MOTIVATING STUDENTS BY "PERSONALIZING" LEARNING AROUND INDIVIDUAL INTERESTS: A CONSIDERATION OF THEORY, DESIGN, AND IMPLEMENTATION ISSUES

Candace Walkington and Matthew L. Bernacki

ABSTRACT

Purpose – *As educators seek ways to enhance student motivation and improve achievement, promising advances are being made in adaptive approaches to instruction. Learning technologies are emerging that promote a high level of* personalization *of the learning experience. One type of personalization is* context personalization*, in which instruction is presented in the context of learners' individual interests in areas like sports, music, and video games. Personalized contexts may elicit* situational interest*, which can in turn spur motivational and metacognitive states like positive affect and focused attention. Personalized contexts may also allow for concepts to become* grounded *in prior knowledge by*

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fostering connections to everyday activity. In this Chapter, we discuss the theoretical, design, and implementation issues to consider when creating interventions that utilize context personalization to enhance motivation.

Design/methodology/approach – *First, we provide an overview of context personalization as an instructional principle and outline the emerging evidence that personalization can enhance motivation and improve achievement. We then discuss the theory hypothesized to account for the effectiveness of context personalization and discuss the approaches to personalization interventions. We close by discussing some of the practical issues to consider when bridging the design and implementation of personalization interventions. Throughout the paper, we anchor our discussion to our own research which focuses on the use of context personalization in middle and high school mathematics.*

Findings – *The theoretical mechanisms through which context personalization enhances learning may include (1) eliciting positive affective reactions to the instruction, (2) fostering feelings of value for the instructional content through connections to valued personal interests, or (3) drawing upon prior funds of knowledge of the topic. We provide hypotheses for the relatedness of context personalization to triggering and maintaining situational interest, and explore potential drawbacks of personalization, considering research on seductive details, desirable difficulties, and authenticity of connections to prior knowledge. We further examine four approaches to personalized learning – "fill-in-the-blank" personalization, matching instruction to individual topic interests, group-level personalization, and utility-value interventions. These approaches vary in terms of the* depth *of the personalization – whether simple, shallow connections are made to interest topics, or deep, meaningful connections are made to learners' actual experiences. The consideration of depth also interacts with* grain size *– whether content is personalized based on the broader interests of a group, or the individual experiences of a particular learner. And finally, personalization interventions can have different levels of* ownership *– an instructor can generate the personalized connections, the connections can be made by the curriculum designers, or learners can take an active role in personalizing their own learning. Finally, we discuss the practical implementation issues when bringing context personalization interventions into K-12 classrooms. Personalization can be logistically difficult to implement, given that learners hold a diverse array of interests, and may experience each of those* *interests differently. In addition, particular types of instructional content may show greater sensitivity when personalization is implemented, and personalization may be most helpful for learners with certain background characteristics.*

Originality/value – *Realizing the promise of personalized learning is an unsolved problem in education whose solution becomes ever more critical as we confront a new digital age. Context personalization has the potential to bring together several well-established strands of research on improving student learning – research on the development of interest, funds of knowledge, and utility value – into one powerful intervention.*

Keywords: Situational interest; (context) personalization; individual interest; funds of knowledge; computer-based curricula; learning technology

As schools and teachers seek ways to enhance student motivation and improve achievement (e.g., Hidi & Harackiewicz, 2000), promising advances are being made in the adaptive approaches to instruction. In adaptive approaches, instruction is designed to be reactive to or based upon the characteristics of individual learners. In particular, learning technologies are emerging that promote a high level of *personalization* of the learning experience (Ellis, 2008) to the prior knowledge, preferences, goals, and interests of individual students (Collins & Halverson, 2009). Such personalization has the potential to fundamentally change the nature of learning and to enhance motivation by giving learners opportunities for interaction with and customization and control of their learning environment. This can, in turn, make academic or school-based learning into an experience that is closer to what is experienced in everyday life as learners pursue their goals and interests (e.g., searching for information online about their favorite movies or sports), and learners are intrinsically motivated to seek knowledge and build expertise.

In this chapter, we discuss one type of personalization for learning environments – *context personalization* (Cordova & Lepper, 1996; Walkington, 2013). Context personalization occurs when instruction in an academic subject is presented in the context of learners' individual interests in such areas as sports, music, politics, or the environment. For example, in an English class, a learner with an interest in music might be given a reading passage to enhance her vocabulary acquisition that focuses on the current events in the music world. In a math class, the same student might be given a mathematical investigation related to algebra that examines the quantitative principles of sound. For these same assignments, the student's classmates would receive different readings or math problems that aligned to their personal interests in other topics like video games or the environment. Making these connections has the potential to both provide motivation for and enhance understanding of the academic subject. In particular, context personalization is hypothesized to be an effective instructional strategy because it may elicit students' interest in the academic material, as well as foster an appreciation of its utility or usefulness (Hidi & Renninger, 2006). Personalization may also allow for important connections to be made between students' prior knowledge and novel learning in a content domain.

Here, we explore the instructional principle of context personalization and its applicability to learning environments. First, we provide an overview of context personalization as an instructional principle and outline the emerging evidence that personalization can enhance motivation and improve achievement. We then discuss the theory hypothesized to account for the effectiveness of context personalization, describing how personalization can elicit interest and draw upon prior knowledge. We next discuss the approaches to personalization interventions, explaining how four types of interventions can be designed with differing levels of depth, grain size, and ownership. We close by discussing some of the practical issues to consider when bridging the design and implementation of personalization interventions, including their feasibility, delivery, and differential effects. Throughout the paper, we anchor our discussion to our own research, which focuses on the use of context personalization in middle and high school mathematics.

CONTEXT PERSONALIZATION AS AN INSTRUCTIONAL PRINCIPLE

Context personalization (which we now refer to as *personalization* for brevity) is an instructional principle that involves finding ways to match instructional content to learners' out-of-school interests. Personalization can involve matching instruction to topic areas that individual or groups of students are interested in, inserting familiar and interest-related references into instructional materials, or supporting learners in seeing how an academic subject relates to their out-of-school interests. For example, learners who are interested in music might receive instruction in an academic content area (like math or reading) that relates to music, receive tasks in which their favorite bands are simply named, or they might be supported in seeing how an academic content area can help them to better understand issues related to music. The principle of personalization applied to an instructional environment is designated an *intervention* for personalized learning.

Research shows that interventions that match instruction to students' interests in different topic areas can enhance interest in psychology (Reber, Hetland, Chen, Norman, & Kobbeltvedt, 2009), and improve both students' immediate performance and their long-term learning in reading (Heilman, Collins-Thompson, Callan, & Eskenazi, 2010) and mathematics (Walkington, 2013). Similar results have been recorded for interventions that insert such familiar referents as favorite foods into mathematics problems (e.g., Cordova & Lepper, 1996). Interventions designed to foster utility value – an appreciation of the usefulness of an academic subject in everyday life – improve motivation (Durik & Harackiewicz, 2007; see Harackiewicz, Tibbetts, Canning, & Hyde, 2014) and academic achievement (Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009) in science, math, and psychology. The above research involves relatively large sample sizes with random assignment to treatment and control groups. Finally, more general research has shown that adolescents tend to perform better on math problems that incorporate familiar contexts relating to family or social situations (Clinton, Walkington, & Howell, 2013).

Two examples of personalized problems that are similar to those used in our studies provide a context for the present discussion:

(1) Nancy has 115 followers on Instagram. She wants to become "Instagram Famous," so she uses hashtags to get more attention when she posts pictures. If Nancy gets 15 additional followers for every hashtag she uses in a post, write an equation relating number of hashtags to her total number of followers.
(2) In an Ultimate Frisbee game, the initial kickoff of the disc lands 20 yards from the end line. The offensive team moves the disc toward the opposite end line 5 yards per minute. Write a rule relating yards remaining to the end line to minutes of play time.

The first problem could be presented to an algebra learner who holds an interest in Instagram, whereas the second could be given to a learner interested in Ultimate Frisbee. We will return to these problems throughout the paper. Before discussing the theoretical, design, and implementation issues to consider for personalization interventions, we provide key results from our past research that used similar problems.

PRIOR STUDIES OF CONTEXT PERSONALIZATION

We presented 24 Algebra I students with sets of normal algebra story problems and problems with the same underlying mathematical structure that had been personalized based on the interviews with students about their out-of-school interests. Results showed that personalization improved performance for (a) students who had low mathematics achievement and (b) problems that had difficult mathematical structures. Students were more likely to attempt personalized problems and less likely to make key conceptual errors on these problems. Students were more likely to use arithmetic-based strategies (like trial and error) based on the actions and relationships in the story situation on personalized problems and, overall, described personalized problems as easier and more relevant to their lives (Walkington, Petrosino, & Sherman, 2013).

To explore how personalization could be used in a computer-based curriculum, we conducted a study within the Cognitive Tutor Algebra (CTA) environment (Walkington, 2013). CTA is an Intelligent Tutoring System (ITS) for Algebra I used by over 650,000 students in the United States and abroad. CTA uses model-tracing approaches to guide problem selection within the software based on students' current estimated level of knowledge, and knowledge-tracing approaches to diagnose errors and provide context-sensitive hints and feedback (Koedinger & Corbett, 2006). CTA focuses on different representations of algebraic functions (story, equation, table, and graph).

In one school that used CTA, we randomly assigned 145 Algebra I students to two conditions. Half received the normal story problems already in CTA for one unit, whereas the other half received versions of these problems that had been personalized based on their responses to a prior interests survey administered to both groups. The unit covered algebraic expression-writing from story problems (see two example problems given earlier). Students receiving personalization had significantly better performance within CTA when learning the difficult skill of algebraic expression-writing. They had increased accuracy and shorter response times when writing expressions, as well as more efficient learning curves (i.e., the software determined they had mastered the skill of expression-writing after fewer attempts). Students who received personalization also had significantly fewer instances of "gaming the system" (i.e., exploiting the tutoring system's hints and feedback; Baker, Corbett, Koedinger, & Wagner, 2004) than students in the control group. Most importantly, four units after the personalization intervention ended, students who had received personalization still performed significantly better when writing more complex expressions, showing both greater accuracy and shorter response times than the control group when writing expressions. Thus, their learning transferred to the solving of nonpersonalized problems that involved different algebra concepts. The positive effects of personalization were significantly greater for one group of students in particular – those identified as struggling with algebra – although effects were positive and significant for all groups.

These studies provide important evidence for the potential of personalization to improve achievement in the difficult content area of Algebra I. Although the effect of the intervention on outcomes was considerable, the reasons why these results occurred were not yet clear. In the next section, we explore the potential mechanisms through which personalization enhances learning.

THEORETICAL MECHANISMS RELATING TO PERSONALIZATION

Three potential mechanisms may explain *why* personalization promotes learning. Personalization may (a) elicit enjoyment-based situational interest, (b) elicit value-based situational interest (i.e., utility value), and (c) promote connections between domain concepts and students' prior knowledge about their areas of interest. The first two mechanisms relate to research on affect and motivation, whereas the third relates to the nature of knowledge acquisition and cognitive development. We begin this section with an overview of situational interest followed by summarizing the theory and research that examines how these mechanisms are associated with learning outcomes. Despite the potential of personalized learning, a final section describes the cognitive and affective mechanisms that suggest ways personalization might *not* be an effective instructional approach for improved learning, namely seductive details, the desirability of learning difficulties, and issues with the authenticity of connections made to prior knowledge.

Situational Interest

Theorists describe interest as a cognitive and affective phenomenon, wherein an individual responds with heightened attention and engagement in response to stimuli (Hidi & Harackiewicz, 2000; Renninger, Hidi, & Krapp, 1992; Schiefele, 1991; see Renninger et al., 2014). *Situational interest* (SI) is a transient state that arises when environmental features are perceived as novel, vivid, or intense, and is distinct from *individual (or personal) interest*, an enduring disposition associated with one's preferences, knowledge, values, and feelings for a topic (Hidi & Harackiewicz, 2000). Hidi and Renninger (2006) describe interest development across four phases, shown in Fig. 1. In phase one, situational interest is *triggered* by the environmental phenomena; in phase two, it is *maintained*, either because the individual finds the environment to be enjoyable or perceives that the learning task has value; in phase three, interest that is maintained becomes an *emerging individual interest*, which then matures into a *well-developed individual interest* in phase four. We hypothesize that (a) personalization interventions can trigger and maintain situational interest by incorporating well-developed out-of-school interests that students *enjoy* and (b) because personalized tasks can demonstrate the *value* of an academic content area to a personal interest area, students may experience higher situational interest in future nonpersonalized tasks in that academic content area. Thus by causing enjoyment and perception of value, personalization can positively affect learning outcomes.

A host of prior studies demonstrate that individuals interested in a learning task tend to engage in patterns of behavior conducive to learning. Individuals show certain behaviors when stimuli trigger and maintain their situational interest, and as individual interest develops. For example, students who report situational interest in a task remain engaged with

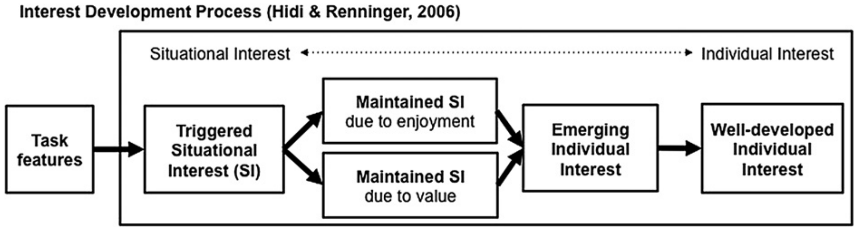

Fig. 1. Diagram of Hidi and Renninger's (2006) Four-Phase Theory of Interest Development.

content for prolonged periods and seek out the content repeatedly (Mitchell, 1993; Renninger & Hidi, 2002). As individual interests emerge, students tend to ask questions and demonstrate increased effort toward learning content (Renninger & Hidi, 2002). When learning about a topic that coincides with a well-developed interest, individuals demonstrate greater use of self-regulated learning strategies and deeper consideration of problem features in problem solving tasks (Lipstein & Renninger, 2006). In addition to associations with learning behaviors, interest has been shown to directly affect academic achievement. Increased interest has a positive predictive effect on undergraduate psychology students' course grades (Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008). We next discuss the ways that personalization may elicit enjoyment-based SI and value-based SI.

Personalization Elicits Enjoyment-Based Situational Interest

Personalization may elicit *enjoyment-based situational interest* by connecting academic content to enjoyable topics. If personalization works simply because students enjoy the topics designers incorporate into tasks, then this method may be considered a sleight-of-hand technique that should be momentarily effective, and these benefits should disappear when students complete later tasks that lack personalization. In the CTA study summarized above (Walkington, 2013), students who received personalization *continued* to perform better than students in a control group in later nonpersonalized units. Because no data were collected on students' enjoyment of problems, however, we cannot say definitively whether the enjoyment experienced when solving personalized problems transferred to nonpersonalized problems in the later unit. It may be that the increased SI due to enjoyment was indeed momentary, but did serve to facilitate improved cognitive and affective processing (e.g., via heightened attention), such that students learned the concepts better in the initial personalized unit. This could in turn enhance the performance in the later unit that covered concepts that built upon the initial concepts. Overall, although it is likely that personalization enhances feelings of enjoyment when students solve personalized problems, it is less clear whether enjoyment-based SI is a relevant mechanism when students later solve nonpersonalized problems.

Personalization Elicits Value-Based Situational Interest

In addition to increasing enjoyment, personalization may also increase the value that students place on the learning task, eliciting *value-based* *situational interest*. If a task involves a personal interest that the student perceives as valuable, the academic domain concepts involved can take on value as well. When the concepts are encountered in the future, this increase in value-driven interest in the domain persists, and the cognitive and affective benefits associated with SI can be observed again. This mechanism has also been referred to as *utility value*, a motivational construct that describes the importance that an individual places on a task because they perceive that engagement in the task is inherently useful (Eccles, 1983). Eccles' (1983) task value theory also describes multiple other kinds of value that an individual may place upon a learning task. In addition to utility value, students' *attainment value* is the importance of doing well in the task, and *intrinsic* or *interest value* is the enjoyment one gains from engaging in the task. Aligning Eccles' (1983) conceptualization to Hidi and Renninger's (2006) model of interest development, situational interest that is maintained due to enjoyment reflects *intrinsic* value, whereas situational interest maintained due to value is associated with *utility* value. Because our primary referent in this paper is theory pertaining to interest, we use Hidi and Renninger's (2006) term "value" to mean *utility* value and draw connections to research on utility value.

In the CTA study (Walkington, 2013), students who received personalization may have perceived the problems to have increased value because they directly involved a topic that had personal relevance in their lives. Further, students who received personalization may have perceived that the math concepts themselves could be useful in pursuit of personal interests, and thus had value. When later instructional units were encountered that involved similar concepts, the learners may have again experienced heightened value-based SI.

We hypothesize that the dual mechanisms of situational interest (i.e., enjoyment-driven and value-driven interest) likely operate in an additive fashion, in which personalization leads to increased enjoyment *and* value (Fig. 2, top), which induces a maintained state of heightened cognitive and affective engagement, producing better learning. Further, we hypothesize that personalization can in some cases induce enduring value-based SI in the *academic domain itself*, which then allows for value-based SI to be maintained in later nonpersonalized problems (Fig. 2, bottom). We see evidence of maintained value-based SI in interventions that boost students' perception of the utility of an academic domain and have long-term effects. Enjoyment-based SI, on the other hand, may only be associated with the personalized components of the task that are not present later on. It is less likely, therefore, that SI based on enjoyment will transfer to future tasks that lack enjoyable features. For SI-based transfer to occur, personalization would require that students perceive the academic domain as more enjoyable in the long term, and there is currently little research to support this idea. Thus in Fig. 2, we do not provide a path in which SI is maintained due to that increased enjoyment of math.

Current Research on Situational Interest and Personalization

At present, most of the evidence regarding the relationship between interest and personalization has been indirect. One important result cited in the CTA study described previously is that students who received personalization engaged in "gaming the system" behaviors (i.e., entering answers quickly and repeatedly, or clicking rapidly through the hints) significantly less than students in the control group (Walkington, 2013). Because gaming is a known form of *help abuse* (Aleven, McLaren, Roll, & Koedinger, 2006), we can interpret the effect of personalization on gaming to represent a desirable outcome with respect to help seeking ability. We also have evidence from smaller-scale pilot work that students find personalized problems

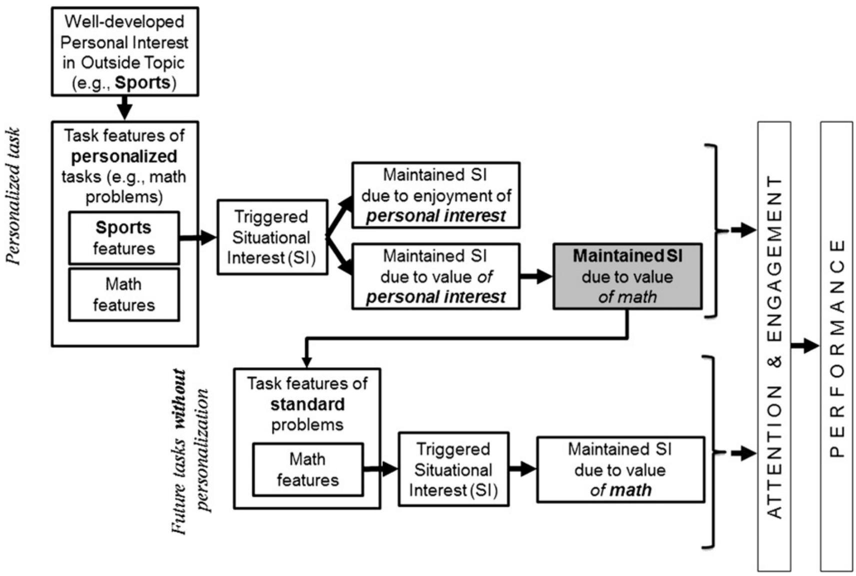

Fig. 2. Hypothesized Motivational Mechanisms by Which Personalization Affects Learning.

easier to solve and more related to their lives and that these students are more likely to attempt personalized problems (Walkington et al., 2013). Students also increased their ratings of the utility value of algebra after completing a personalization intervention designed to allow them to connect algebra to their out-of-school interests (Walkington & Bernacki, 2014). In sum, although we can say that students report greater motivation, evidence less gaming, and achieve better learning outcomes when problems are personalized, we cannot yet identify the specific motivational components that drive the effect of personalization on learning.

Additional studies are ongoing that use self-report and data-mining techniques to assess students' triggered and maintained SI (based on enjoyment and on utility value) between a personalization condition and a control condition. This will allow us to determine whether (a) specific types of interest are triggered by personalization, (b) interest levels are maintained after personalization is removed, and (c) specific types of interest are associated with learning outcomes. With research into motivational mechanisms ongoing, we now turn our attention to a third potential mechanism that may explain the impact of personalization on learning, wherein personalized tasks activate students' prior knowledge.

Grounding and "Funds of Knowledge"

Students interested in a topic area, like sports or music, tend to have some prior knowledge of that topic area from prior pursuit of their interest. Context personalization has the potential to leverage this prior knowledge by connecting it to academic learning in areas such as math or science. Theoretical work relating to equity and social justice in education, for example, has accentuated that all students bring to the classroom their unique "funds of knowledge" (Civil, 2007; Moll, Amanti, Neff, & Gonzalez, 1992), or their ways of reasoning in their home and community lives. This perspective accentuates the strategic use of historically accumulated and culturally developed bodies of knowledge from students' communities in the classroom. Indeed, we have found that students draw upon rich algebraic ways of reasoning when considering their score in video games, their accumulation of "friends" in social networking programs, or their progress in sports (Walkington, Sherman, & Howell, 2014). These experiences with popular culture represent an important class of "funds of knowledge" that adolescents may possess. Our example problems given earlier were based on student discussions of their interests exemplified by a quote from the discussion surrounding the Instagram problem:

> Instagram … You can have a whole bunch of people follow you, you can follow people and count your likes. And if you put hashtags sometimes you can get a whole bunch of likes. And there's like "Instagram famous" people who have like 25k followers. If I do hashtags, I get anywhere from 30 to 50 or 60 likes. Sometimes I put like 10 or 11.

This student discusses how the use of hashtags can generate 30–60 likes for a picture, with a maximum of 11 hashtags typically used. This student may therefore receive 5–6 likes per hashtag, which describes a linear rate of change. Similarly, the student who authored the Ultimate Frisbee problem given earlier also clearly had quantitative knowledge that was evident in the selection of a slope term (yards advanced per minute), the selection of a reasonable unit for the slope term (5 yards per minute), and the awareness that an intercept is introduced when the opposing team "kicks off" by throwing the disc from their own end line toward the receiving team's end line. Thus these funds of knowledge clearly exist, even in more advanced subjects like algebra, and the opportunity to draw upon these funds of knowledge may allow students to be more successful when given a personalized task.

Research from cognitive science also supports this "funds of knowledge" approach, arguing that relevant contexts can allow abstract ideas to become *grounded* in concrete everyday experiences, such that they become easier to grasp. Goldstone and Son (2005) found that presenting concepts in concrete formats prior to presenting them in abstract formats improved learning and transfer. The redundancy of grounded representations with a learner's prior knowledge can improve inference making (Koedinger, Alibali, & Nathan, 2008), or learners' ability to make valid judgments and predictions when they confront tasks. Grounded representations can also support students in coordinating different representations of a concept. Nathan, Kintsch, and Young (1992) found that animations that were grounded in algebraic ideas in real-world situations improved learners' ability to write symbolic expressions. Personalization may thus allow learners to directly draw upon relevant prior knowledge of situations to support their understanding of new, abstract ideas and representations. This allows for metacognitive awareness of the appropriateness of certain strategies and the feasibility of particular answers.

When we engaged students in think-alouds while solving algebra story problems (Walkington, Sherman, & Petrosino, 2012), they sometimes were able to use their everyday knowledge of situations to successfully implement informal, arithmetic strategies and to catch certain types of mistakes. For instance, in the Instagram example, if Nancy discovered that she had 25,000 followers and was "Instagram famous" after only using a few hashtags, a problem-solver familiar with Instagram might realize that a math mistake has likely been made. In this way, their prior knowledge of the parameters of their interest area, Instagram, may support their learning of algebraic concepts.

Cautionary Research on Competing Mechanisms

Although we have outlined several potential mechanisms that explain why personalization may be important for improved learning, there are also theoretical reasons to suggest that personalization might not improve outcomes. These theories come from both research on affect and interest and research on cognitive processes. They suggest some additional mechanisms through which personalization may detract from, rather than enhance, learning.

We described how personalization is hypothesized to elicit interest by making connections to learners' developed interests in nonacademic topics like sports or movies. Although these connections may serve to elicit interest in the content to be learned, they may also act as *seductive details*. Research in reading education has shown that the addition of such information (i.e., passages that are highly interesting but unrelated to main themes) can distract readers, interfering with text recall and problem solving (Schraw & Lehman, 2001). These seductive details can prime learners to organize information around inappropriate schemas (Harp & Mayer, 1998). Thus personalization that adds irrelevant or decorative details to a task may actually detract from learning outcomes.

In the Ultimate Frisbee example, the reference to this motivating, outdoor game may distract the problem-solver, focusing them away from the algebraic concepts and toward thoughts relating to physically experiencing Frisbee, Frisbee strategies, upcoming and past games, and so on. Our research has shown that personalization is less effective when used in conjunction with a personalized colorful, illustration (Walkington, Cooper, & Howell, 2013). In particular, we gave seventh-grade students percentage story problem sets that included (a) normal/standard story problems, (b) story problems personalized to interests indicated on a survey, (c) normal/standard story problems with colorful illustrations, and (d) personalized problems with colorful illustrations. We found that although illustrations alone and personalization alone improved performance for some groups of students over normal problems with no illustrations, the combination of personalization and an illustration was not significantly better than a normal problem with no illustration. Although both personalization and the illustration may have had the potential to elicit learners' interest in the problem, both together might have been powerful enough to draw attention away from the mathematics and toward irrelevant aspects of the problem.

Cognitive research also offers some reasons why personalization may not be effective. Research on *desirable difficulties* (Schmidt & Bjork, 1992) and the level of transfer students obtain from abstract versus concrete materials (Sloutsky, Kaminski, & Heckler, 2005) provides additional mechanisms through which personalization may be harmful. This research suggests that such difficulties as decreasing feedback can actually increase learning in the long term (Schmidt & Bjork, 1992); that making a task *easier* does not necessarily mean that students *learn* more from the experience. Research on transfer has suggested that abstract instructional materials promote transfer better than materials that are concrete and perceptually rich, because the prior set of materials has greater generality and allows learners to better see the underlying structure (Sloutsky, Kaminski, & Heckler, 2005). For instance, assume that a student interested in Frisbee only receives problems in algebra class like the one we presented earlier, and never sees a different context. As a result, his learning of algebra may be shallow and tied to the specifics of the single context.

Finally, we described how personalization can make useful connections to learners' prior knowledge. However, the degree to which this prior knowledge is useful for problem solving is highly dependent on the authenticity of the tasks being posed (Walkington et al., 2012) and the quality of the connections that are made to learners' actual experience. For instance, in our Instagram problem, suppose that getting 15 additional followers per hashtag is not a realistic amount, or that hashtags are not really related to gaining followers in a useful way. In this case, connections made to students' prior knowledge might actually be disruptive, and cause them to dismiss correct answers as being infeasible. A plethora of research in mathematics education has shown that when students attempt to apply their richly situated real-world knowledge to overly generic mathematics story problems, this knowledge can actually lead to incorrect assumptions and answers (e.g., Cooper & Harries, 2009; Inoue, 2005; Kazemi, 2002; Ladson-Billings, 1995).

In summary, we have outlined several cautionary mechanisms that are important to reflect on when considering the theoretical basis of the effectiveness of context personalization. This cautionary research, when taken in combination with theoretical work that suggests reasons why personalization is effective, can offer important guidance into the design of interventions. This is discussed in more depth in our next major section on design approaches.

Summary of Theoretical Mechanisms

In this section, we discussed the theoretical mechanisms potentially at work in personalization interventions. The hypothesized mechanisms through which context personalization enhances learning include (a) personalization elicits situational interest through feelings of enjoyment and positive affect, (b) personalization elicits situational interest by fostering feelings of value for the instructional content, and (c) personalization draws upon prior knowledge of the topic, grounding the content in experience. While the first two mechanisms draw upon research on affect and interest, the third mechanism is grounded in cognitive theories relating to knowledge acquisition.

We argue that the combination of these three mechanisms is what makes context personalization an especially important and promising instructional principle. For example, although there are many instructional modifications that tap into the affective domain by eliciting enjoyment-based interest (e.g., adding colorful graphics to a task), few of these also have the potential to both draw upon students "funds of knowledge" and to allow students to truly perceive the value of the content to their lives. As personalization involves all of these areas (enjoyment, value, and knowledge), it can dramatically change how students conceptualize and interact with ideas, and thus have robust and prolonged effects on motivation and learning. However, an intervention may also prioritize one of these three mechanisms over the others; for example, some interventions may be designed to make stronger or weaker connections to prior knowledge, or give more or less emphasis to the utility of the content. To continue this discussion, we turn to a discussion of design approaches for personalization interventions.

DESIGN APPROACHES FOR PERSONALIZATION INTERVENTIONS

In this section, we discuss four approaches to designing personalization interventions that have been presented in the research literature. These approaches have different allowances regarding the *depth* of the personalization: whether simple, shallow connections are made to topics the learner is interested in or whether deep, meaningful connections are made to learner's actual experiences pursuing a personal interest area that have the potential to activate relevant prior knowledge. The consideration of depth also interacts with the *grain size* of the personalization intervention; whether content is personalized based on the broader interests of a group of people or the experiences of a particular learner. And finally, personalization interventions can have different levels of *ownership*: the curriculum designers can generate the personalization, the personalized can be done by the instructor, or the learners themselves can take an active role in personalizing their own learning. Also, in order to design a personalization intervention, consideration must be given to how to study student interests such that tasks can be designed that will be potentially relevant to a certain student population. The ways in which student interests are studied impacts the quality of connections that can be made to students' prior knowledge and whether they will perceive the content to have value.

Approach 1: "Fill-in-the-Blank" Personalization

One popular approach to context personalization is to have students supply information like the names of their friends, pets, and favorite foods, which is inserted into problems or tasks. There is evidence that this approach improves performance (Chen & Liu, 2007; Davis-Dorsey, Ross, & Morrison, 1991) and learning (Cordova & Lepper, 1996) when solving arithmetic problems. Although such approaches are feasible to implement and may elicit situational interest, this form of personalization has little relevance to the content to be learned (Mitchell, 1993); there is no real opportunity to draw upon funds of knowledge, or to allow students to see the utility value of learning an academic subject. Although this approach allows for interest-based references that are highly specific to the individual learner, the class of problems that can be posed this way is also limited and perhaps artificial. For example, you would not be able to insert a different sport name into the Ultimate Frisbee problem because of the terminology and relationships particular to this game.

The details added to tasks with this approach might further be seductive and distract learners, as suggested by our cautionary research. In addition, the connections made to learners' prior knowledge may be inauthentic or false, causing learners to misapply their prior knowledge of their interest area. These shortcomings may explain why, overall, there is mixed evidence of the effectiveness of this type of intervention, with a number of studies reporting null results (Bates & Wiest, 2004; Cakir & Simsek, 2010; Ku & Sullivan, 2000; Simsek & Cakir, 2009). Learners may feel some sense of ownership when they see specific people and items from their lives appearing in instructional tasks. This approach is feasible to implement with technology, and requires little prior study of students' interests. Even though the grain size is highly specific to the individual learner, this approach to personalization has little depth in terms of the quality of connections made to prior knowledge.

Approach 2: Matching Instruction to Individual Topic Interests

A related approach is to survey and/or interview (e.g., Renninger, Ewen, & Lasher, 2002; Walkington et al., 2013) students about topics they are interested in, and then present tasks in the context of their interests. This approach can be implemented on a large scale using computer systems that adapt problem selection to learner characteristics, like ITSs – Carnegie Learning's (2012) *MATHia* curriculum uses this approach. This type of personalization can also be implemented by teachers during instruction, especially during one-on-one tutoring, if they are familiar with student interests. This approach has been shown to improve outcomes in reading (Heilman, Collins, Eskenazi, Juffs, & Wilson, 2010), and also has benefits for arithmetic problems (Renninger et al., 2002). This approach was used in our CTA study described previously (Walkington, 2013) and was associated with significant long-term learning gains.

One important issue with this approach concerns how to assess students' interests. Students can numerically rate their level of interest in different topics (e.g., sports, music, and movies), and/or subtopics (e.g., soccer, country music, and scary movies), and then tasks are selected for individual students based on these interests (e.g., Walkington et al., 2013). The main design decision with this approach rests with how numerical ratings are converted into the specific interest-based content and terminology for the problem. For example, how would you know the specifics of how adolescents actually use quantities in Instagram to be able to write a sensible problem task, if all the information you had was a numerical ranking of their level of interest in Instagram?

Our typical method (e.g., Walkington, 2013) is to use a two-tiered design. Our approach is first to generate problem tasks by conducting in-depth interviews and open-ended surveys with students to study the ways in which they use quantities when pursing their interests. We then write a broad set of problems that relate to a selection of the most popular interest areas (e.g., for sports, a problem set includes problems on football and basketball). Second, we select problems for individual students within the curriculum by having students take a second closed-ended survey, in which they numerically rate their level of interest in different topics. These survey responses determine which interest-based variations on the task are selected for each student. However, student interviews can be time-consuming and, as we discuss later, this approach can be challenging to scale because of issues with the diversity, volatility, and evolution of students' interests.

These interventions may better connect the content to be learned to students' prior knowledge, allowing for a moderate level of depth of the personalization since the problem tasks can be written based on examining how the students actually experience their personal interests in different topic areas. However, the grain size is only mediocre – all students interested in a particular topic or subtopic may receive the same tasks. For instance, all students who report interest in social networking may receive our Instagram problem, whereas all students who report interest in sports might receive our Frisbee problem, even though individual students might not be interested in these subtopics. This limits the degree to which authentic connections can be made to students' experiences, and the funds of knowledge that can be drawn upon. Further, students have little ownership of the personalization, which may be invisible to them, or feel artificially imposed on them by task developers. This approach has only moderate feasibility since different variations on every task may need to be written for learners with different interest categories, and technology may be needed for the delivery of personalized problems.

Approach 3: Group-Level Personalization

A third approach is to personalize instruction to group-level interests rather than individual-level interests. For example, if the majority of students in a class mentioned an interest in Instagram, all students in the class might be given the Instagram problem we presented earlier without assessing individual student interests to assign tasks. Personalization that occurs at the individual level can be logistically difficult to accomplish, especially without the aid of technology (Hidi, 1990, 2001). Group-level personalization is easier to implement, as it can utilize interests that many students share. In one of the only studies comparing different approaches to personalization, Lopez and Sullivan (1992) found that both individual-level and group-level personalization supported performance over a control group, but were not significantly different from each other. In our work we have found a great deal of overlap in the topics students are interested in. For example, in a recent series of interviews with adolescents about their out-of-school interests (Walkington et al., 2014), nearly all of the students discussed such activities as downloading music and considering how many text messages they send. Group-level personalization may have a low to moderate level of depth for a student depending on how well their interests match the larger group's interests. The grain size is very broad and nonspecific to an individual learner, and in terms of ownership there is little or no involvement of the student in the personalization. However, this approach is highly feasible to implement, with or without technology, provided careful research on student interests is conducted.

Group-level personalization can be implemented by researching the topics in which certain age groups of students are interested, in order to present students with "group-personalized" problems that relate to common interests. We recently conducted a study that explored how different story topics (as measured by LIWC software – see Pennebaker, Chung, Ireland, Gonzales, & Booth, 2007) influenced students' ($N = 3{,}394$) accuracy when solving algebra problems. Topics of story problems included such areas as food, business, families, money, and leisure. Analyses showed that algebra problems involving actors performing intentional actions (like cooking a meal or making a phone call) in *social* and *family* contexts are easier for students to solve, whereas stories that involve *business*, *healthcare*, or *physics-related* contexts are more difficult (Clinton et al., 2013). However, keeping in mind the cautionary work on transfer we discussed earlier, it is ultimately important that students see concepts they are learning in a variety of contexts – not just those contexts that are easiest for them. Certainly students should leave algebra class able to apply algebraic concepts to business.

Approach 4: Utility-Value Interventions

A final approach to personalization involves informing students of the relevance of the content to be learned to their interests, experiences, or future careers (Durik & Harackiewicz, 2007; Sansone, Fraughton, Zachary, Butner, & Heiner, 2011), or having students generate themselves how the content they are learning is relevant to their lives and interests (Chazan, 1999; Hulleman et al., 2010; Hulleman & Harackiewicz, 2009). The latter approach is especially feasible for widespread implementation, as it takes the burden of generating the personalization away from instructional designers and teachers, and allows students to find the relevance for themselves. These programs are called "utility-value" approaches, as they emphasize the usefulness of the content. Although simply informing students of utility value may not be effective for struggling learners (Durik & Harackiewicz, 2007), the latter approach in which connections are generated by the learners themselves can foster interest and achievement for high school and college students (Hulleman et al., 2010; Hulleman & Harackiewicz, 2009). However, this research has typically involved students doing writing assignments in which they discuss generally how they feel the content they are learning is relevant to their lives. These interventions do not always target specific or particular concepts to be learned within an academic content domain.

Although little prior work has attempted to involve students in making interest-based connections to particular concepts, this is the approach we focus on here. An example of this type of personalization might be an intervention in which students go into their communities and explore how an academic concept like linear functions is being used in day-to-day life (Chazan, 1999). Here, the depth of the personalization is extensive since learners can make realistic and high-quality connections to prior experiences, provided they have proper scaffolding and examples to draw upon. The grain size is also very small, as each learner generates connections specific to their individual experiences. Finally, the ownership is completely student-driven – students are personalizing and taking control of their own learning.

Such a utility-value approach for mathematics could involve having students pose problems related to their personal interests. Recently, we conducted a study in which students ($N = 24$) were asked to generate algebra story problems about the things they were interested in outside the school, and that related to particular concepts about linear functions. The two example problems on Instagram and Frisbee we presented earlier are actually the adapted versions of problems written by these students. We found that students with little formal knowledge of algebra could successfully pose problems, and that posing and solving personalized problems significantly improved students' ratings of utility value for learning algebra (Walkington & Bernacki, 2014). However, we also found that problem-posing presented students with a number of difficulties in using accurate and precise wording of their problem statements, and sometimes required significant instructor scaffolding. This type of intervention is complex to implement – each student will be engaging in qualitatively different tasks, potentially going in very different directions with the personalized connections they generate. Larger-scale experimental work is needed to further investigate the potential of such an intervention and to investigate the ways to make implementation more feasible.

Summary of Design Approaches

Each of the four approaches to designing personalization interventions reviewed here involves trade-offs in terms of the depth of the personalization (how well it connects to students' actual experiences in the world), the grain size of the personalization (whether it is formulated for an individual learner or for a group of learners), and the ownership of the personalization (whether students have a role in personalizing their learning). These considerations have implications for the intervention's potential to elicit enjoyment, enhance utility value, and draw upon prior knowledge. The design of these types of personalization interventions is also impacted by the initial decisions that are made regarding the methods of studying student interests (surveys, interviews, etc.). We summarize the four approaches to personalization in Table 1. We note that little research has directly compared one approach to another. Although each approach individually has some experimental evidence of its effectiveness, it is not yet clear which approaches have the greatest potential for enhancing motivation and achievement.

To close this section, we reflect on the cautionary mechanisms we described earlier, such as seductive details, transfer and desirable difficulties, and issues with authenticity. Although we believe that personalization of learning can offer distinct cognitive and affective benefits, we also stress that those who personalize learning tasks should exercise caution in the design process. Although conscientious personalization should improve learning, well-intentioned but clumsy design approaches can offset these productive features and minimize the effects by prompting unproductive cognitive processes. Table 1 also accentuates that each type of personalization varies in its feasibility of implementation, which is discussed in more depth in the next section.

Table 1. Summary of Approaches to Context Personalization.

Type	Depth	Grain Size	Ownership	Feasibility
1. "Fill-in-the-blank" Personalization	Very shallow	Small/specific to individual	Some student ownership	Very feasible, with technology
2. Personalization to individual topic interests	Moderate	Medium/specific to all individuals interested in topic	Little student ownership	Somewhat feasible, with technology and careful study of topic interests
3. Personalization to group topic interests	Low to moderate	Large/targeted to groups of students with potentially different interests	No student ownership	Very feasible, with careful study of group interests
4. Utility-value approaches	Deep	Small/specific to individual	Student owns personalization	Somewhat feasible/unknown feasibility

BRIDGING THE DESIGN AND IMPLEMENTATION OF PERSONALIZATION INTERVENTIONS

In this section, we discuss the practical design and implementation issues to consider when bringing personalization interventions into classrooms. Depending on the decisions made about which design approach to use, personalization can be logistically difficult to implement, given that learners hold a diverse array of interests and may experience each of those interests differently in everyday activity. In addition, personalization interventions may lend themselves better to particular types of instructional content, and personalization may be most helpful for learners with certain background characteristics. We review each of these issues, and then discuss how these design and implementation issues can be navigated by instructional designers, teachers, and students.

Diversity, Volatility, and Evolution of Interests

When instructional tasks are personalized to the interests learners hold in different topics, the design and implementation of such interventions can be challenging. Learners hold diverse interests, even within a particular topic. For example, a learner interested in sports may specifically be interested in Ultimate Frisbee, football, or track, which would lend themselves to very different instructional tasks. Even learners who are all interested in football may experience the sport very differently. One learner might only have experience actually playing the game in a middle school league, while another might watch only professional football on TV and search online stats of pro players, while a third might only be familiar with the football video game *Madden*. Thus, although a personalization intervention was designed to be relevant to all students interested in a particular topic or subtopic, in practice it may not have relevance to many of these students. Even when students generate the personalization themselves, each student may connect their experiences to different math concepts, with a great variation in the quality of the connections being made.

At the topic (e.g., sports, music, and movies) and subtopic (e.g., football, baseball, hockey) levels, our studies have found a reasonable amount of overlap in students' interests. In a recent interest survey ($N = 45$ ninth graders), we found that 91% of students report being interested in sports, cell phones, and movies, 87% like food or restaurants, and 93% like music. These patterns are typical of other interest surveys we have conducted. At the subtopic level, in a study of seventh graders ($N = 143$), we found that 66% like pop music, 73% like action movies and Italian food, 61% like strategy or adventure games, and 71% like YouTube. Nearly every student in our seventh-grade sample liked at least one of the subtopics that were most popular according to the ratings of their peers. Thus there are some topics in which group-level personalization may be feasible. However, we have found that interests vary by geographic location and community culture. At one school, rap music and basketball were most popular, whereas at another school, country music and hockey were very popular instead for the same age group.

In addition, we have found that interests tend to change over time. We conducted our first CTA study in the 2009/2010 school year (Walkington, 2013), and are conducting another in the 2013/2014 school year, and thus far have found that interests have shifted between these two time periods for students in the same grade and school. The new and currently popular video games, social networking apps, music artists, TV shows, and movies are all relatively volatile, whereas interests relating to sports, shopping, and food seem generally more stable. In 2009/2010, we included an interest category for "computers;" however, in our more recent study, "cell phones" was determined to be a more appropriate category, given that many of the things students once did on their computers (e.g., social networking, games, and music) have now shifted to a cell phone platform. Personalization interventions of this type may have a shelf life of perhaps two to three years before redevelopment of tasks is necessary. In addition, students' interests may evolve even over a given school year – students may decide they like new topics or get bored of old ones.

If problems are framed generically with few specific details, they may be applicable to more learners and have longer shelf lives. For example, instead of a problem about Frisbee, a problem could be written about scoring "points" in a generic "sport." As the connections to students' interests become shallower and the grain size the problem is used at becomes larger, it is likely that sacrifices will be made for the potential of personalization to elicit interest, enhance utility value, and draw upon prior knowledge. However, interventions that tap into students' experiences in authentic ways are difficult to implement, given the great diversity of interests, unless students themselves are taking part in personalizing their own learning, or there is deep and sustained research on the interests of the particular student population.

Learner and Task Characteristics

There is evidence from our research that personalization might be most effective for particular subgroups of students and for particular content within a curriculum. This suggests that when personalization interventions are implemented, they may have differential outcomes based on learner and task characteristics. In our experimental study within CTA (Walkington, 2013), we found that the positive effect of context personalization on performance and learning was greatest for students identified as struggling with Algebra I. These were the students who were lagging far behind their course expectations in terms of their progress through the CTA curriculum over the school year. This corresponds to Mayer's (2001) *individual differences principle*, which describes how design effects are greatest for low-knowledge learners who do not have the resources to compensate for a lack of support within the instructional environment.

In another study (Walkington et al., 2013), we found that personalization was primarily beneficial for students who had mixed attitudes about math – students who reported being good at math but liking math less or students who reported being weaker at math but liking math. Students who both did not like math as much and felt they were not as good at math, who were the lowest performers, were not helped by the personalization; this group may have needed even more explicit scaffolding to succeed. Similarly, the strongest students who liked math and felt competent at math already had a performance level close to the ceiling; as a consequence, the personalization may have made little difference. This is consistent with other research suggesting that personalization is most effective for students with low academic performance or expectations (Hulleman et al., 2010; Hulleman & Harackiewicz, 2009).

Finally, our research suggests that personalization may be most important when students are struggling with a particularly difficult concept. In algebra, we have found personalization matters most for skills involving writing algebraic expressions from story problems (Walkington, 2013). Broadly, based on the research on student and content characteristics, it might make sense to frame context personalization as a form of instructional assistance. A central dilemma in cognitive science, then, is determining when it is appropriate to give assistance to which learners. Certainly, the stronger performers do not need the assistance, and even for learners who struggle, assistance should eventually be faded out to add in the "desirable difficulties." The utility of a personalization intervention may be in providing additional support to learners who are confronting a new and challenging topic, with this support faded out as their expertise develops.

Navigating the Logistics

Several different possibilities for the delivery of personalized learning systems exist. Personalization can take place within an adaptive, computer-based environment or can be manually done through pencil-and-paper interventions. Personalization can be generated by the teacher spontaneously during the course of instruction, or through carefully designed predetermined group activities. Finally, personalization can be generated by the students themselves as they become the authors of their own personal connections to the content being learned. In the final part of this section, we discuss the ways in which the design and implementation of personalization interventions can be made feasible for curriculum/instructional designers, teachers, and students. Although the major difficulties curriculum designers confront are related to design, teachers and students must more directly confront issues with the implementation of these approaches in the classroom.

Curriculum/Instructional Designers

Two of the central problems confronted by curriculum developers interested in designing personalization interventions are (a) finding ways to build curricula that adapt to individual learner interest areas and (b) finding ways to provide instructional content that reflects the rich, up-to-date, interests of individual learners. With respect to the first issue, technology-based curricula now allow for a high level of adaptivity to student preferences, if systems are built into these curricula that assess students' level of interest in different topic areas, and then differentiate instruction based on these interests. These interest assessments, in the form of surveys requesting information about out-of-school interests, can be administered to students as they work through the curriculum, with the curriculum becoming more adaptive as it "gets to know" the student over time. Curricula could request information regarding how relevant and enjoyable students find different personalized problems to further guide problem selection. In the future, curricula may be built to explicitly communicate with students' social networking profile or other centralized websites containing personal preferences to gain information about students' interests without having to directly request the information. Such innovations would raise issues with privacy, certainly, but much of our activity on the web is becoming increasingly personalized via electronic information stored about our preferences and history.

However, with respect to the second issue, in order to develop and author the interest-based content that students actually receive, instructional designers must conduct careful research on the interests of their targeted student population. They must recognize that these interests will change over time, by age group, and by location and school context. To this end, there is emerging research on technology-supported environments that allow students to explore and rate their interests and even generate new interests in different topic areas. The *My Interests Now for Engagement* (MINE) online tool allows students to profile their interest in different topic areas using an engaging, graphical tool in which they rate the cognitive and affective dimensions of their engagement (see Ely, Ainley, & Pearce, 2012). Instruments that continuously and dynamically assess interests as they emerge and develop, like Ely et al.'s (2012) MINE tool, are important to capture changes in interests.

Curriculum developers must also be committed to providing flexible, detailed, and continuously updated personalized tasks for their learners, while also taking advantage, when possible, of interests that many students tend to hold, or that tend to be stable over time. Finding ways to better automate the construction of personalized tasks, while still incorporating the necessary depth to draw upon funds of knowledge and enhance utility value, should be a paramount concern for curriculum designers. The curriculum company Tuva Labs (2013) has come up with a clever approach to confronting this dilemma. They built an engine that surfs the web for data like current sports statistics of different teams and current events in different communities, and then uses this information to generate up-to-date personalized mathematics problems. The middle school math curriculum, MATHia (Carnegie Learning, 2012), has students use stars to rate their level of interest in four topic areas (art & music, the environment, sports, and money), and then adapts some of the tasks students receive to those interests. Students can also update their interest ratings throughout the year as their interests change.

Personalization may be most feasible for curriculum developers if it is targeted to particular tasks within the curriculum where it will have the highest leverage for enhancing motivation and achievement, and where the content being covered has the most natural connections to students' areas of interest. The cautionary research discussed earlier suggested that students need to experience concepts they are learning in a variety of contexts, both abstract and concrete, and the ideal use of personalized learning may be as a strategy to introduce learners to a difficult, new idea. However, it is also important to remember that many concepts from domains like math or science (e.g., factoring polynomials or stoichiometry) may not really be appropriate for a personalization intervention. When personalized contexts are used, the cautionary research also suggests it is important to explicitly connect them to more abstract representations. In the algebra interventions we use, for each personalized problem students receive, they must write an algebraic expression using symbolic notation. This requirement may allow learners to first tackle a difficult concept in a familiar context, and then create an abstract representation that ensures their understanding of the concept can be flexibly applied.

It is also not clear how many interest-based variations need to be offered on each task to appropriately capture learners' interests, but it may not be very many (perhaps only 3 or 4), depending on the degree to which the intervention is intended to actually draw on funds of knowledge. Finding ways to keep the development demands of personalization interventions at a reasonable level will be critical to creating curricula that can scale. Curriculum developers might also take advantage of "crowd-sourcing" approaches, in which they have educators and students contribute to the development of updated content personalized to different specific interest categories, like Reber et al.'s (2009) "Example Wiki" for posting personalized psychology scenarios. The act of problem-posing in and of itself is a cognitively beneficial experience for students to have (Singer, Ellerton, & Cai, 2013), and this is a means by which curriculum designers could empower teacher and student control and ownership.

Overall, for curriculum developers Approaches 1 ("fill-in-the-blank" personalization) and 3 (group-level personalization) might be most feasible to implement and most scalable in the long term. Approach 2 (matching instruction to individual topic interests) is certainly possible, especially in the context of educational research projects, but more innovation is needed to find ways to make the development demands of individually personalized tasks more feasible.

Teachers

Often teachers are the designers of instructional tasks in their classrooms, and thus they can implement personalized learning interventions by matching their instructional approaches to student interests. Logistically, it can be very difficult for teachers to accomplish personalization, given our preceding discussion about the diversity and volatility of students' interests. However, research on students' funds of knowledge has explored how teacher education programs can support teachers in building on the cultural, home community-based knowledge and interests that students hold. In one program, TEACH MATH, preservice teachers go on "community walks" and visit community locations in order to design instructional tasks that draw upon these knowledge bases (Turner et al., 2012). These teachers also conduct interviews with individual children, in which they get to know the child and their ways of interacting in school, community, and home settings. However, this work acknowledges that eliciting funds of knowledge can be challenging if the teacher feels like an outsider in the community, and that instructional tasks designed by teachers to make connections to students' interests can make connections that are either superficial or meaningful.

An important method for teachers to become instigators of personalized learning is to simply get to know their students and the communities their students live in. Spending small amounts of class time, or time between classes, discussing students' interests and bringing out aspects of those interests related to a content area is important for teachers, as well as engaging in community-based and after-school events with students and their families. Once teachers have an idea of students' interest areas, they can incorporate them into whole-class discussions, and design both short closed-ended tasks and extended investigative projects that draw upon common areas of interest. Teachers can even divide students into groups based on shared interests, and allow different groups to pursue the same conceptual ideas using different perspectives. For example, in an algebra class, different student groups could explore how the algebraic concept of rate of change is used in video games, sports, and after-school jobs (see Walkington et al., 2014). Finally, teachers can facilitate activities in which individual students explore the ways in which their interest areas are connected to the academic content being learned. Overall, Approaches 3 (personalization to group-level interests) and 4 (utility-value approaches) to personalization interventions might be most feasible for teachers to implement on their own.

Students

In any classroom, the students themselves can be put in charge of personalizing their own learning experience, taking the instructional design burden away from the teachers or instructional designers. However, students need scaffolding in several areas when they enact their own personalization.

First, students may not see the content they are learning as connected to their interests, so peers or teachers who are knowledgeable about their interest area may be needed to assist them in seeing these connections. Second, students might have difficulty connecting their interest area to particular academic content (like linear functions in our example problems). It may require some creativity and adaptation in order to make these connections, which could compromise the authenticity of the personalization intervention. Also, if a student makes a connection to a different but related concept, this connection could still be valued and returned to in the classroom at a later time. We have found that students need explicit scaffolding to pose problems that are appropriate within the norms and canonical forms of a content area (Walkington & Bernacki, 2014), so having a content expert give feedback on student-generated personalized work is essential. Finally, it is important to keep in mind that different students are at different points in their learning of an academic subject, with personalization perhaps being most effective for struggling students or students learning a new concept. Overall, Approach 4 (utility-value approach) allows students to take an active role in the personalization.

Summary of Bridging Design and Implementation

In summary, the design and implementation of personalization interventions involves substantial challenges, whether these interventions are driven by curriculum designers, teachers, or students, and whether they occur in or outside of technology environments. In this section, we have discussed challenges related to the diversity, volatility, and evolution of students' interests, all of which make the design and implementation of a lasting intervention that makes high-quality interest-based connections a complicated endeavor. We have discussed how student-level and content-level characteristics may be associated with differential learning outcomes for any intervention, and have provided some guidance to curriculum developers, teachers, and students in how to implement personalization feasibly and effectively. It is important for curriculum developers to both tap into the richness of students' interest-based experiences and to find ways to automate or ease the development of personalized tasks. It is also important for teachers to get to know the worlds of their students, and for students to be given explicit support when solicited as creators of their own personalized learning experience.

DIRECTIONS FOR FUTURE RESEARCH

Emerging research suggests that context personalization – the matching of instructional tasks to personal interests – is an important approach to enhance motivation and improve achievement. However, there are important research investigations still to be conducted to settle the theoretical, design, and implementation issues discussed here. Research is needed to better tease apart the mechanisms through which personalization enhances learning and to understand how these mechanisms interact with the motivational states. Research is also needed to better understand the affordances and constraints of the four types of personalization interventions we described, as well as other novel approaches, and to understand the feasibility of each in classroom settings. Further, more sophisticated methods for assessing student interests, continuously and deeply, are needed. Finally, we need to know more about how to make personalization interventions actually happen with all the complexity of school settings, academic standards, technological limitations, different student needs, and teacher schedules. Novel solutions like Tuva Lab's engine will allow the field to leap forward, but only if they are coupled with careful research on their effectiveness and conditions of implementation. Interventions in which teachers facilitate close connections between the content and students' community, cultural, and home-based knowledge are incredibly important, but are in need of more research that directly explores their resulting impact on student achievement and motivation.

A VISION FOR PERSONALIZED LEARNING

As we close this paper, we describe one possible vision for the future of personalized learning. We discussed how online curricula may one day be able to tap into students' social networking sites to gain information about their interests, but what if we think bigger? The network of digital devices students use day-to-day has the potential to collect an enormous amount of information about the learner and their preferences. Imagine a centralized system that knew which TV shows the learner watched, which video games they played and for how long, which social networking apps they used (and with which friends) and how active they were on each (e.g., posts, likes, tweets, etc.), which sports teams they kept up with on TV and online, what movies they purchased tickets to go see, and which after-school or community events they searched for online. This information could all become available to online learning curricula as a mechanism to personalize the instructional content to the experiences of that individual learner. This level of intrusion may sound off-putting at first, but many popular apps and programs like Google Now (named the 2012 "Innovation of the Year") already have the beginnings of such capabilities, and their artificial intelligence will only grow over time. Personalization and adaptivity are hallmarks of the technological era we live in, and it will only be natural to begin to apply these powerful innovations to the learning of academic subjects.

However, we see future personalized learning environments as incorporating more than just a checklist of all the things students care about and engage with. Our vision for personalization involves learners receiving tasks in online curricula that integrate their unique funds of knowledge – the resources they bring from home, community, and cultural bodies of knowledge – directly into their learning experiences. This integration could come from smart technology, as described above, as well as the teacher and the students themselves. In this way, learners could engage in complex, open-ended, collaborative projects in computer-supported environments that are connected to their interests. The software could work in conjunction with teachers to structure the investigations to match with particular academic concepts in a content domain, and to provide additional resources and feedback to the learner. The technology system could take all the information they have on student-, group-, and school-level characteristics, and in partnership with the teacher could pose rich and authentic tasks that deepen students' appreciation of both the academic subject and their area of interest. Students would also have the opportunity to explore and develop new areas of interest – like politics, art, business, the environment, or other social issues. This type of learning environment would be able to "bring in" learners who are typically excluded from or struggle with the academic domain, by leveraging their unique knowledge bases and making instruction more relevant and timely.

Personalization interventions have enormous potential to enhance motivation and achievement, as personalization offers a way to bring students' out-of-school interests, and the associated knowledge, value, and affect, directly into learning environments. The National Academy of Engineering named the development of personalized learning systems as a Grand Challenge for the 21st century (Ellis, 2008), alongside initiatives like understanding the nitrogen cycle and reverse-engineering the brain. Similarly, the

U.S. Department of Education recently cited personalized, individualized, and differentiated approaches as a Grand Challenge in their National Education Technology Plan (2010). Schools today face pressing issues with student motivation and achievement, and novel research into the theory, design, and implementation of motivation-based interventions can offer guidance for overcoming these challenges.

Realizing the promise of personalized learning is an unsolved problem in education, whose solution becomes ever more critical as we confront a new digital age. Context personalization has the potential to bring together several well-established strands of research on improving student learning – research on the development of interest, funds of knowledge, and utility value – into one powerful intervention. As argued in the National Education Technology Plan by the U.S. Department of Education (2010), "The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners that mirror students' daily lives and the reality of their futures" (p. VI). In this way, applications of context personalization to learning environments represent a critical type of motivation-based intervention for the 21st century.

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