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Students Authoring Personalized "Algebra Stories": Problem-Posing in the Context of Out-of-School Interests

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Abstract

Algebra is an important subject for students' educational and economic futures; however student interest in mathematics tends to decline over adolescence. Students often do not see algebra as accessible or connected to their lives and experiences. Bringing together research on personalizing learning to student interests and on student problem-posing offers a potentially important avenue to enhancing access to and motivation for learning algebra. In the present study, we engaged N = 24 students in sessions where they posed and solved algebra story problems based on their out-of-school interests in topics like sports, video games, and social networking. We found that students had a number of difficulties with problem-posing, including using precise language and conceptualizing a functional relationship between unknown quantities. However, students' "funds of knowledge" about their interest area seemed to act as an important scaffold for problem-posing, and participating in the problem-posing task improved students' attitudes towards mathematics. This study offers teachers, researchers, and curriculum developers important insights for how students' out-of-school interests can be meaningfully used as a scaffold for learning algebraic concepts.

Objectives

Schools today face pressing problems with student motivation (Hidi & Harackiewicz, 2000), especially at the secondary level where interest in subjects like mathematics can decline (Fredicks & Eccles, 2002; Frenzel, Gotez, Pekrun, & Watt, 2010). As interest is declining, mathematics achievement becomes increasingly important for students' educational and economic futures (Cogan, Schmidt, & Wiley, 2001). Algebra I has been identified as a gatekeeper to higher-level mathematics (Kaput, 2000); however teachers report challenges in making algebra accessible and working with unmotivated learners (Loveless, Fennel, Williams, Ball, & Banfield, 2008). Accordingly, students' confidence in using mathematics and its perceived usefulness decline during algebra courses (McCoy, 2005), and both students and teachers often view algebra as disconnected from everyday experience (Chazan, 1999).

Recent research on "personalization" of learning offers important opportunities to enhance motivation by implementing instruction that is tailored to the learner – to their prior knowledge, interests, and goals (Collins & Halverson, 2009). Accordingly, the National Academy of Engineering recently named personalized learning as a "Grand Challenge" for the 21st century (Ellis, 2008). We introduce an approach to personalized learning where students author problems based on their out-of-school interests in areas such as sports, video games, and social networking. We hypothesize that posing personalized algebra problems can help students to see the utility of algebra for modeling the world, an important motivational variable associated with learning (Hulleman & Harackiewicz, 2009). Second, we propose that by leveraging students' prior knowledge about their interests, they can develop a deeper understanding of algebra by incorporating terms and contexts that are personally meaningful. In this way, we seek to leverage students' mathematical "funds of knowledge" (Civil, 2007; Moll & Gonzalez, 1992) about their interest area – the prior experience they bring from reasoning quantitatively in home and community life.

Theoretical Framework

Context personalization is an approach where students experience instruction in the context of their out-of-school interests (Walkington, 2013). Context personalization has the potential to elicit students' *situational interest*. *Interest* is defined as the psychological state of engaging and the pre-disposition to re-engage, and situational interest is a type of interest triggered in-the-moment by characteristics of the environment, such as personal relevance (Hidi & Renninger, 2006). Personalized contexts may enhance students' tendency to see the usefulness of a topic like algebra, referred to as *utility value* (Eccles et al., 1983). Utility value is associated with the triggering and maintenance of situational interest (Hulleman, Godes, Hendricks, & Harackiewicz, 2010). Hulleman and Harackiewicz (2009) had biology students use journals to generate examples describing how biology was relevant to their lives and found that this approach improved achievement.

Personalized contexts may also draw upon students' everyday experience with the content. Connecting instruction to concrete experience has been called *grounding* (Goldstone & Son, 2005), and the redundancy of grounded representations with prior knowledge can improve inference making (Koedinger et al., 2008), or students' ability to identify appropriate or inappropriate responses. This is a critical component of successfully coordinating different representations in algebra (Nathan et al., 1992). However, the degree to which personalized problems allow for grounding depends upon the depth of the connection – problems may only connect to student interests at a surface level, limiting students' ability to filly apply their prior knowledge.

Prior research on personalization in algebra found that presenting students with problems in the context of their out-of-school interests improves long-term learning (Walkington, 2013). However, writing personalized problems to fit with many different interests is time-consuming, and problems quickly become obsolete as interests change. In addition, problems written by curriculum developers will always be disconnected from students' actual experiences, as it is not feasible to write unique problems that perfectly match the experiences of each learner.

To confront this problem, we looked to research on students authoring mathematics problems. Such *problem-posing* "improves students' problem-solving skills, attitudes, and confidence in mathematics, and contributes to a broader understanding of mathematical concepts and the development of mathematical thinking" (Singer, Ellerton, & Kay, 2013, p. 2). Problem-posing is a cognitively demanding task, especially for lower achieving students with weaker prior knowledge, and students may get bored quickly (Yu et al., 2005). However, an intervention where students pose problems related to their out-of-school interests has the potential to overcome these issues by leveraging both motivation and prior topic knowledge.

In this paper, we discuss a study where students posed personalized algebra story problems during one-on-one interviews. Our research questions were: (1) What difficulties do students encounter when posing personalized algebra story problems? (2) What commonalities do we observe among students who were most successful at posing problems? (3) How is posing personalized algebra story problems associated with changes in attitudes towards mathematics?

Methods

The study was conducted in two waves with N= 24 students (13 male, 11 female). Ten of the students were in an eighth grade remedial (pre-algebraic) mathematics course at a suburban Southern school and participated during their normal math class. The other fourteen students were enrolled in grades 6-10, and were recruited from a university subject pool in the mid-Atlantic region. Eighteen of the students were Caucasian, 4 were African-American, 1 was Hispanic, and 1 was Asian; two spoke English as a second language.

Participants first completed a survey that assessed their attitudes towards algebra including situational interest, utility value, and self-efficacy. Items were drawn from established instruments (Hulleman & Harackiewicz, 2009; Linnebrink-Garcia et al., 2010; Bandura, 2006). Participants next indicated their out-of-school interests (e.g., sports, video games) and researchers engaged students in a semi-structured discussion about how numbers and quantities are involved in each interest area.

After this discussion, students were given an algebra problem involving a linear equation with only a slope term that they were told had been written by another student interested in a particular topic (see Table 1, Questions 1a and 1b). They were asked to solve the problem with the interviewer providing scaffolding when needed. The student was then asked to pose a similar problem, but base it off of one of their interests. After posing and subsequently solving their problem, students were given another problem to solve that now incorporated an intercept term (see Table 1, Questions 2a and 2b). Once completed, students were asked to pose and solve a second problem that followed a similar structure, and incorporated the same interest area. Finally, students who completed both rounds of problem solving and posing were asked to pose one final problem related to a different area of interest. Students were then given the attitudes survey again.

Table 1

Problems given during sessions

Question 1a	Maria is interested in social networking, and just started a Twitter account. Every time she tweets, she gets four more followers on Twitter. a) Write a rule relating how many times Maria tweets to how many followers she has. b) If Maria tweets 12 times, how many followers will she have?
Question 1b	Jordan is interested in sports, and especially likes to play basketball. He noticed that he makes two baskets during each game he plays. a) Write a rule relating how many games Jordan plays to how many baskets he makes. b) If Jordan plays 9 games this season, how many baskets do you think he will make?
Question 2a	Maria is interested in social networking, and just started a Twitter account. She currently has 25 followers. Every time she tweets, she notices that she gets four more followers on Twitter. a) Write a rule relating how many times Maria tweets to how many total followers she has. b) If Maria tweets 6 times, how many total followers will she have?
Question 2b	Jordan is interested in sports, and especially likes to play basketball. He has already scored 12 baskets this season while playing for the basketball team. He thinks that he will score an additional 2 baskets for each game that remains in the season. a) Write a rule relating how many games Jordan plays to how many total baskets he will make this season. b) If Jordan plays another 4 games this season, how many total baskets do you think he will make for the whole season?

Data Sources

All sessions were video recorded with one camera focused on the student, and written work was collected. Video and student work were analyzed collectively using thematic analysis techniques (Braun & Clarke, 2006), where common mistakes in posing problems were coded. Videos of students who were highly successful at the problem-posing activity (defined by their ability to pose rich, mathematically valid, interest-based algebra problems) were examined to identify important characteristics of successful problem-posers. Analyses were exploratory, given that to our knowledge this approach has not been attempted in either research on problem-posing or research on personalization. Pre/post differences in attitudes were examined using paired *t*-tests.

Results

RQ1: Common Difficulties

Three major issues emerged when students posed personalized algebra story problems. First, many students struggled to write a prompt asking the respondent to "write a rule" describing the relationship between the independent and dependent quantities in their story (see part (a) of questions in Table 1). In fact, participants had an easier time writing an algebra rule itself than writing a question prompt asking the respondent to write an algebra rule. Figure 1 shows work from a student who described how her mom gives her money for each basket she scores when she plays at Nationals. Near the top of the work, we see an unsuccessful attempt to write the prompt for the rule ("Write an equation…") and at the bottom we see a second attempt that is more complete, but still somewhat unclear.

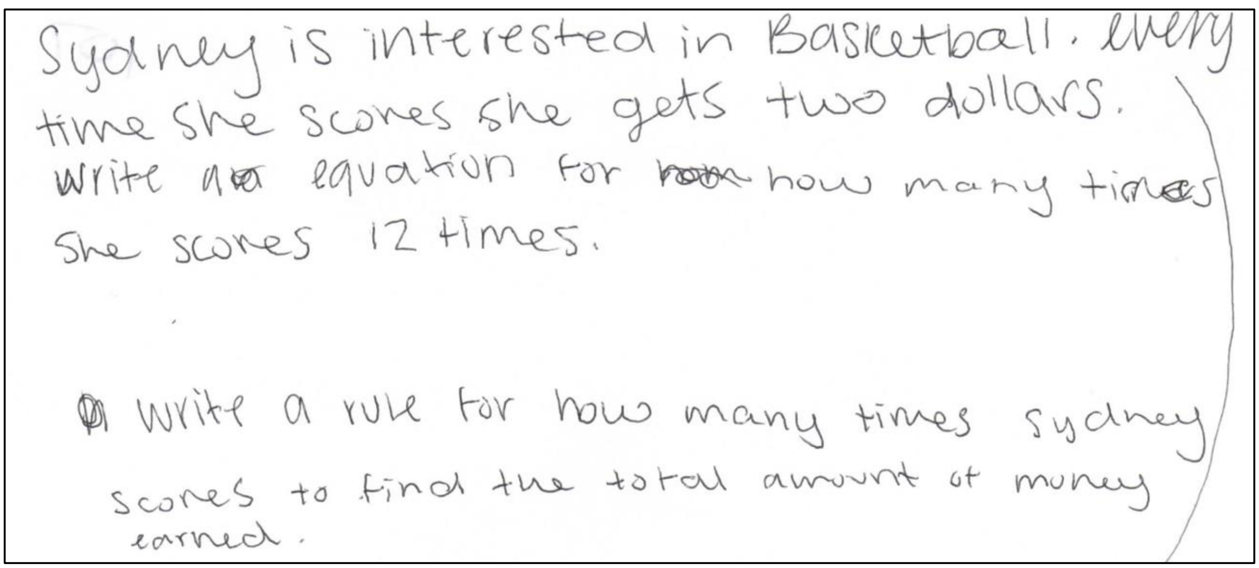

Figure 1. Student has difficulty writing the algebra rule question prompt

A second difficulty students encountered related to the precision of their language. When an algebraic relationship includes an intercept, often language like "total" or "altogether" is needed so that the solver knows to include the intercept, rather than just the amount of change. Figure 2 shows an example of a student who decided to change his wording from "5 people" to "another 5 people" to make sure this was clear – he explained that "he attacked people before to get the gold he has." However, other students needed assistance from the interviewer to use language that took into account the intercept.

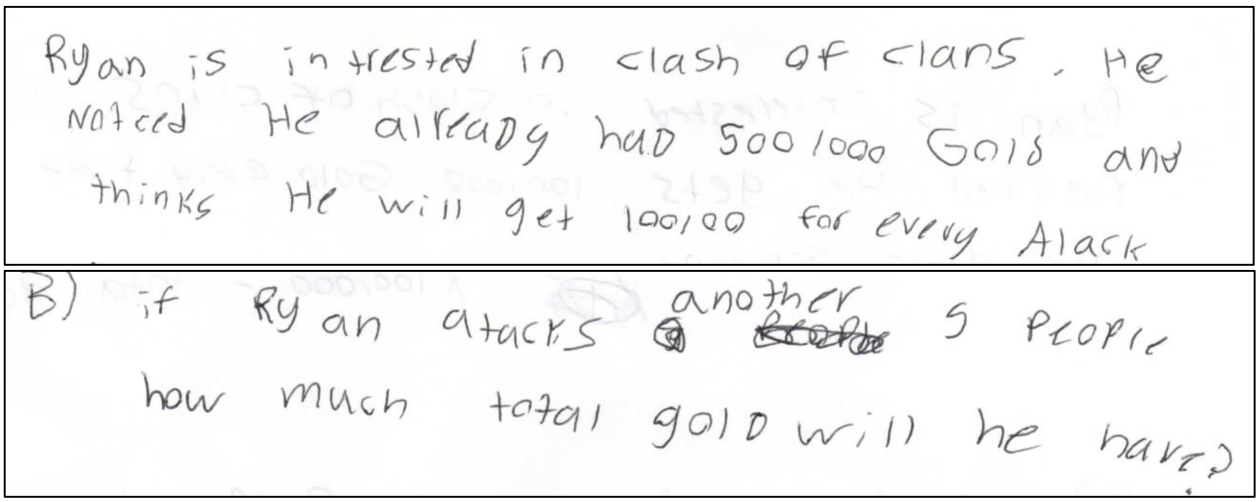

Figure 2. Student changes language to clarify that intercept term is needed

Third, the students who struggled most had difficulty describing a general linear relationship between two quantities, rather than supplying a specific value of one quantity and asking the solver to calculate the other. Figure 3 shows the work of a student who, rather than posing a problem about a general linear relationship (e.g., cost=1.25×songs–15), kept giving a particular number of songs for a solver to use. This scenario involves arithmetic rather than algebra.

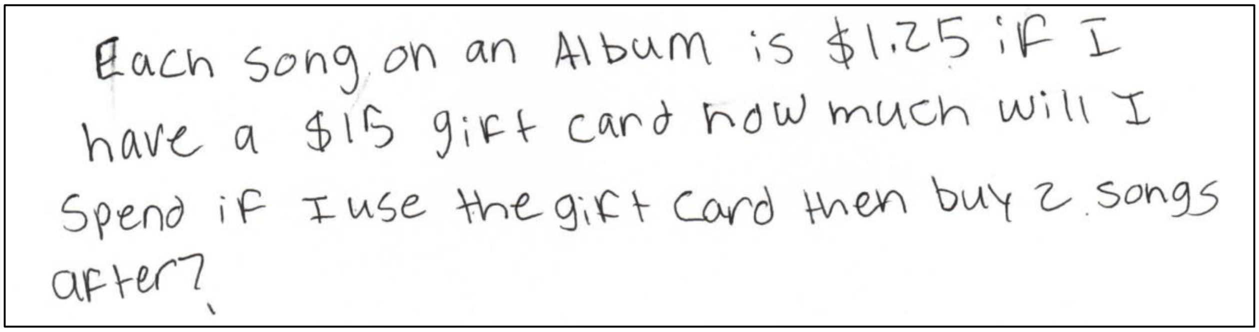

Figure 3. Student has difficulty writing problem with general relationship

RQ2: Successful Problem-Posers

Students who excelled at problem writing typically had either deep knowledge of their interest, some prior knowledge of linear equations, or both. The transcript in Figure 4 is from a student in the remedial eighth grade mathematics class who had little prior exposure to algebra. However, she had deep knowledge of how quantities and change operated in her interest area (Instagram). This allowed her to excel at problem-posing, compared to other students who did not have as deep engagement with their interest area, or who had an interest area with fewer quantitative aspects. She posed several interesting problems about relationships between quantities in Instagram.

Teacher: Instagram… tell me a little bit about that one.

Student: That's mostly sharing like pictures of whatever you're doing. 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.

Teacher: So how many people do you get liking your pictures usually?

Student: If I do hashtags, I get anywhere from 30 to 50 or 60 likes.

Teacher: How many hashtags do you put on any picture?

Student: Sometimes I put like 10 or 11.

Teacher: Do you have a lot of friends on Instagram?

Student: I follow like two hundred and something and I have 442 followers.

Teacher: How long did it take you to get 442 followers?

Student: I've had my Instagram since September.

Teacher: What about your friends, how many followers do they have?

Student: Well my best friend, she has 1110.

Teacher: Why does she have so many followers?

Student: Sometimes you can get a "shout out" from people who have lots of followers, and you'll have more followers. You can gain like 100… 150.

Figure 4. Transcript from successful problem-poser

Another student who excelled at problem posing had deep personal interest in ultimate Frisbee, as well as a fair amount of exposure to algebra. In his session, he demonstrated intimate knowledge of Frisbee tactics, and had completed Algebra I in school. This student quickly identified a linear relationship that was critical to scoring (yards the disc advanced per minute), and had no trouble prompting the respondent to write a rule (Figure 5). Interestingly, students' attitudes toward mathematics had little bearing on their ability to complete problem-posing tasks. Both of these students indicated low interest in mathematics, yet when prompted to incorporate their interests into math problems, engaged readily and excelled.

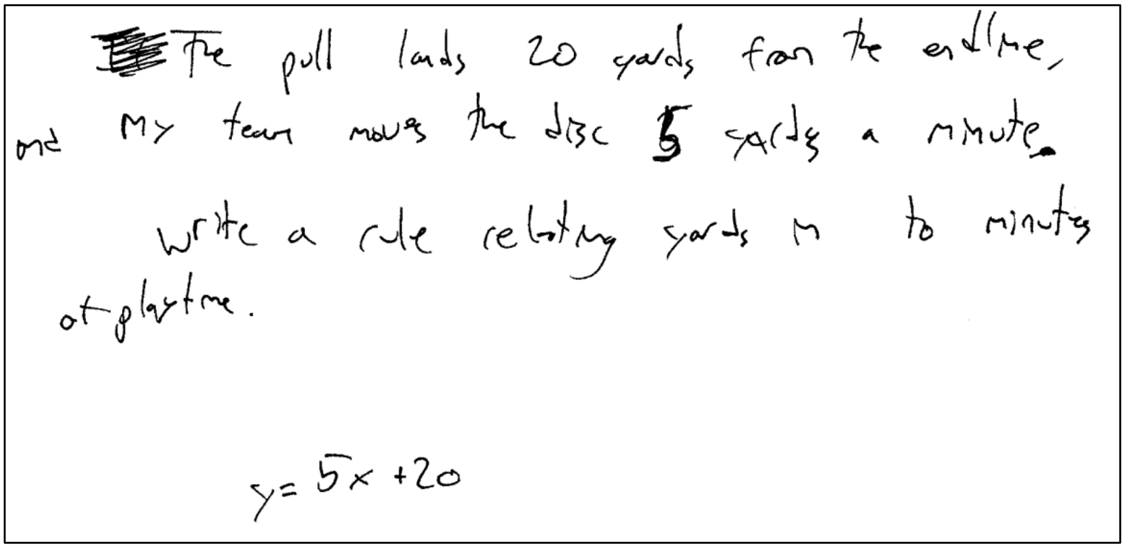

Figure 5. Written work from successful problem-poser

RQ3: Utility Value

Participating in the problem-posing session was associated with significant gains in utility value for learning algebra, captured by two survey items: "I can apply algebra to real life" and "Algebra can help me in my daily life outside of school." The mean rating on the pre-survey was 3.3 and 2.8 respectively, and at post was 4.1 and 4.1. Both gains where statistically significant: $t(23)=5.44$, $p=.003$; $t(23)=4.61$, $p=.009$.

Implications

Posing personalized problems is a difficult task; students struggle with precision of language and the idea of a general relationship between unknown quantities (Chazan, 1999). However, students' mathematical "funds of knowledge" (Civil, 2007) about their interest area can act as a key scaffold. Those with deep knowledge of their interests were able to identify relationships readily, while those with shallower knowledge often struggled. Having negative attitudes towards mathematics did not inhibit writing personalized problems, and problem-posing improved attitudes towards mathematics. Such attitude changes may promote achievement (Hulleman & Harackiewicz, 2009).

This study represents a starting point towards a larger goal of designing online systems for personalized problem-posing. In these systems, students could write and solve problems based on their out-of-school interests, learning important mathematics concepts and improving their attitudes towards mathematics along the way. Such systems would offer an up-to-date bank of personalized problems for teachers and curriculum developers. Here we provide some initial evidence for the promise of this approach, as well as challenges to be overcome.

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