which requires scaffolding intersubjectivity and transfer of responsibility. This paper focuses on the second cycle of a design-based research study to develop learner autonomy in wiki-supported KB. A learner autonomy framework guided the re-design of the instructional theory with content from the relevant literature. The theory was implemented in an undergraduate design course to validate and refine the theory. We analyzed the data from observations, wiki content, interviews with the expert instructor and two other instructors and a focus-group interview with students. We found that the KB principles helped students understand KB; and the self-regulation and meta-cognition strategies increased motivation and confidence in KB. From the success of this case, we propose that scaffolding learner autonomy for a wiki-supported KB calls for a change in students' learning mindsets and requires careful instructional design to support the cognitive, behavioral and affective aspects of change to reduce resistance.

Background

Technology Transformation Requires Mindset Change for Learning?

Technology integration commonly supports existing classroom practices, despite its potential to transform education to meet the learning needs for societies that are transforming (Reigeluth & Joseph, 2002). As a result, it often reinforces students' traditional learning mindsets, which refers to their way of thinking about learning formed by beliefs, values and cultures. However, through the convergence of emerging technologies and a collaborative constructivist approach, technology can transform higher education by creating communities to reduce passive learning and promote interactive participation through communication, creation and sharing (Garrison & Akyol, 2009). Prior research has focused on teachers' pedagogical beliefs and ideas to support innovative technology integration (Ertmer, 2005; Kim, Kim, Lee, Spector, & DeMeester,

Practitioner Notes

What is already known about this topic

- Knowledge building (KB) should be practiced to enhance students' competency in innovating and improving ideas collaboratively for societal progress.
- Wiki-supported whole-class KB is more difficult than wiki-supported small-group projects owing to students' lack of experience in KB.

What this paper adds

- An instructional theory designed to foster learner autonomy in KB on a class wiki.
- Success in fostering KB on a class wiki validates the instructional methods and suggests refinements to help students understand KB and increase their motivation and confidence in doing so.

Implications for practice and/or policy

- Autonomy in KB requires scaffolding in the behavioral, cognitive and affective aspects.
- Although wiki-supported KB challenges students who have a teacher-centered mindset of learning or have been immersed in a culture of competition, it brings an opportunity to change students' mindset to favor co-constructed learning and create a culture of sharing in the process of adopting it.

2013), but lacks attention to students' mindsets to help overcome their resistance to the imposed changes in learning. How can one avoid technology being subservient to inadequate student mindsets for learning? We address the question at the end of this article: What does collaborative constructivist learning supported by innovative technology imply for student mindset change?

Convergence of Knowledge Building and Wikis

Education has laid great stress on individuals acquiring knowledge, but insufficient attention is placed on promoting learners' participation in collective knowledge advancement (Scardamalia & Bereiter, 2010). Knowledge building (KB) in education refers to the production and continual improvement of knowledge of value to one's community (Scardamalia & Bereiter, 2003). KB is seen as essential for societal progress because the health and wealth of a society depend on its capability to advance knowledge through members' innovating and improving ideas during collaborative problem solving (Scardamalia & Bereiter, 2003). Knowledge Forum is an education software program designed to support KB, featuring posting and exchanging ideas, viewing and re-structuring ideas using graphics and communicating with peers (Scardamalia, 2002).

Meanwhile, an emerging technology, wikis, has been developed to support massive collaborative content creation from Web browsers. Similar to Knowledge Forum, wikis allow users to post, access, modify and communicate ideas with others. Although wikis provide less explicit scaffolding for suggesting KB actions compared to Knowledge Forum, they offer appropriate KB environments for mature learners, whose cognitive capability allows for determining actions to take. On Knowledge Forum, graphics are used by learners to connect or modify the links among ideas; on wikis, relevant ideas are organized on a wiki page or linked with internal hyperlinks. Wikis also have unique features, including a history of content modifications and a watchlist to track changes. From its features and its success on Wikipedia, it is reasonable to envision wikis to support KB in education (Cress & Kimmerle, 2008).

However, despite wikis being perceived powerful in supporting collaborative and constructive learning (Ajjan & Hartshorne, 2008; Norton & Hathaway, 2008), early adopters found students' reluctance to edit others' work or have their work edited by others (Alyousef & Picard, 2011) and hesitance to post in-progress work (Beames, Klenowski, & Lloyd, 2010). A meta-analysis of 73 peer-reviewed empirical studies on higher education wikis categorizes three barriers to wiki collaboration: bad group dynamics, issues with publicity and lack of collective ownership (Kummer, 2013).

To overcome these barriers, we initiated a design-based research study to develop an instructional theory of wiki-supported collaborative learning (Lin & Reigeluth, 2016): An initial theory was created based on Vygotsky's social constructivist framework as the pedagogical approach with strategies drawn from motivation, blended learning, and cooperative learning research:

1. Based on Vygotsky's work (1978), students' potential of learning may be achieved through teachers' guidance and peer collaboration. Additionally, blending online and face-to-face learning enables more interactive pedagogical approaches with other advantages, including easy access to knowledge, social interaction and ease of revision, compared to face-to-face or distance education settings (Graham, 2006). Therefore, the initial theory stresses scaffolding to foster collaborative learning in social contexts, including in both face-to-face and class wiki settings.
2. To overcome the first barrier of the wiki collaboration process (bad group dynamics), we included instructional methods from blended learning and cooperative learning literature, such as including early opportunities for face-to-face interaction (Garrison & Vaughan, 2008), and forming small groups of 2–4 members to ensure accountability (Johnson & Johnson, 1999). Note that the latter is relevant to small-group projects, but not to whole-class KB.
3. To overcome the other two barriers (the issue of publicity and the lack of collective ownership), we included strategies from motivation literature, such as explaining the relevance of wiki tasks to learning, recognizing wiki contributions and giving credits as an extrinsic reward, and offering choices and promoting diverse contributions to value personal interests as an intrinsic driver of learning.

Then, the theory was implemented by an expert instructor in a 68-student undergraduate course for 12 weeks, where both small-group project-based learning and whole-class KB were encouraged on a class wiki. Findings indicated that students did not develop autonomy in sustaining the whole-class KB community on the wiki. We suggested that wikis for whole-class KB should be considered a different genre requiring carefully re-designed scaffolds because most students have neither experience nor schema for KB to be transferred to the wiki, unlike they do for small-group projects (Lin & Reigeluth, 2016).

Although small-group projects succeed easily, given students' familiarity with such projects, it does not mean that researchers should not bother to design instructional methods for whole-class KB on wikis. As summarized earlier, education has not paid sufficient attention to learners' continual participation in creating and improving knowledge of value to one's community, which influences a society's capacity for collaborative problem solving. How can we bridge the gap between theory and practice when it comes to unlocking the full potential of wikis for KB in higher education? Thus, this article focuses on developing effective instructional methods for wiki-supported KB in higher education, and later discusses the implications for transforming students' learning mindset during the KB process.

Research Questions

How well does the re-designed instructional theory work for wiki-supported whole-class knowledge building in one higher education course? What possible improvements could be made to the theory? What are the possible implications for students' mindset change in the KB process?

Theory Development

This section describes the instructional methods (v4) re-designed before the second implementation.

Framework

Scaffolding describes the process offered by knowledgeable adults to guide novices' participation in problem solving by gradually adding task complexities to develop competence (Wood, Bruner, & Ross, 1976). In a study of scaffolding to engage students in creating and negotiating ideas through conversations with peers, Roehler and Cantlon (1997) found scaffolding important to help students understand that they can teach and learn from each other, leading to taking responsibility for their own learning and respecting others' thinking.

Similarly, the goal of scaffolding in this study is to support students' adoption of whole-class KB and to become independent in KB by helping students realize that they can advance knowledge of value to their community by collaboratively contributing and improving ideas on wikis. Note that the previous instructional theory (v3) included minimal scaffolding for KB, such as suggesting tasks and tracking edits, with the intention to promote learners' autonomy by eliminating the instructor's intervention. However, its implementation confirmed students' resistance to whole-class KB in the wiki and suggested re-designing the scaffolding to foster learner autonomy for whole-class KB (Lin & Reigeluth, 2016). It also called attention to the need to help students re-think learning during whole-class KB, which is related to Hannafin, Land and Oliver's (1999) suggestion for meta-cognitive scaffolding in open learning environments.

The design of the instructional theory (v4) involved changes in scaffolding intersubjectivity and transfer of responsibility: Intersubjectivity refers to communicating with students about the upcoming KB tasks, similar to Rogoff's (1990) example as she describes mothers' introducing a new toy by drawing infants' attention and demonstrating how to play with it. The transfer of responsibility refers to helping students gradually take responsibility and leadership to become independent in making choices in KB tasks.

Littlewood's (1996) autonomy framework was selected to guide the theory advancement because it aligns with our goal of students' self-sustaining the KB community on a wiki, and it suggests components for developing scaffolds for autonomy: ability and willingness. Autonomy is defined as "a capacity for thinking and acting independently that may occur in any kind of situation" (Littlewood, 1996, p. 428). Furthermore, this capacity depends on one's (1) ability (knowledge and skills), and (2) willingness (motivation and confidence), making four components in all. Hence, the instructional theory (v4) aims to foster learner autonomy in KB by scaffolding intersubjectivity (knowledge and skills for KB) and transfer of responsibility (motivation and confidence for KB).

Instructional Methods

The rationales for the instructional methods (v4) are presented in the following paragraphs. The scaffolds are marked in italics with codes to indicate a corresponding component to support autonomy—K for knowledge, S for skills, M for motivation and C for confidence (see Appendix for the summary of the instructional methods).

Intersubjectivity—developing autonomy through scaffolding knowledge and skills
As the wiki platform had a low technology barrier to students, we focused on developing their knowledge regarding KB by using KB principles proposed by Scardamalia and Bereiter (2003). The highlights of the instructional principles include: (1) real ideas, authentic problems: an *authentic problem is needed to encourage sharing and advancing ideas through KB* on wikis [K1]; (2) improvable ideas and democratizing knowledge: given students' resistance in changing others' texts on wikis, it is essential to establish an understanding among students that *most ideas posted are improvable* [K2a] and are *for anyone to improve* to make ideas stronger [K2b]; and (3) epistemic agency: because a student-sustained KB community is the goal, it is crucial to *encourage self-identifying actions on wikis* [K4].

Transfer of responsibility—developing autonomy through increasing motivation and confidence
To increase motivation, the instructor needs to remind students of what is assessed for KB, ie, their (3) collective cognitive responsibility: *all students are required to participate and be responsible for their own and peers' learning* [M1]; and the benefits from the KB fruits, ie, (4) symmetric knowledge advancement: *helping students understand how their learning gains through giving and taking in KB is the key to develop the sharing culture* [M2]. To increase students' confidence, Keller (1987) suggested the progressive disclosure strategy to help overcome the fear of the unknown and prevent overwhelming students with detailed requirements in the beginning. In this case, we kept the instructional method of tracking students' edits on the wiki and added a meta-cognitive strategy to foster class discussions on KB as students proceed to *encourage reflection and to help become self-directed during group progress* [C1 b] (Hmelo-Silver & Barrows, 2008).

Research Methods

Design-based Research
Design-based research (DbR) addresses the knowledge gap between theories and practice for studying educational technology innovations (Wang & Hannafin, 2005). DbR researchers use iterative development of solutions to a real-world problem through close collaboration with practitioners (McKenney and Reeves, 2012). Figure 1 presents the DbR process of this study and the current second cycle of instructional theory development for v4 and v5.

Research Site
The instructor (Expert B) had used wikis to support student learning for 6 years. The 12-week Web design course was required for the first-year undergraduates in the program. The course aimed at basic design competencies, independent research, and peer learning to build a community to support diverse learners. The students were divided into three classes taught by Expert B, Instructor C or Instructor D. The classes met in a computer lab where each student had access to a computer. The researchers focused on the class with 21 students taught by Expert B, called Case 2. Most students, except three, in Case 2 were new to the wiki environment.

Data Collection and Analysis
Data were collected through class observations, interviews with Expert B (instructor), a focus-group interview with five volunteer students at the end, wiki content analysis and individual interviews with the two other instructors, whose students contributed to the same wiki. This study did not investigate the improvement of students' KB skills. In accordance with the research questions, we studied students' participation and perceptions of KB over time.

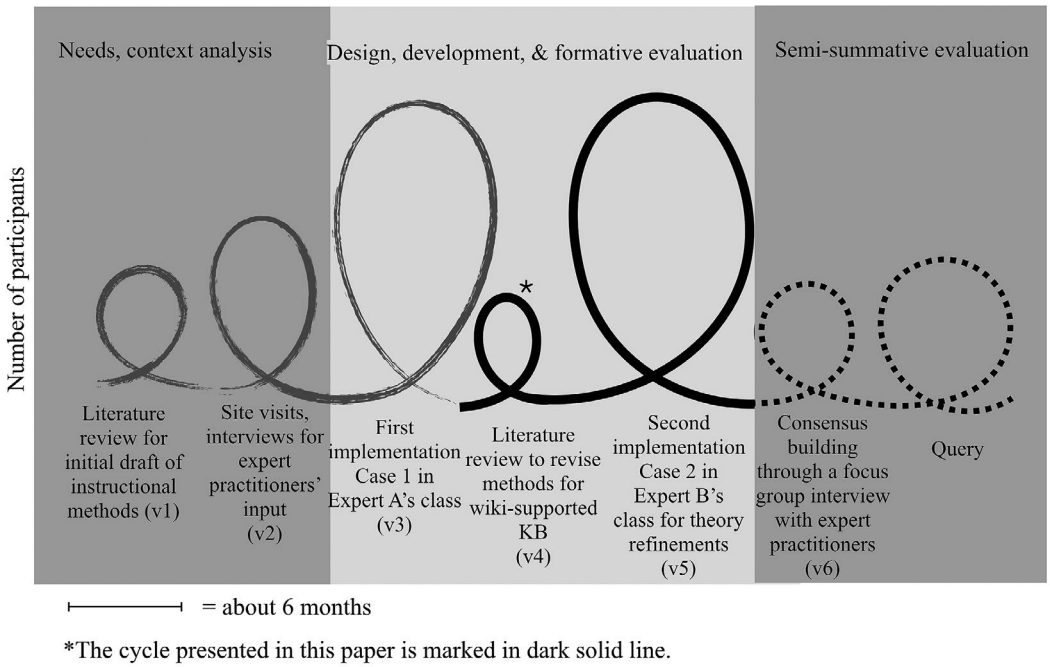

Figure 1: The DbR process of the instructional theory development for wiki-supported collaborative knowledge building. Adapted from McKenney & Reeves, 2012

Two types of evidence are reported and interwoven in this article: (1) contextual information, describing the context within which the theory was implemented, which offers background information to help readers make decisions on using the methods or making adjustments; and (2) instructional methods, focusing on both how and how well the instructional methods were implemented in the local setting. The documentation allows interested researchers and designers to trace the emergence of the instructional methods (Wang & Hannafin, 2005).

Findings

The findings are presented in stages: Stage0–preparing, Stage1–introducing KB on wiki, Stage2–fostering KB, and Stage3–evaluating learner autonomy for KB. The scaffolds are marked in italics with codes to indicate a corresponding component to support autonomy. The prime symbol (') in the findings section marks the additional scaffolds implemented to complete the original design.

Stage0–Preparing

A class wiki was created to allow all students from the *three sections to collaborate* for KB. Expert B explained that the design "turning small villages into a big city" offers interesting *diversity* on the wiki M4'a. The project descriptions were posted on the wiki and summarized as follows:

- *Individual design projects*: Students would learn and apply technical skills and knowledge; the advanced learners would be encouraged to integrate design principles into projects. K1
- Whole-class KB project: Students would make *contributions to the collective knowledge* K2b on wiki by updating individual projects, sharing to help others and *improving the content*. K2a

- In activity logs: *each student would keep activity logs*, visible to all, to document activities, including project updates, KB edits, and peer feedback. Reflections were encouraged. M5'
- Peer feedback: students would explore peers' activity logs and *offer constructive feedback* by applying knowledge in various contexts. M2

Stage1–Introducing KB and Wiki (Week 1)

Connect

When introducing the course, Expert B helped students connect course learning objectives, KB on the wiki, and their identity as prospective designers. Given that students came in with different prior knowledge and interests, they were expected to *undertake independent creative and technical learning and research* K1'a during their projects because "*designers are curious* people M3'a " (Expert B, lecture). Expert B argued that *knowledge construction is a more appropriate model of learning than traditional knowledge transmission* K4'b, especially in the design field, "*because design is about constructing experiences* M3'b" (lecture). Meanwhile, students were expected *to share and collaboratively build on* these technical or inspirational *ideas* on the wiki K1'b; Expert B said in class, "I encourage the culture of sharing. That's very important in the work place too. *People like to be around the sharers in a [design] studio* M3'c."

Require to participate; speak of weirdness

Expert B explained that the nature of the KB project was seeking ways to improve the content, beginning with small tasks for which *everyone is responsible.* "Let's say someone has written something there that is not organized properly; *your job is to go in and change it, fix it up,* M1, K4 OK?" (lecture). He further *spoke of students' concern about collaborative editing as he explained the concept of KB* C3':

> It sounds weird, right? 'Someone else wrote that; I am not going to touch that; that's their stuff.' But this doesn't work like that, OK? *Most stuff you put there is for anyone to change and update* K2a, K2b. (lecture)

Expert B shared a personal reflection by comparing the wiki-based KB with school assignments, which also *explains the embedded evaluation of KB* through peer editing to improve ideas K3:

> The very first time I used a wiki, that concept and that idea were really counter to what I learned all the way in school. See, most times all the way through school, you get work done, you hand it to the teacher, the teacher writes comments on it, gives you a grade and hands it back. What happens in the wiki is that you create something, and *you hand it out to everyone and everyone writes on it* K3'a, and rather than handing it just back to you, now it's out and open. (lecture)

Tour

After introducing the KB concepts, Expert B *toured the wiki environment and demonstrated some features* S1. He *helped each student create a username/password and a personal wiki page* S1'. He *required students to edit their page by the next class* because he found that the key to helping students master wiki skills and reflect on the wiki concepts is to *assign small and doable wiki tasks as soon as possible* so they could *observe the results of collective effort in KB* C2'.

Stage2–Fostering KB (Weeks 2–5)

Help re-define publicity by re-shaping mindset for learning

The next class began with projecting students' updated activity logs on the screen to *show* the initial results of KB and *the diversity of ideas to support peer learning* M4 'b. Expert B said to the class,

> When we have stuff here [wiki] …. You can see everyone and everyone can see you. One of the things I'd like to encourage here is to *look at other people's work and give some critical feedback. Really try to learn from each other* [M2 ′, K4] (lecture).

However, the expansion of audience can generate students' fear of publicity, previously identified as a barrier to wiki collaboration (Kummer, 2013). To overcome it, Expert B first *recognized how students might feel and encouraged developing a new way of thinking* [C3'] about KB for *a give-and-take culture* [M2]. That is, when a student sees a peer's remarkable work on the wiki, rather than feeling intimidated, the student should seize the opportunity to learn (which is the scaffold for *changing mindsets from fixed to growth intelligence* [K4 ′a]):

> When you see someone did something absolutely amazing, rather than being completely freaked out and think 'I don't know how to do that'; but you go, 'WOW, I want to do that too,' or 'I want to learn how that person did that. So I am going sit beside that person in the next class and ask him.' You know, things like these can really help you get more out of the class. (Expert B, lecture)

Expert B also *used an "apples versus ideas" metaphor to illustrate the KB benefits* [M2 ′], "If I have an apple, and you have an apple, we exchange apples, we each have an apple. But if I have an idea, and you have an idea, we exchange ideas, we each have two ideas (lecture)."

Help identify actions to take according to the knowledge of value

In the end of Week-2 class, Expert B *suggested doable tasks* [C2'], ie, the KB contributions by *extending in-class learning to the wiki* [K5 ′a, K 4]

> For the stuff we are learning today, you might have a valuable insight on how to do something. 'I figured out how to take, you know, the sliced image from Photoshop and get the image to my Web document really easily. And here is the process to do that. And I can spell it out for people and hopefully they will get learn how to do that.

He continued, *explaining the value of the knowledge for peers' learning* [K3'b]:

> You know, there were people in the class who were struggling with that. [Pause] That's high value. That means that you're hitting the mark, you are doing something that's going to contribute to the class. (lecture)

The criteria for quality KB contributions were posted to the wiki for reference, and included edits that are (1) *highly valued,* (2) *timely to help others and* (3) *relevant to the course* [K3'b].

Expert B *tracked students' wiki behaviors by subscribing updates in email* [C1a]. He *discussed with students regularly about their progress and strategies to make adjustments* [C1'c, K4] For instance, in Week 4, he brought students' attention to the wiki contributions and discussed considerations to improve them:

> It's not really that helpful, 'cause all you can see is the 255 blue text underlined. We are just overwhelmed! But maybe there is a way to annotate them, describing what's in there, what part is useful. That's more valuable. … That's more interesting and shows that you're actually thinking, and it kind of starts the conversation, which [is] kind of what the wiki can be to start a conversation. (lecture)

Meanwhile, he *re-emphasized the collective ownership of wiki texts* [K2a, K2b, K2'c], saying:

> If you're looking at that and going, "Oh, that's really kind of lame; that's only got a couple of links there and maybe I will go in and add things," by all means. Free territory. That isn't his link; that's everyone's! This is sort of a giant group project. You're allowed to go in there to change it or to adjust it…. Reorganize the page if you don't like it. You know, if somebody doesn't like it, he will improve upon that. *So, don't be offended, but don't be afraid either. OK?* [C3'] You have to do it. (lecture)

Encourage giving-and-taking and reinforce the culture through reflection

Close to the end of the first project, the instructor *arranged a peer feedback activity in class on Week 4 and soon helped students transfer this giving-and-taking experience online* [K5'b]. He randomly assigned students into groups. A group at a time was called to sit around a large table, and the rest participated silently. Each student presented their project while others, including the instructor, asked questions and gave feedback. The presenter responded to comments or clarified design ideas. Students practiced articulating their design, giving effective (eg, constructive, specific, actionable) feedback to peers, and receiving feedback for improving projects. Expert B then introduced the peer feedback task on the class wiki. He talked about its goal and process in the KB perspective *to learn from others and help others* [M2]:

> That's another way we can participate. One of the things you're going to do is to look around to other people's links to their work and offer them feedback, okay? You are going to do it for at least two people, and you can traverse across different sections. Look how you can help and give some feedback… *Try to look at different work and see what people are up to there.* [M4'b]…. (lecture)

In the next week, the instructor *helped the class reflect on the fruits of wiki participation, including online peer feedback and wiki contributions, to reinforce the giving-and-taking culture* [C1'c, C1b]. In this class discussion, students thought "giving peer feedback [and teaching others] would reinforce what you think" and others' feedback "gives insights on your own work" in things that you didn't notice from your own perspective [Results of M2']. Further, Expert B helped students *gain confidence and get into the driver's seat by emphasizing the value of peer coaching* [C4'b]:

> Your insight is just as valuable as mine. I might have a good mark experience, a better or maybe more depth of knowledge. But I think you guys are involved with the project so you have a pretty good idea about the kinds of things you're up against. So, that perspective is really valuable. You can help each other in doing stuff. (lecture)

Students also reflected on their perceived benefits of KB in Week 5. Several indicated that the student-collaboratively-created content on the wiki was helpful and insightful, especially step-by-step instructions or examples allowing them to complete their projects at home or inspiring them. Additionally, students shared in an interview that they felt emotionally and cognitively supported when seeking and receiving help on the wiki, or even felt positively challenged to do better work when interacting with others online during the peer feedback process. Expert B often *recognized contributions or project accomplishments publicly to create a sense of success* [C4'a]. He shared excitement about seeing students' work on the wiki, saying:

> I get really excited [when browsing the class wiki] because I see where people started in this course and in four or five weeks, it's kind of getting to blow my mind. Really exciting! I am pretty impressed and pretty happy with what's going on! (lecture)

Stage 3–Evaluating Autonomy for KB

Give a floating grade

The instructors graded individual projects, KB contributions, and peer feedback (all documented in personal activity logs on the wiki) after each project period, three times in total. All three instructors mentioned in interviews that constant monitoring on the wiki and guiding students in the process had reduced time in grading because they ran into few problems. Expert B shared his grading approach in an interview: Individuals' activity logs were used to track students' contributions with the criteria (high-value, relevance and timeliness) to judge the quality. He offered written feedback and assigned a letter grade, which he called a "floating grade."

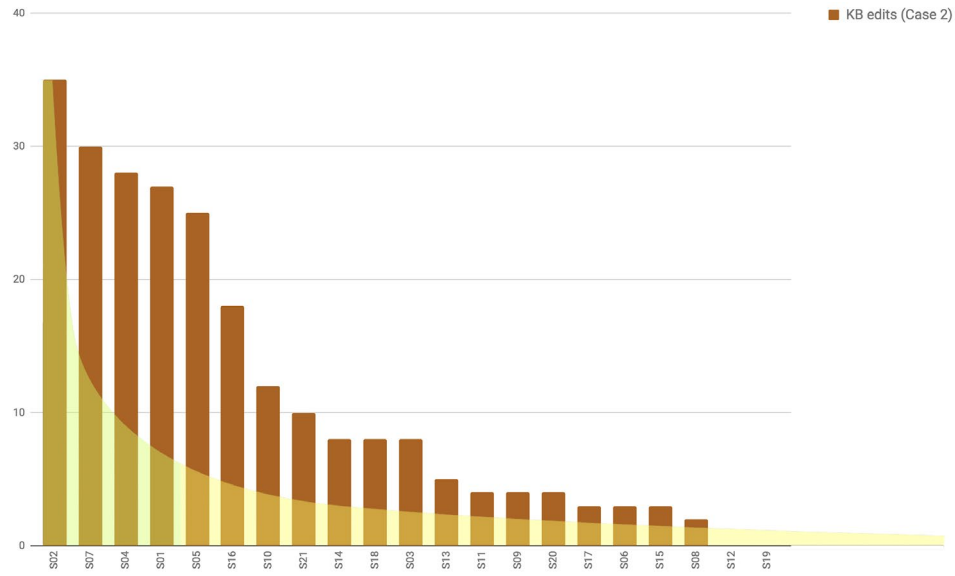

Figure 2: Numbers of KB edits made by each individual student in Case 2 (the bar graph). The curve retrieved from Wikipedia illustrates a typical long-tailed distribution for comparison [Colour figure can be viewed at wileyonlinelibrary.com]

A *floating grade* showed one's effort to participate in KB from Day 1 until the time of assessment. The method *encourages students to make effort, adjust strategies and succeed* M1'a. Rather than grading their participation at the end, Expert B assessed it at three different times. To him, the idea of assessment is to inform students how well they performed and offer opportunities to improve. The letter grade served to encourage students to continue making effort to participate rather than to penalize those who didn't do well.

> I think it [floating grade] encourages them so they don't feel defeated; they don't feel like 'oh I screwed it up. I am just going to forget about it!' They can still see, 'Okay I didn't do well, but he said that if I continue to work, my grade will go up!' So I am hoping that motivates them to continue to work. And it works, I think. (interview)

We also found the method of *requiring personal activity logs itself was key to supporting autonomy through self-monitoring* M5' in this case. By constantly updating activity logs, students kept track of their own progress and gained insight and feedback from peers and instructors. A reflection in a student's activity log is shown below:

> This is the first time I ever did anything like this [activity log] …. I loved it! It was a great way to organize information and work out any inconsistencies before any detailed work has been done. …. I felt pleased with how I developed in this class…. I feel confident with exploring code, and I'm not scared to get my hands dirty. (retrieved from wiki)

Research analysis of KB behaviors

We analyzed the KB activities on the wiki:

- Wiki pages: excluding personal activity logs, 14 out of 26 total pages were edited by students for KB. The rest included pages describing project requirements.

- KB edits: 237 KB edits were made by 21 students in Case 2. Most students made different types of contributions, including organizing content, posting information, adding screenshots, rephrasing sentences, and asking or answering questions.
- Messages: 118 messages were received on Case-2 students' discussion pages for personal activity logs.

Patterns

On Wikipedia, a long-tail effect (see, for example, the curve in Figure 2) was found in participation (Greenstein, 2007), and a similar effect was found in the previous design of whole-class KB (Lin & Reigeluth, 2016). However, the bar graph in Figure 2 shows that the students' KB edits in Case 2 have a higher percentage of contributions in KB than typical KB contributions on Wikipedia in a long-tail effect, and gradually, not dramatically, decrease.

Further, Figure 3 presents the numbers of total KB edits over the 14 weeks of the course, revealing increasing participation during the course. This may be attributed to the methods, including class discussions, floating grades and activity logs, which aimed to help maintain engagement and adjust strategies over time.

Research analysis of perception of KB on the wiki

The content analysis shows that most students received at least one peer feedback. The findings from the interviews with students and instructors confirmed high-quality and useful feedback. Instructor D described that students had offered analyses of each other's work in "very advanced and interesting ways to better their projects." According to the interview, the use of wiki also allowed all students, including first-year international students, to provide quality feedback regardless of their cultural backgrounds or lack of presentation skills.

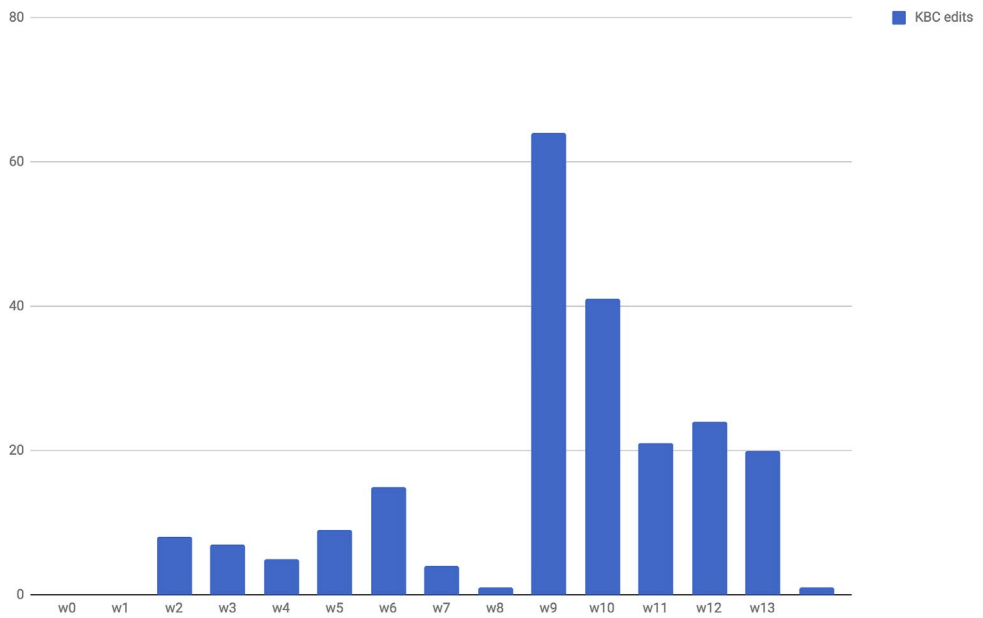

Figure 3: Case 2 students' KB edits over the course. No class on Week 8 [Colour figure can be viewed at wileyonlinelibrary.com]

In the focus-group interview with students, one described her observation of self-directed tasks in KB, and others agreed, which provided evidence of student autonomy in building collective knowledge:

> For me, if you do something on the wiki and then that's when I started thinking and changing what you did. The more you add ideas, the more you brainstorm, and the more your ideas get better and stronger. That's one of the strongest things about the wiki.

This statement from a student helps explain how one's adoption of wiki concepts may become motivation for participating in KB (ie, symmetric knowledge advancement). Students' confidence in making self-identified changes and having their texts changed suggests positive group dynamics and a collective ownership of KB content. Moreover, students expressed in the interview that they felt supported by their peers and felt less isolated, given the transparency of the learning process on the wiki. The issue of publicity, which was identified as a barrier to wiki collaboration in the literature, was perceived as positive to support learning in Case 2. By committing to KB, students learned and accomplished more than what they normally could have done within the regular class time. As Instructor D shared:

> So I would say that it's the power of the collective. In an environment like wiki, and the actual class environment, we managed to do more than just delegating the lecture and asking people to hand in their projects in a memory stick at the end of the day. (interview)

Discussion and Conclusions

This cycle of the design research focused on developing an instructional theory to support whole-class KB on a class wiki and to overcome the wiki collaboration barriers, including group dynamics, lack of ownership and the issue of publicity (Kummer, 2013). Our research contributions are discussed as follows.

Local Evidence: Improved KB Participation

RQ1. How well does the re-designed instructional theory work for wiki-supported whole-class knowledge building? In this implementation, we found that students increased KB participation over time and perceived KB experience as positive. Moreover, the issues of wiki collaboration identified in the literature were not perceived barriers in this case, but aids to learning. For instance, students felt the publicity of wiki edits offered "transparency of learning" for cognitive and affective support; and instructors felt students had achieved more through peer learning on the wiki than they normally could in traditional settings. Furthermore, students' KB participation improved, compared to the previous implementation. Figure 4 presents box plots for comparing the students' KB edit distributions between the previous version of the theory (v3) in Case 1 (data from Lin & Reigeluth, 2016) and the current version (v5) in Case 2. In Case 1, the lower 75% of student contributors (the three quartile groups in Figure 4: QG1, QG2 and QG3) edited between 1 and 4 times for KB, whereas in Case 2, the lower 75% edited between 0 and 21.5 times. The median of student KB edits increased from 2.5 in Case 1 to 8 in Case 2. Additionally, in Case 1, the top 25% of student contributors (QG4) edited between 4 and 44 times for KB, whereas in Case 2, the top 25% contributed between 21.5 and 35 edits for KB. In other words, the KB edits made by the top quartile group were widely dispersed in Case 1 but were clustered in Case 2. Overall, the students' KB participation in Case 2 was higher than it was in Case 1.

Refined Theory: Methods for Learner Autonomy

RQ2. What improvements could be made to the theory according to this implementation? Several instructional methods were suggested by the expert instructor, and their effectiveness was

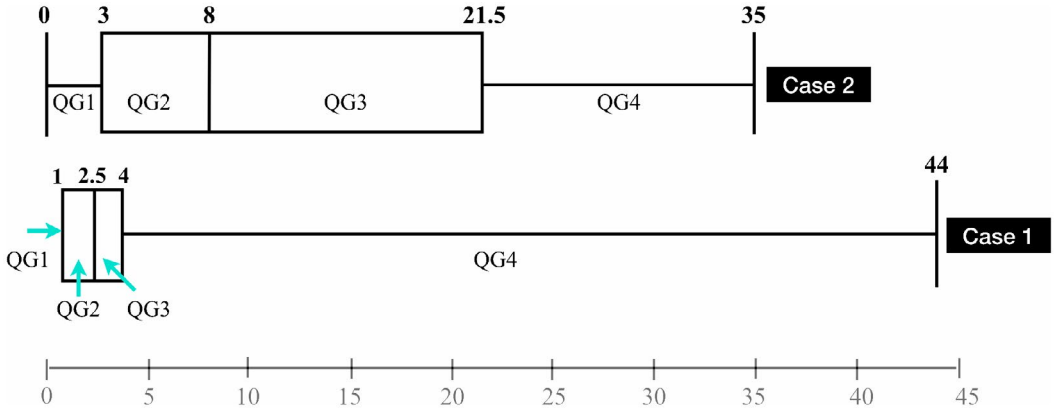

Figure 4: Box Plots of students' KB edits in Case 2 (this paper) and in Case 1 (Lin & Reigeluth, 2016). QG refers to quartile group [Colour figure can be viewed at wileyonlinelibrary.com]

validated through implementation, including the methods to scaffold cognitive and affective aspects regarding KB on class wikis (eg, how to think and feel about KB). We compared the re-designed instructional theory for wiki-supported KB before the second implementation (v4) and the refined instructional theory after the second implementation (v5) in Appendix. Note that 11 out of the 12 KB principles are included in v5, along with the metaphors and explanations to scaffold students' KB on wiki, such as that the content posted to the wiki becomes a gift to the class and has its own life since it shall be updated by others. Even though the KB principles were originally suggested to guide KB on a specially developed platform, Knowledge Forums (Scardamalia & Bereiter, 2006), the results of this research suggest they also seem effective to guide KB on class wikis.

Another contribution involves several methods to enhance learner motivation and confidence in KB. Meta-analysis of educational wiki research reveals "optional use of wikis is not purposeful when collaboration is desired" (Kummer, 2013, p. 12), implying that KB on class wikis benefits from all students participating; however, required participation does not guarantee successful KB. In fact, resistance may still occur due to students' mental conflicts with their existing mental models about learning, such as knowledge transmission and the culture of competition. The refined theory (v5) suggests methods to help students understand KB, guide their behaviors, address their concerns and realize the benefits. The methods include the criteria for quality KB, personal activity logs for self-monitoring, discussions about the value of KB and floating grades to encourage improvement. Moreover, methods to increase intrinsic motivation and engagement (ie, learners' curiosity, job-related identity) have now been added, such as to include multiple sessions to collaborate on the same wiki and to foster the culture of sharing among perspective designers.

To conclude, by reviewing the refinements of the instructional methods, we have realized that to help learners adopt the new genre of wiki-supported KB requires scaffolding not only in the behavioral aspect, but also in the cognitive and affective aspects, to prevent resistance. See indicators {C}, {B}, {A} in Appendix for the matching methods.

Theoretical Implications: Change of Mindset through KB on Wiki

RQ3. What are the implications for students' mindset change in the KB process? The implementations and improvements of the theory offer two implications. First, not only does KB on a wiki propose

an innovative classroom practice, but challenges students' industrial-age learning mindsets. Adopting KB means transforming the role of learners from individual, passive receivers into collaborative, active contributors to knowledge creation and advancement. If we define "education paradigm" as the structure designed to meet societal needs and define "learning mindset" as the learners' expectations regarding the education paradigm, we suggest the success of wiki-supported KB depends crucially on the success of changing students' learning mindset to fit the information-age paradigm in this instructional theory. Second, we find the key to fostering whole-class KB on a class wiki is to reduce the discrepancy between what is aimed for and what is performed in collaborative constructivist learning by offering the class feedback on the tasks, on the strategies and on their mindsets about learning, to increase motivation, effort and task processing for autonomy, which align with Hattie and Timperley (2007) suggestions for effective feedback. Table 1 illustrates the concept alignment among education paradigms, learning mindsets and class wiki behaviors for KB.

To conclude, this cycle of DbR for wiki-supported KB makes three contributions. First, it provides a rare case for how to use KB successfully on wikis in higher education. Second, it provides theoretically and empirically constructed and validated instructional methods to support learner autonomy in KB. Third, it implies that the instructional theory does not only maximize wikis' potentials for KB, but also transforms students' experiences and mindsets for the information-age paradigm of education. Future research is needed to increase the theory's generalizability and usability through implementation in different contexts to suggest refinements and situationalities, to seek evidence of technology-supported KB for increasing learner autonomy in collaborative problem solving and knowledge-advancement to better prepare young generations for future challenges.

Table 1: The alignment of education paradigms, learning mindsets, and class wiki KB behaviors

	Examples of	
	KB doesn't occur	*KB occurs*
Education paradigms	Centralized control	Autonomy
from Reigeluth and Joseph (2002): Industrial (left) and Information age (right)	Autocratic leadership	Shared leadership
	Adversarial relationship	Cooperative relationship
	Conformity	Diversity
	Culture of competition	Culture of sharing
Learning mindsets	Learning from instructor	Learning from and with peers
from the research findings in Lin and Reigeluth (2016) and this paper	Knowledge is delivered	Knowledge is co-constructed
	Following instruction	Self-directed learning
Class wiki behaviors	Reluctance to share	Sharing ideas and work
from the research findings in Lin and Reigeluth (2016) and this paper	Reluctance to change content	Improving ideas and content
	Reluctance to help peers	Helping or teaching peers
	Reluctance to participate	Determining actions to take

Statements on open data, ethics and conflict of interests

a. The data of this study are available upon request to the corresponding author.
b. The ethical guidelines were reviewed and approved by Indiana University's ethics committee.
c. The authors declare that there is no conflict of interest.

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APPENDIX: Scaffolds for whole-class knowledge building on wiki

Designed scaffolds before implementation (v4)				Added Scaffolds after implementation (v5)	
Scaffolding intersubjectivity (Ability for autonomy)	Knowledge	KB: Real ideas, authentic problems	Announce design projects for learning techniques and applying design principles. Discuss KB examples and list them on the wiki K1	Add detail Add KB: Constructive use of authoritative sources	Personal inquiry during individual projects becomes KB contributions K1'a Give examples of constructive use of authoritative sources–inquiry results become KB contributions K1'b {C}
		KB: Improvable ideas	Explain that content posted on the class wiki is improvable K2a [G]{C}	Metacognition (metaphor)	"Anything you submit to the wiki *is like a gift to the class*. It is not yours anymore. Anyone can change it to improve it or build on it. The content will change. *It now has its life."* K2'c [G][O]{C}
		KB: Democratizing knowledge	Explain that anyone can improve content K2b [O]{C}		
		KB: Embedded evaluation	Explain that embedded evaluation by peers' reading and editing improves content K3 {C}	Metacognition Add criteria	Discuss mindsets: from instructor-as-reviewer to everyone-as-reviewer K3'a {A}{C} (1) Valuable to help peers learn, (2) Relevant to course, (3) Timely to be relevant and valuable K3'b [G][P]{C}
		KB: Epistemic agency	Encourage students to determine what actions to take and to act K4 {C}	Metacognition	Discuss mindsets: from fixed to growth intelligence K4'a [G][P]{A}{C} Discuss mindsets: from knowledge transmission to knowledge construction– constructive learning is important to designers K4'b [O]{A}{C}
				KB: Pervasive KB	Encourage students to initiate or contribute to wiki by extending in-class learning or discussions K5'a {B}{C}
					Arrange presentations in small groups for peer learning, giving and receiving feedback in person and on wiki K5'b [G]{B}
	Skills	Offer a tour of wiki S1 {B}		Add task	Help each student create username/ password and a blank activity log page S1' {B}

Scaffolding transfer of responsibility (Willingness for autonomy)	**Motivation**	KB: Collective cognitive responsibility; Extrinsic	Require all to participate. Remind students what will be assessed M1 {B}	Add detail	Give *floating grades* and informative feedback at multiple points of time to encourage improvement M1'a {A}{B}
		KB: Symmetric knowledge advancement	Explain the goal to develop a give-and-take culture in KB on the wiki M2 [G]{C}	Metacognition (metaphor)	Ideas become more and stronger by exchanging, unlike apples M2' [G][O]{A}{C}
				Metacognition Identity	Designers are curious people M3'a Designers learn through constructing experience. M3'b {C} Designers who share are popular in the work place M3'c {A}{C}
				KB: Idea diversity; Intrinsic	Include students from other sessions to KB community. Turn small villages into a big city to offer interesting diversity on wiki. M4'a [P]{A} Invite students to browse diverse work on wiki and interact with peers to learn M4'b [G][P]{B}
				Self-monitoring	Require students to keep *personal activity logs* to document, annotate, and link to projects, KB edits, and peer feedback. Logs support self-monitoring, peer learning, and evaluation M5' [G][P]{B}
	Confidence	Wiki research KB: KB discourse	Track KB edits and discuss constructive and unconstructive behaviors C1a {B} Use meta-cognitive questions to help reflect on group progress and become self-directed C1b [G]{C}	KB: KB discourse	Host frequent discussions to share observations, give examples to help class reflect on progress, strategies, concerns, and future improvements C1'c [G][P][O]{B}{C}
				Reduce complexity to begin	Assign a small and doable KB task as soon as possible to help begin KB C2' {B}
				Metacognition Help re-frame feelings and thoughts in a new learning mindset to overcome hesitance	Speak of students' concerns and help them reject old learning mindset–telling them that feeling hesitant at first is common because KB on wiki contradicts past experiences and mindset; however, you should think in a new mindset when engaging in KB to maximize learning. C3' [O][P]{A}{C}
				Metacognition Social persuasion	Create a sense of achievement C4'a {A} Place learners in the driver's seat "Instructors might be more experienced in grading, but you are the ones who are doing the project. You are developing insights of how to, which are more valuable to helping peers learn." C4'b [O]{A}{C}

Note: Indicators for methods which address class wiki collaboration challenges: [O] lack of ownership, [P] issue of publicity and [G] group dynamics. Indicators for methods which scaffold changes in {C} cognitive, {B} behavioral and {A} affective aspects.