

Evaluation Plan for Integer Multiplication Learning Object

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IDT 8130: Master's Project

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February 6, 2022

Background & Needs Statement

When the Common Core Math Standards were introduced in 2013, there were three key shifts in how mathematics was taught: focus, coherence, and rigor (CCSSI, 2022a). The standards were intended to allow for more in-depth instruction in fewer topics, help students make connections between the mathematical concepts taught in each grade, and deepen students' authentic understanding of the content (CCSSI, 2022a). Rigor was further divided into three components: conceptual understanding; procedural skills and fluency; and application (CCSSI, 2022a). No longer was it acceptable for students simply to be able to memorize rules and mathematical facts; instead, students needed to understand the concepts behind the mathematical facts and apply them in different contexts.

It is in this context that the Integer Multiplication learning object was designed. Integer multiplication is a frequent area of challenge for many middle and high school math students. Integer multiplication refers to multiplication of not just positive whole numbers (without decimals or fractional parts), but also negative whole numbers (without decimals or fractional parts). The math problem $-3 \times 4 = -12$ is an example of integer multiplication. While the skill is foundational to future success in high school math courses, including Algebra and Geometry, many students struggle to multiply negative and positive numbers without a calculator due to a lack of understanding in the conceptual underpinnings of integer multiplication. In order to address this conceptual issue, the Integer Multiplication learning object was created using Storyline to reinforce students' classroom learning of integer multiplication. In the learning object, conceptual understanding is reinforced in an application of integer multiplication, as the learner helps their friend, Tim, calculate how much money he has left at the end of the month. Learners go through a series of interactive scenarios that show multiplication of both negative

and positive integers, concluding with a practice activity where learners build their procedural fluency.

Common Core Math Standard 7.NS.A.2 states that students will “apply and extend previous understandings of multiplication and division and of fractions to multiply and divide rational numbers” (CCSSI, 2022b). This standard extends students’ 6th grade math knowledge of negative and positive (rational) numbers to performing operations with said numbers. Based on when the standard is covered, the target learners for the learning object are students in 7th through 12th grades. In particular, this learning object is intended to support learners who either struggle to understand the concept of integer multiplication or who need additional practice with the concept. It has been designed to be used independently and asynchronously, without teacher support, although there is the option to download a report or view a student’s mastery at the end of their use of the object to determine if additional support or practice is needed.

The structure and content of the Integer Multiplication learning object was heavily influenced by Keller’s ARCS Model of Motivation. The ARCS categories of attention, relevance, confidence, and satisfaction are embedded throughout the learning object in order to engage and motivate the learner (Keller, 2010). When the learner opens the learning object, they are introduced to Tim and put into the scenario as someone who is helping their friend. This structure, which makes the learner an active participant in a real-world context, is designed to get the learner’s attention through the use of perceptual and inquiry arousal strategies (Keller, 2010). Perceptual arousal and inquiry arousal are two of the three strategies that comprise attention in Keller’s ARCS Model (Keller, 2010).

Relevance is another one of the categories of Keller’s ARCS Model (Keller, 2010). As the learner navigates through the Integer Multiplication learning object, they are presented with

different real-world scenarios where negative and positive integers are used to calculate money. In one scenario, Tim has borrowed money from a friend, while in another scenario Tim's brother owes him money. These are situations which the learner is likely to be familiar with and which the learner will likely experience themselves if they have not already. This structure demonstrates goal orientation and familiarity, two of the strategies for making learning relevant in Keller's model (Keller, 2010).

The third category of Keller's ARCS model is confidence, which is the learner's desire to feel successful in learning (Keller, 2010). Keller provides three strategies for addressing learners' confidence: learning requirements, success opportunities, and personal control (Keller, 2010). All three of these strategies are embedded in the Integer Multiplication learning object. At both the beginning and end of the learning object, the learner is presented with the learning objectives to both guide and summarize the learning experience. Throughout the learning object, the learner is asked to interact with each scenario by selecting a visual, numerical, or verbal expression. Based on their response, the learner is then directed to feedback that either confirms their choice or provides additional guidance to help the learner adjust and try the problem again.

The final category of the ARCS Model is satisfaction, which is how satisfied the learner is with the outcomes of the learning process (Keller, 2010). Keller suggests that learner satisfaction can be influenced through the use of natural consequences and equity in learning experience (Keller, 2010). In the learning object, the natural consequence of the learning is the praise or feedback given throughout the learning object, as well as the real-world applicability of the skill learned (multiplying positive and negative integers in the context of money). Since money is something that all learners will have experience with and will need to understand, the application of negative and positive integer multiplication in this context gives the learner a

natural consequence: building the skills necessary to navigate monetary decisions. Learners are also able to immediately apply their learning in the eight-question practice section at the end of the learning object. Keller also notes that learners can lose motivation if they perceive either their experience or outcomes to be inequitable to another's experience or outcome (Keller, 2010). The learning object addresses this by ensuring that the learning outcomes are presented at the beginning of the learning object, are referenced throughout, and are summarized at the end of the learning process to ensure that the learning object is consistent.

The Integer Multiplication learning object has already been assessed for content validity by both a middle and high school math teacher as well as a special education teacher, who served as subject matter experts. The content of the learning object was found to be appropriate for the grade level and to fully cover the content. The examples, activities, and embedded practice were all found to align with the learning objective and Common Core Math Standard 7.NS.A.2. The learning object now needs to be evaluated by users to collect information about their user experience, as well as the effectiveness of how the content is covered. The evaluation of the learning object seeks to answer the following questions:

1. To what extent is the learning object effective at reinforcing students' conceptual understanding of integer multiplication?
2. To what extent is the learning object effective at building students' procedural fluency with integer multiplication?
3. To what extent is the learning object easy to use?
4. To what extent is the learning object engaging for learners?

Evaluation Methodology

This user evaluation is part of the iterative and ongoing revision of instruction in the ADDIE Model (McGriff, 2000). Throughout the design process, evaluations and feedback have been incorporated into the learning object to improve the product. After evaluation by subject matter experts, changes were made to the phrasing to ensure that the content met the level of the standard. The user evaluation is another opportunity for formative evaluation of the learning object, which will result in data that will suggest changes and adjustments that are needed so that the learning object is effective in supporting learners in meeting its learning objectives.

Since the Integer Multiplication learning object is designed to be used without any additional support, a self-administered questionnaire will be used to assess the usability and effectiveness of the learning object. Using a self-administered questionnaire offers an additional benefit: while the learning object is designed for struggling learners from grades seven through twelve, integer multiplication is technically a 7th grade concept and skill. As such, there is some shame and embarrassment among older students who still struggle with the concept. Having students, especially older students, participate in a focus group or usability test may decrease the validity of their responses due to embarrassment or anxiety. Since the learning object was designed to support struggling learners, feedback from this group is extremely important. For this reason, a self-administered questionnaire was chosen as the method for the survey in order to collect useful information to evaluate and refine the learning object.

The survey will be administered using Google Forms because of accessibility and the array of question types available on the platform. Additionally, Google Forms collects the data in a spreadsheet which will be helpful for analysis. The evaluation of the learning object will consist of three parts. The first part will take place before the learner interacts with the learning object. In two sections in the Google Form, learners' demographic information (age, gender) will

be collected and their baseline knowledge of integer multiplication will be established. Students' baseline is important because two of the questions of interest seek to determine whether the learning object is effective at reinforcing students' conceptual understanding and whether it builds students' procedural fluency of integer multiplication. Without a baseline, the effectiveness of the learning object in these areas could not be assessed. Learners' baseline will be established using the same eight items that are in the embedded practice in the Integer Multiplication learning object. The items include matching, multiple choice, and fill-in-the-blank type items, which will be replicated in Google Forms.

The second part of the evaluation will be the user interaction with the learning object. This will take place in Schoology, which is a learning management system (LMS). The learner will be given time to work through the learning object itself. They will complete the four different scenarios and associated questions, as well as the embedded eight-item practice at the end. Data for each question will be collected directly from the learning object via Schoology and will be downloaded into a spreadsheet. This data will serve as the post-test for statistical analysis.

The third and final part of the evaluation process will be items in the Google Form. The items will be in a separate section of the Google Form to prevent learners from going back to previous sections and changing any answers. Items in this section will ask about the user experience. This section of the questionnaire will consist of 20 items selected from the User Experience Questionnaire+ (UEQ+) and Visual Aesthetics of Websites Inventory (VisAWI) questionnaires. These items will be 7-point Likert-scale items. Information collected in this section will provide data about the final two questions of interest about ease of use and learner engagement.

Evaluation Instruments

A cohesive questionnaire will be created to evaluate the learning object. The questionnaire will be a Google Form. As previously stated, the first part of the questionnaire will collect demographic information including grade level and gender. The second part of the questionnaire will be an integer multiplication pre-test. Learners will then complete the learning object. Finally, learners will complete 20 closed questions about the user experience.

To facilitate statistical analysis and allow for meaningful conclusions, a matched pre- and post-test model will be used to assess learners' conceptual understanding and procedural fluency. In the learning object, there is an 8-question practice that assesses learners' mastery of the content after completing the learning object. The questions assess students' conceptual understanding and procedural fluency with integer multiplication. These same eight questions will be administered to students at the beginning of the questionnaire, before students begin the learning object. Once students have completed the Integer Multiplication learning object, they will answer items about the user experience. A user experience questionnaire for this learning object was previously developed in IDT 7085. The user experience questionnaire measures perspicuity, stimulation and aesthetics. The User Experience Questionnaire+ (UEQ+) and Visual Aesthetics of Websites Inventory (VisAWI) questionnaires were used in the development of the user experience questionnaire.

The items selected from UEQ+ measure perspicuity and stimulation. Perspicuity means "Is it easy to get familiar with the product? Is it easy to learn? Is the product easy to understand and clear?" (Schrepp et al., 2017, p. 41). This is important to measure because it is an indicator of how easily the learner could understand and use the structure of the learning object. If the structure of the learning object is too difficult for the learner to easily understand, the learner will

not be able to engage with the content. The objective for the learning object is that learners will develop a deeper, more transferable understanding of integer operations. To increase learner engagement, real-world examples involving money are used to illustrate the concepts of integer multiplication because it is relatable and realistic. To measure whether the learning object engages the learner effectively, the questionnaire assesses the stimulation of the object. Schrepp et al. (2017) describe the items assessing stimulation as addressing the questions "Is it exciting and motivating to use the product? It is fun to use?" (p. 41). A total of eight items (four assessing each construct) were used in the questionnaire. The items use a 7-point Likert scale "from -3 (fully agree with negative term) to +3 (fully agree with positive term)" (Schrepp et al., 2017, p. 40).

The items from VisAWI measure the visual aesthetics of the learning object. According to Moshagen & Thielsch (2010), visual aesthetics have been linked with perceptions of increased usability, performance, affect and satisfaction. Additionally, they note that there are "beneficial effects of visual aesthetics in the context of learning environments, for example by increasing ease and effectiveness of learning, enhancing transfer of knowledge, and increasing motivation" (p. 691). VisAWI was developed for the evaluation of websites, which the Integer Multiplication Learning Object is not. However, the items selected from the VisAWI questionnaire provide important information about the aesthetics of the learning object and will allow for improvements to the visual aesthetics of the learning object in order to increasing learning and transfer. The items used for this evaluation measure three subscales (simplicity, craftsmanship, and diversity) which were determined to best measure the construct of interest. In developing the user experience questionnaire, terminology was adjusted from the VisAWI questions to reflect that the item being evaluated is not a website but is instead a web-hosted learning object. The

items use a 7-point Likert scale "ranging from 1 "do not agree at all" to 7 "do fully agree"" (Moshagen & Thielsch, 2010, p. 8).

Sampling Methodology

The population of interest includes students in grades seven through twelve who struggle with the concept of integer multiplication. These could include students who have IEPs or 504s with noted mathematical deficiencies; 7th grade students who need additional practice with the grade-level concept; or older middle and high school students who need further clarification and practice with the concept. This population is quite large, which poses issues with creating a representative sample across all subsets. Additionally, since the population consists of students, including students with disabilities, which are a special population, additional considerations are necessary, including receiving parental permission and clearly informed consent for participation in this evaluation process.

Due to time constraints and ease of access, I have decided to select the sample from students enrolled in mathematics courses at Diamond Oaks Career Campus, where I am a math teacher. The questionnaire and learning object will be administered to 36 high school seniors who are enrolled in Financial Algebra. This math class covers concepts involving personal finance, which aligns with the scenarios in the learning object. This group of students was selected for two reasons. First, as the classroom teacher, I am able to ensure that the data collection process, including questionnaire administration and interaction with the learning object, has minimal issues, and I am able to ensure that students are given an appropriate amount of time to complete the full evaluation process. Additionally, of the 36 students in this group, 15 (42%) have IEPs or 504s, eight of which (22% of the class) have documented challenges with integer operations, including integer multiplication. Since this was a group of interest in the

development of the learning object, this group is an appropriate choice for the evaluation process of the Integer Multiplication learning object.

Students will complete both the questionnaire and learning object at their own pace during a typical 45-minute class period. This would mimic a possible setting in which the learning object could be used (independently by students to provide additional support and practice). The process will be verbally explained and then a paper will be sent home to parents before students are given the learning object and questionnaire. A passive consent process will be used, since there is a minimal risk of adverse outcomes during the administration of either the learning object or the questionnaire. Students from the selected classes will be included in the sample unless their parents specifically opt to refuse their participation. Students will be able to opt-out of the process at any time.

Analysis Procedures

To analyze the data, multiple statistical analyses will be used. Demographic items will be coded to allow for statistical analysis. In order to address the research questions about the effective of the learning object at reinforcing students' conceptual understanding of integer multiplication and at building students' procedural fluency with integer multiplication, a matched t-test will be used. A matched t-test is an appropriate test to use when there is pre- and post-test matched data, as there is in this case. The t-test will be used to determine if the difference between the pre- and post-test responses is statistically significant, which will indicate the learning objects impact on conceptual understanding and procedural fluency of integer multiplication.

The ease of use (perspicuity) and engagement (stimulation, aesthetics) of the learning object will be measured by user experience questionnaire items that were developed from the

UEQ+ and the VisAWI. These items will be analyzed based on the questionnaire guidance. The UEQ+ provides documentation for data entry and analysis of the Likert scale items, including analysis of the reverse-coded items. The VisAWI questionnaire items do not require special interpretation and instead will be analyzed based on mean, median, mode, standard deviation, and variance. The statistical analysis of each item will be analyzed for each construct and subscale.

After the statistical analyses have been performed, the results will be examined to identify any patterns or trends in specific constructs and by demographic information, including age and gender. The results of these analyses will provide evidence to inform and direct any necessary changes to the learning object based its effectiveness at reinforcing students' conceptual understanding, building students' procedural fluency, ease of use, and engagement.

Conclusion

Integer multiplication is a foundational skill essential for student success in higher math courses, including Algebra I and Geometry. While it is covered in the 7th grade Common Core Math Standards, many students, including students with disabilities, continue to struggle with the concept well beyond their 7th grade math class. In order to improve students' conceptual understanding of and procedural fluency with integer multiplication the Integer Multiplication learning object was developed. Keller's ARCS Model of Motivation heavily influenced the structure, interactions, and feedback incorporated into the learning object. While it has been evaluated by middle and high school math teachers, as well as a special education teacher, the learning object has not yet been evaluated by the target audience. In order to understand learners' perceptions of the ease of use and engagement of the learning object, a three-part evaluation process has been developed that used a pre- and post-test structure, as well as items to measure

the perspicuity, stimulation, and aesthetics of the learning object. An evaluation of the user experience is the essential next step in the development of this learning object so that statistically-supported improvements can be made to the learning object before it is made available to a wider audience. While the Integer Multiplication learning object has been approved by subject matter experts, without the input of the user, understanding learner engagement with it will be lacking, which will limit the ability of the learning object to improve students' skills with integer multiplication.

References

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Appendix A: User Experience Questionnaire

The purpose of this evaluation is to determine the effectiveness of the learning object at supporting students with integer multiplication, as well as how easy the learning object is to use and whether students find the learning object engaging. The purpose of the learning object is to help students better understand how the multiplication of negative and positive numbers works. The information collected from the survey will be used to improve the Integer Multiplication Learning Object.

Welcome to the evaluation of the Integer Multiplication Learning Object! Thank you for your time and participation.

What is the evaluation process?

- First, you will answer a few basic questions about yourself. Then, you will complete 8 integer multiplication practice questions.
- Next, you will go to Schoology and complete the Integer Multiplication Learning Object, which consists of some scenarios and embedded practice problems.
- After you complete the learning object, you will return to this Google Form, and answer questions about your experience completing the Integer Multiplication Learning Object.

Remember, you are not being tested - the Integer Multiplication Learning Object is! Thank you for your input!

Click "Next" to get started!

Section 1: Demographic Questions

1. What is your age?
 - a. 12 or younger
 - b. 13 – 14
 - c. 15 – 16
 - d. 17 – 18
 - e. 19 or older
2. What gender do you identify as?
 - a. Male
 - b. Female
 - c. Non-binary
 - d. Prefer not to say

Please click "Next" to continue.

Section 2: Integer Multiplication Questions

Do NOT use a calculator for these questions.

1. Match the problem with the correct rule.

	Positive x positive = positive	Negative x positive = negative	Positive x negative = negative	Negative x negative = positive
$6 \times 5 = 30$				
$-3 \times 10 = -30$				
$15 \times -2 = -30$				
$-1 \times -30 = 30$				

2. Find the product: $-6 \times 4 = ?$

- 2
- 24
- 24
- 2

3. Find the product: $3 \times -9 = ?$

- 6
- 27
- 6
- 27

4. Find the product: $-8 \times -4 = ?$

- 12
- 32
- 12
- 32

5. Check the box next to the correct product. Answers can be used multiple times.

	30	-30	20	-20
6×-5				
4×5				
-4×5				
4×-5				
-4×-5				
6×5				

6×-5				
-6×5				

6. Multiply to find the product: $6 \times 10 = ?$ Type your answer in the box.
7. Multiply to find the product: $16 \times -2 = ?$ Type your answer in the box.
8. Multiply to find the product: $-3 \times -10 = ?$ Type your answer in the box.

Click "Next" to continue.

Section 3: Integer Multiplication Learning Object

Go to Schoology and find the Financial Algebra course. The first item in the Schoology course is the Integer Multiplication learning object. Click the play button to get started. YOU WILL NEED HEADPHONES.

Remember, you are not being tested - the Integer Multiplication Learning Object is! Thank you for your input!

When you have reached the "Results" screen, you will come back to this survey and click "Next" below to continue.

Section 4: User Experience Questions

Please complete the following questions to assess the learning object. The following items contain opposing pairs of product properties. The grades between the opposites are indicated by circles. Click one of the circles to indicate your level of agreement with the individual terms.

Try to make a spontaneous decision! It is important not to think too long about the terms to reach a direct assessment. Please always check one answer, even if you are insecure about your assessment of one pair of terms or if you think that it does not fit the product.

There are no "right" or "wrong" answers. Your personal opinion is all that counts!

1. In my opinion, handling and using the learning object is... not understandable / understandable
2. In my opinion, handling and using the learning object is... easy to learn / difficult to learn
3. In my opinion, handling and using the learning object is... complicated / easy
4. In my opinion, handling and using the learning object is... clear / confusing

5. In my opinion, handling and using the learning object is... not interesting / interesting
6. In my opinion, handling and using the learning object is... boring / exciting
7. In my opinion, handling and using the learning object is... inferior / valuable
8. In my opinion, handling and using the learning object is... demotivating / motivating

Click "Next" below to continue to the next screen.

Please evaluate the learning object according to the following statements on a scale ranging from 1 (strongly disagree) to 7 (strongly agree).

	Strongly Disagree	Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
9. The layout appears too dense.	1	2	3	4	5	6	7
10. The layout is easy to grasp.	1	2	3	4	5	6	7
11. The layout appears well structured.	1	2	3	4	5	6	7
12. Everything goes together in the learning object.	1	2	3	4	5	6	7
13. The layout appears professionally designed.	1	2	3	4	5	6	7
14. The layout is not up-to-date.	1	2	3	4	5	6	7

Please evaluate the learning object according to the following statements on a scale ranging from 1 (strongly disagree) to 7 (strongly agree).

	Strongly Disagree	Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
15. The learning object is designed with care.	1	2	3	4	5	6	7
16. The design of the learning object lacks a concept.	1	2	3	4	5	6	7
17. The layout is pleasantly varied.	1	2	3	4	5	6	7
18. The layout is inventive.	1	2	3	4	5	6	7
19. The design appears uninspired.	1	2	3	4	5	6	7
20. The design is uninteresting.	1	2	3	4	5	6	7

Press "Submit" below to finish the evaluation. Thank you!