# Patterns for Learning-support Design in Math Online Learning Systems

PAUL SALVADOR INVENTADO AND PETER SCUPELLI, School of Design, Carnegie Mellon University

Online learning systems have been gaining popularity, but are not without its challenges. For example, enrollment in MOOCs has slowed down, which is attributed to lack of sustainability. Research shows that introducing learning activities with appropriate learning support may increase students' learning gains as much as six times compared to just delivering content in MOOCs. These results emphasize the importance of high quality designs for learning activities and learning support in online learning systems. Patterns for designing learning activities and learning-support are necessary because most pedagogical patterns operate at a higher level (e.g., course design, lectures, interaction with students). This paper presents three design patterns that may help online learning system stakeholders such as system developers, content creators, and teachers, to design learning-support for math problem-solving activities in online learning systems.

Categories and Subject Descriptors: **H.5.2 [Information Processes and Presentation]**: User Interfaces—*User-centered Design*; **K.3 [Computers and Education]**: Computer Uses in Education—*Distance learning*;

General Terms: Design, Human Factors

Additional Key Words and Phrases: Design patterns, online learning systems, math, learning support, data driven design pattern production, ASSISTments

**ACM Reference Format:**

Inventado, P.S. and Scupelli, P. 2016. Patterns for Learning-support Design in Math Online Learning Systems. In Proc. of Conf. on Pattern Lang. of Prog. 23 (October 2016), 13 pages.

## 1. INTRODUCTION

Increasingly, online learning systems have been gaining popularity. Examples of such systems include Massively Open Online Courses (MOOCs) (e.g., Coursera[1], edX[2]) and online tutoring systems (e.g., ASSISTments[3], Cognitive Tutor[4]). Although MOOCs are still popular, course enrollment has started to slow down, which is often attributed to its lack of sustainability [Allen & Seaman 2015].

A recent article by Koedinger et al. [2015] suggests that students can learn as much as six times more when they engage in learning activities with appropriate learning support aside from studying MOOC content (e.g., view video lectures, read content). Such improvements in learning design may help address issues in learning systems, such as sustainability, so there is a need to facilitate the use of these designs.

Online learning system stakeholders, such as system developers, content creators, and teachers, may find design patterns useful to encapsulate high quality designs. Several design patterns are used to enhance the quality of pedagogy at different levels such as the course level, class level, and student level (e.g., Bergin et al. [2012], Iba et al. [2011], Köppe et al. [2015], Mor and Warburton [2015]), but there are fewer design patterns that specifically address the design and implementation of learning activities and learning support.

This paper presents three design patterns that focus on supporting student learning as they engage in math problem solving activities in online learning systems: **Animation-Enhanced Hints**, **Personal Video Hints**, and **Reinforce the Growth Mindset**. The following sections provide a review of related literature, a brief discussion about the methodology used to discover the patterns presented in the paper, the design patterns, and future work.

[1] https://www.coursera.org/

[2] https://www.edx.org/

[3] https://www.assistments.org/

[4] https://www.carnegielearning.com/learning-solutions/software/cognitive-tutor/

## 2. RELATED WORK

Several design patterns have been developed for the educational domain. For example, Christian Köppe and his colleagues are compiling in-class-meeting design patterns for flipped classrooms [Köppe et al. 2015]. These patterns help with the design and delivery of in-class meetings to ensure that students get necessary support in deepening their understanding of knowledge, and to correct possible misconceptions they acquired. Some examples of these patterns are **Add Value Beyond Feedback**, **Compare Solutions**, and **Use Student Solutions**.

Takashi Iba and his colleagues are compiling design patterns for creative learning, which promotes learning through experience and through the creation of something new [Harashima et al. 2014, Iba et al. 2011, Shibuya et al. 2013]. Some examples of these patterns are **Learning Through Accidents**, **Mission Possible**, and **Provoke for High Quality**.

Design patterns for online learning environments are also being investigated. Mor and Warburton are compiling a pattern language for MOOCs to address various challenges such as those involving course management, online discussions, interaction between learners, course content, individual differences, and failure points in the technology [Mor & Warburton 2015, Warbuton & Mor 2015]. Some examples of these patterns are **Checkpoints, Provocative Question**, and **Six Minute Video**.

The pedagogical patterns developed by Joseph Bergin and his colleagues are quite robust and can be applied in various learning settings such as traditional learning in classrooms, flipped classrooms, and MOOCs. The patterns address various problems on active learning, feedback, and experiential learning to name a few [Bergin et al. 2012]. Pedagogical patterns for experiential learning and feedback such as **Try It Yourself**, **One Concept – Several Implementations**, and **Feedback**, are particularly interesting because they can be applied in designing content and feedback for online learning activities.

## 3. DATA-DRIVEN DESIGN PATTERN DEVELOPMENT

The design patterns presented in the following section were uncovered using the data-driven design pattern production (3D2P) methodology. 3D2P is a four-step iterative process used to uncover design patterns from data collected in a particular domain [Inventado & Scupelli 2015b].

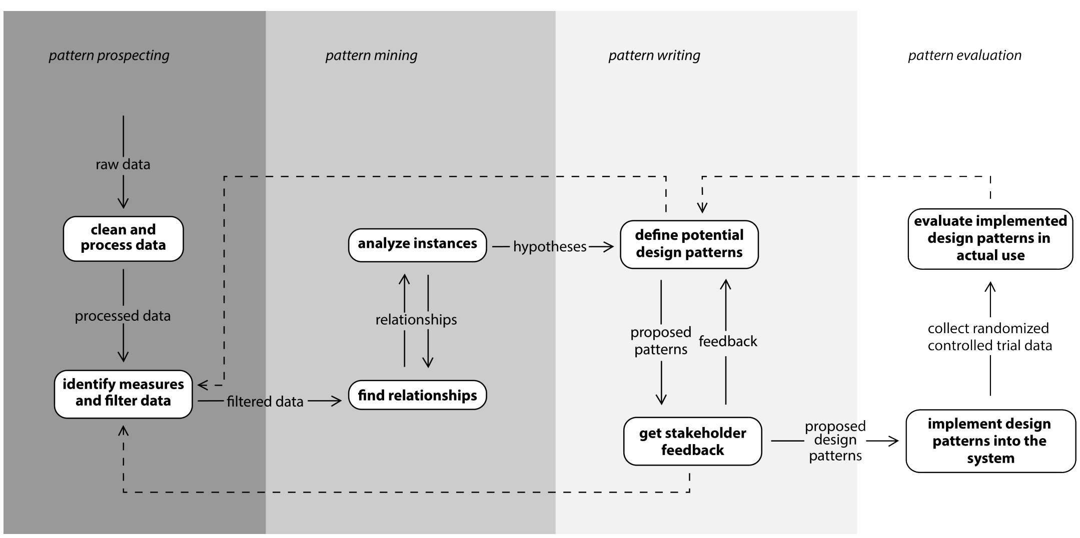



**Figure 1. Data-driven design pattern production methodology (Image courtesy of the Learning Environments Lab).**

Figure 1 illustrates the 3D2P methodology, which starts by prospecting data to find interesting relationships in the data. These relationships are investigated further in the pattern-mining step to develop hypotheses based on recurring problems and high quality solutions uncovered. Literature and experts in the field are consulted to confirm the validity of the hypotheses. Resulting hypotheses are used to write proposed patterns and are refined through a feedback loop that usually involves stakeholders, shepherds, and writing workshop participants. Accepted design patterns are evaluated by implementing them into existing systems and evaluating their performance. Randomized controlled trials are conducted to compare the resulting outcome measures (e.g., learning gain, time on task) between applying the design pattern and not applying the design pattern. Results of the evaluation are used to further refine the design pattern as needed. Details about the methodology and the data used to uncover the patterns are reported in [Inventado & Scupelli 2015b].

## 4. DESIGN PATTERNS

Figure 2 illustrates the patterns presented in this paper, which are part of a pattern language currently being compiled by the authors for Math problems and its associated learning support in online learning systems. The pattern language focuses on Math education because the patterns were uncovered from students' interactions with Math problems in the ASSISTments online learning system using the 3D2P methodology. We suspect that some patterns may apply to other domains, but at this point, we opt to limit the scope to Math until we can gather more evidence of their effectiveness in other domains.

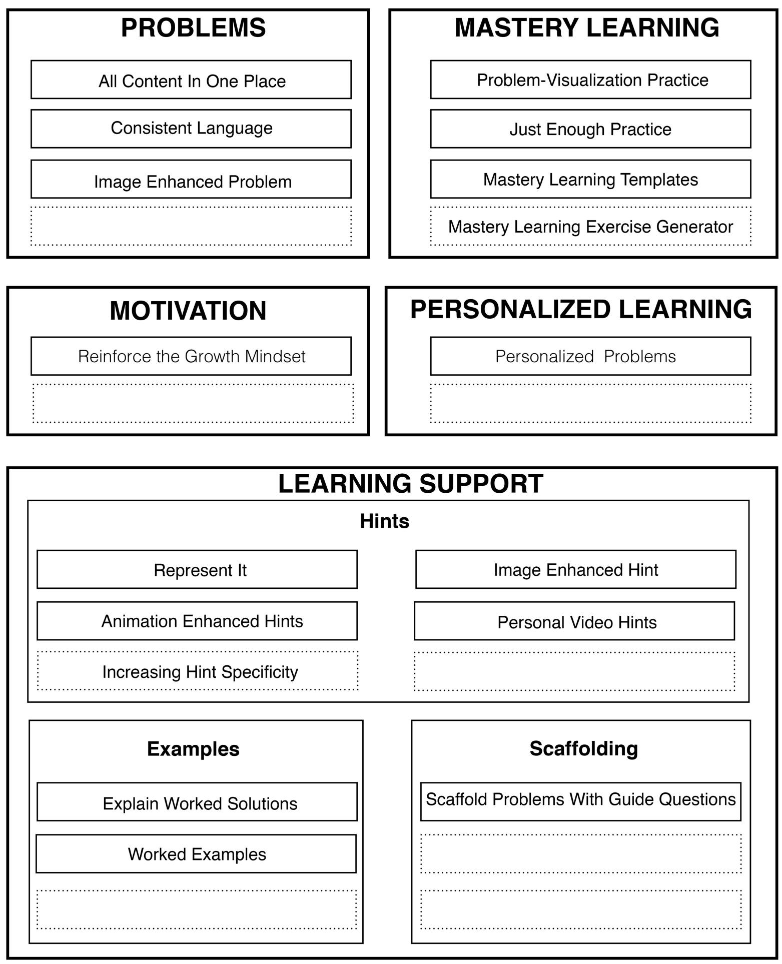



**Fig. 2. Visualization of the pattern language for Math problems and its associated learning support in online learning systems (Image courtesy of the Learning Environments Lab).**

The innermost rectangles represent design patterns. Published patterns are drawn using solid lines and patterns-in-development are drawn with dotted lines. Empty rectangles indicate that other patterns may later be included in the language. The design patterns are grouped into five categories represented by outer rectangles that enclose the patterns: *Problems*, *Learning Support*, *Personalized Learning*, *Motivation*, and *Mastery Learning*. *Problems* refer to patterns that deal with the design of math problem content. *Learning Support* refers to patterns that deal with the design of math learning-support content, how they are presented, or how much learning support should be provided. It is further categorized according to the type of learning support provided such as *Hints*, *Examples*, and *Scaffolding*. *Personalized Learning* refers to patterns that deal with designs for adapting problem content or learning-support content so that it is more appropriate to the student's background knowledge, affective state, personality, and so forth. *Motivation* refers to patterns that deal with designs for maintaining student motivation while maximizing learning. Finally, *Mastery Learning* refers to patterns that deal with the design of math problems or problem sets to promote skill mastery. Some of these design patterns have recently been published, which can be found in Inventado and Scupelli (2015b), Inventado and Scupelli (2015c), Inventado and Scupelli (2016a), and Inventado and Scupelli (2016b).

The pattern format used in this paper separates each section with a heading much like other pattern formats (c.f., [Carlsson 2004, Dearden & Finlay 2006]). It contains the commonly used *context*, *problem*, *forces*, and *solution* sections. The *benefits* section describes how the solution addresses the forces in the problem and the *liabilities* section presents issues that may arise from implementing the solution. The *known implementations* section describes instances when the pattern was applied successfully, and the *related patterns* section lists other design patterns that are referenced or references the pattern in question. A *supporting theories* section was introduced to allow the reader to learn more about the theoretical foundation of the problem and solution described in the pattern.

Table 1 provides summaries of the three patterns presented in the following subsections. Table 2 provides summaries of design patterns referenced in the paper.

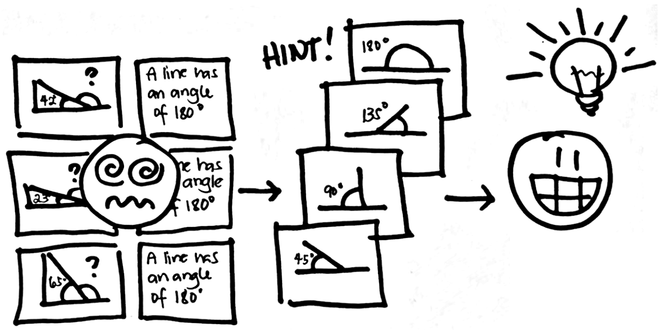
Table 1. Patterns for helping students represent math problems in online learning systems.

| Design Pattern | Summary |
|---|---|
| **Animation-Enhanced Hints** | Incorporate animations in hints to break monotony, to capture attention, and to provide alternative ways to analyze or solve the problem. |
| **Personal Video Hints** | Use personal videos to make hints more meaningful to students. |
| **Reinforce the Growth Mindset** | Present feedback with motivational messages to remind students that they are capable of learning skills despite difficulties they may experience while learning. |

Table 2. Referenced Patterns

| Referenced Design Patterns | Summary |
|---|---|
| **Build and Maintain Confidence** [Bergin et al. 2012] | Give students problem-solving activities with appropriate feedback, so they apply what they learned, discover there are multiple solutions, and realize they can implement solutions themselves. |
| **Feedback Sandwich** [Bergin et al. 2012] | Start and end suggestions for improvement with positive reinforcing comments so as not to undermine students' confidence. |
| **Image-Enhanced Hint** [Inventado and Scupelli 2016b] | Clarify hints for math problems by adding images that disambiguate confusing terms and explanations. |
| **Image-Enhanced Problem** [Inventado and Scupelli 2016b] | Clarify ambiguous terms and explanations in the math problem by adding appropriate images. |
| **Keep It Simple** [Cunningham and Cunningham 2014] | Designs should be kept as simple as possible while ensuring it achieves its purpose. |
| **Represent It** [Inventado and Scupelli 2016b] | Encourage students to externalize their thoughts using representations to help them better understand the problem and figure out the answer. |
| **Try It Yourself** [Bergin et al. 2012] | Ask students to perform an exercise that requires them to understand the topic they were taught. |

# Animation-Enhanced Hints




**Context:** Students are asked to answer math problems on an online learning system to help them understand a topic they recently learned.

**Problem:** Students may get bored or disengage from problem solving activities that contain dull, monotonous problems and hints that are often made with static text and images.

**Forces:**

- *Dull content*. Static text and images, especially when presented repeatedly, may be boring and cause students to disengage from the activity.
- *Monotonous problems*. Students may feel bored and disengage from problem solving activities when they are asked to answer dull problems successively. For example, solving for $x$ in the following problems: (a) $x = 2x +3$, (b) $x = 5x + 2$, and (c) $x = 4x + 1$.
- *Monotonous hints*. Students may feel bored and disregard hints that are dull and repetitive. For example, constantly being asked to “Remember, a line has an angle of 180°.”
- *Long hints*. Students may not pay attention to hints that are long and difficult to understand.
- *Limited resources*. Attention and patience is limited so students may disengage from the activity when they get bored.

**Solution:** *Therefore, incorporate animations in hints to capture students’ attention and provide alternative ways to think about the problem or solution*. The movement of objects in animations can capture students’ attention and help break the monotony of text and static images. However, animations can easily increase cognitive load and present extraneous information that may overload students’ working memory. *Cueing* may help focus students’ attention on important elements of the animation at a specific point in time. Cueing can be implemented in many ways such as providing markers (i.e., arrows that point to relevant parts of the screen), spotlighting an important area (i.e., darken or lighten unimportant areas of the animation), or changing the font style (e.g., change the size, weight, or color of important text. Simply converting static text or images into an animation may not really be helpful to students. Introduce new perspectives on the problem or solution so students will find it worthwhile to understand the animated hint. Do not overuse animations otherwise it may lose its novelty, which affects how much it can capture students’ attention.

**Benefits:**

- Animations can help break the monotony of viewing visually similar problems or hint elements.
- Incorporating animations in hints may help reduce boredom by providing alternative ways to view a problem even though students might have answered similar problems previously.
- Incorporating animations in hints may capture students’ attention and motivate them to read and understand the hint, especially when they offer alternative perspectives.
- Animations can encapsulate ideas succinctly, which may grab students’ attention and require less time to process and understand concepts.

- Animations may help keep students interested in the learning activity and allow them to spend more time working on it.

**Liabilities:**

- It takes more time and effort to create animations compared to text and static images.
- Extraneous information in animations may distract students or increase their cognitive load.
- Animations need to be managed throughout a problem set so that students' attention is captured when necessary, but not too much to distract them from the learning activity.
- Several animations need to be developed because those that have already been seen may no longer capture students' attention.
- Poorly designed animations may cause poorer learning gains compared to other presentation strategies (e.g., series of static images).

**Supporting Theories**

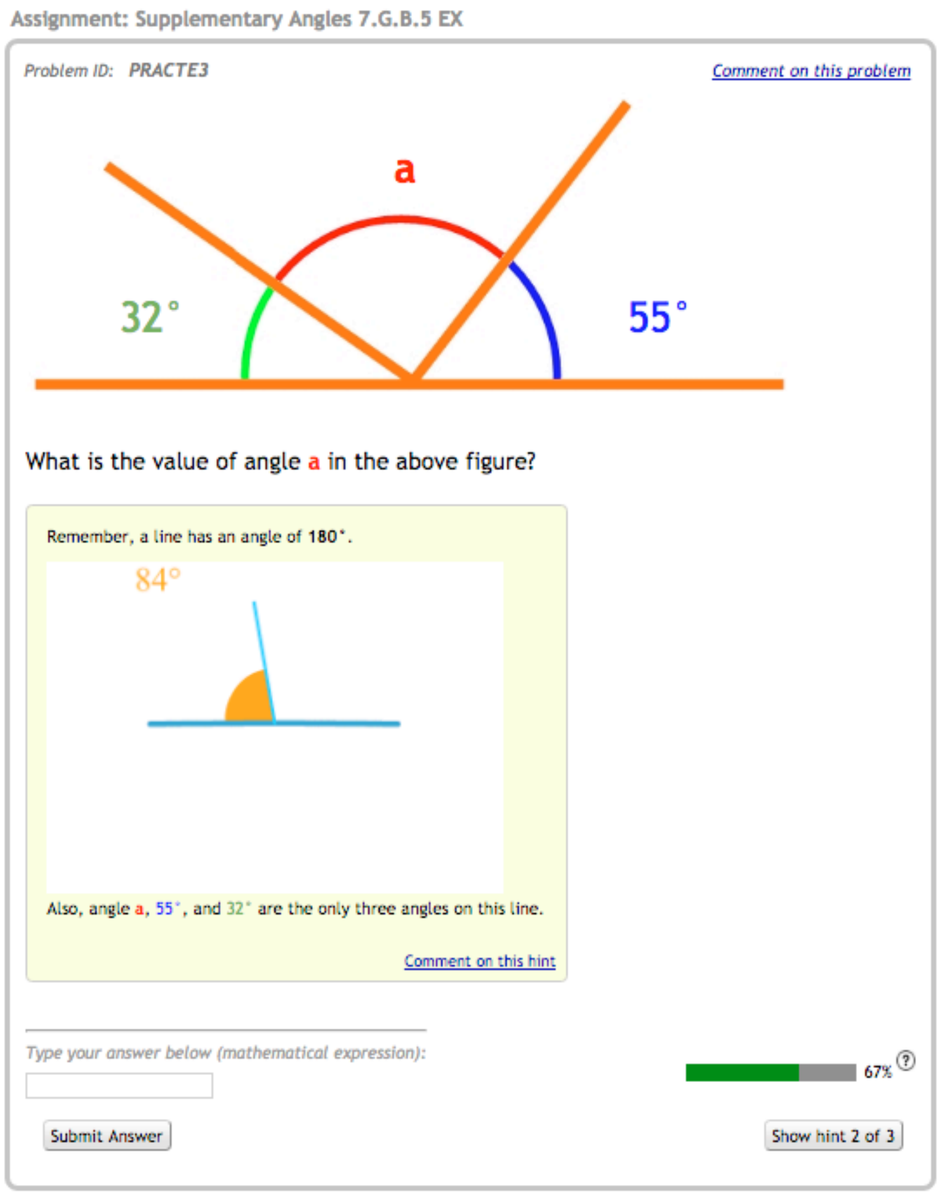
- Animations are useful to capture students' attention and arouse their interest [Rieber 1990].
- The novelty effect of animations may be short-lived so their utility must be maximized [Large 1997].
- Animations may convey the same information as a series of static images, but result in less learning gains when not designed properly [Clark & Mayer 2011, de Koning et al. 2010].
- Student attention and patience is a limited resource possibly affected by pending deadlines, upcoming tests, achievement in previous learning experiences, motivation, personal interest, quality of instruction, and others [Arnold et al. 2005, Bloom 1974].
- Students who are unable to solve a problem may eventually feel bored and disengage from the activity [D'Mello & Graesser 2012].

**Known implementations:** Animations have been used to capture students' attention and convey information successfully in different contexts. For example, animations with appropriate cueing mechanisms were used successfully to explain the human cardiovascular system [de Koning et al. 2010].

Research on animations reported their effectiveness for teaching hands-on procedures such as paper folding, tying knots, and completing puzzle rings [Clark & Mayer 2011].

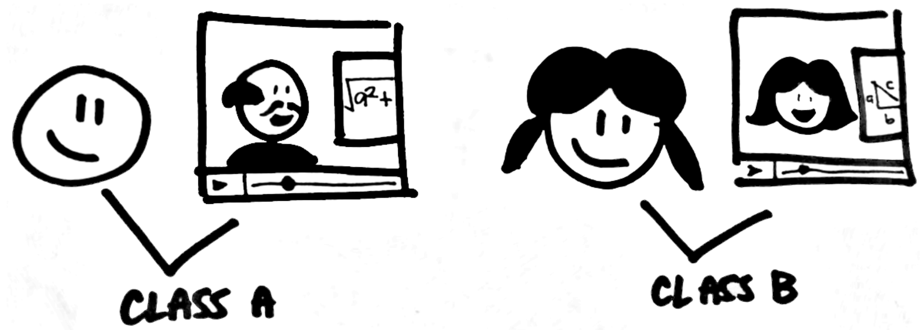
The ASSISTments online learning system supports the use of animations to create problems and their corresponding learning support. The system allows teachers to create or reuse problems, compile problems into problem sets, assign them to students, and even view a report of students' performance [Heffernan & Heffernan 2014]. These animations may help capture student attention and help students understand concepts more easily as they solve problems in ASSISTments.

The following figure shows a problem about supplementary angles and its corresponding hint in the ASSISTments online learning system. The hint contains an animation that shows the change in the angle value (changing from 0° to 180°; currently 84° in the image) in relation to the orientation of the line (light blue) and the size of the angle (orange half circle). The animation helps students visualize the problem more easily and at the same time provides a visually appealing representation that can capture their attention.




**Related Patterns:** The **Animation-Enhanced Hint** design pattern can be used to help keep students' attention when they are asked to practice skills they learned such as what is described in the **Try It Yourself** design pattern [Bergin et al. 2012]. It can be interleaved with other hints such as those created using the **Represent It** and **Image-Enhanced Hint** design patterns [Inventado & Scupelli 2016b] to break the monotony of similar problems and hints.

# Personal Video Hints




**Context:** Students are asked to answer math problems on an online learning system to help them understand a topic they recently learned.

**Problem:** The lack of personal connection in hints may cause some students to neglect it.

**Forces:**

- *Generic hints*. Students may ignore hints if they do not feel it addresses their current situation because it was built to address student concerns in general.
- *Misused hints*. Students who do not value hints may use it just to get the correct answer instead of learn from it (e.g., consecutive hint requests to reveal the answer).
- *Lack of personal connection*. Students may lack the feeling of guidance and support when they view generic hints.

**Solution:** *Therefore, provide students with personal videos as hints*. Teachers and content designers can identify appropriate hints for particular math problems and create videos that can be presented to students when they request help. Videos can also be created for hints that are already available in the system. Videos do not have to appear too professional. What is important is that students feel a human connection with the learning support provided and it is not just a mechanical system testing their knowledge. In this case, it may even be better for students to see videos from their own teachers. Make sure video hints are not too long so they do not bore the student and present only what is necessary to avoid revealing the solution process or answer too early. This gives students the chance to figure out answers on their own.

**Benefits:**

- Personal videos may encourage students to spend time understanding hints because it makes them feel that their concerns are addressed.
- Personal videos may be more meaningful to students so it may discourage them from misusing it.
- Students may feel more support from hints that are presented by an actual person; they may even value hints more if it comes from their own teacher.

**Liabilities:**

- Instructional videos may be more helpful to novice rather than expert students.
- It takes more time and effort to design, create, record, and upload video hints.
- Video hints may need to be created for specific content to have meaningful impact. However, more videos mean more time and effort to create them.
- Videos often take longer to load over the network compared to text, images, or animations.
- Videos may not always appear as intended due to uncontrollable factors (e.g., screen size, color and screen resolution supported, video streaming is not supported, audio is not supported).

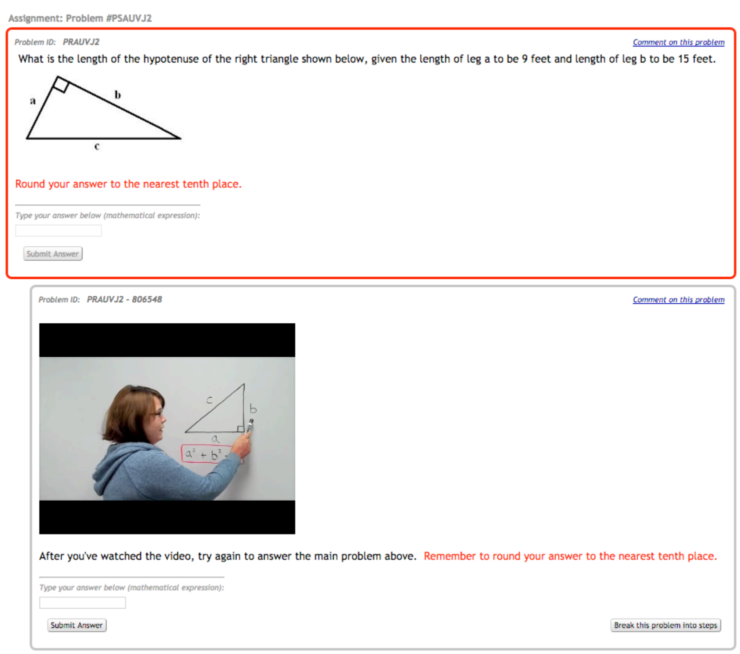
**Supporting Theories**

- Students spend more time watching and possibly internalizing video hints compared to textual hints [Ostrow & Heffernan, 2014].
- Students misuse learning systems due to several reasons such as having a fixed-mind set, dislike of the subject matter, lack of self-drive, frustration, and lack of trust in the system [Baker et al. 2008].
- Students are less likely to misuse video hints because students tend to watch videos instead of skip them. It also takes more effort to find the correct answer in the video [Ostrow and Heffernan 2014].
- Students find shorter videos more engaging – six minutes appears to be a good duration [Guo et al. 2014].
- Students may feel more engaged when videos are *personalized* or directed at them [Guo et al. 2014]. Talking-head videos, videos that show teachers' faces with the content, were also found to be more engaging because they evoked more personal and intimate feelings with students.

**Known implementations:** Isaac Physics is an online learning system that provides students with video hints when they request help in answering problems in the Physics domain. Initial research on the platform showed that video hints helped students learn better [Cummins et al 2016].

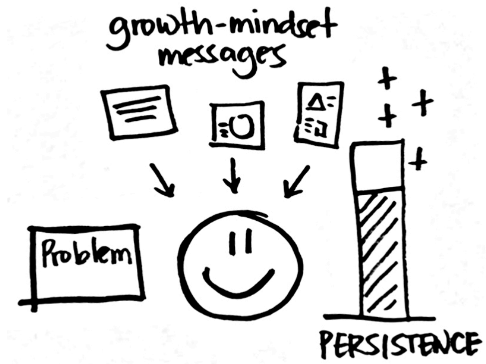
The ASSISTments online learning system allows teachers and content designers to create math problems and associated hints to support student learning. Teachers can create and upload videos that are presented as hints to help students learn better [Heffernan & Heffernan 2014]. Research indicates that video hints are more effective than textual hints [Ostrow & Heffernan 2014].

The following figure illustrates an example of using video hints in the ASSISTments online learning system. The top box shows the main problem, a problem on the Pythagorean theorem. The box below shows a video hint with the instructor explaining the first step of the Pythagorean theorem: "Substitute the values of the triangle's sides into variable *a* and *b* of the Pythagorean equation to solve for side *c*".




**Related Patterns:** The **Personal Video Hint** design pattern can be used to help facilitate students' understanding of the problem and may help maintain their motivation as described in the **Build and Maintain Confidence** design pattern [Bergin et al. 2012]. Use the **Keep It Simple** design pattern [Cunningham & Cunningham 2014] when designing video-hint content so that unnecessary details do not distract students or reveal learning objectives too quickly. The pattern may also be used to improve hints such as those created with the **Represent It** and **Image-Enhanced Problem** design patterns [Inventado & Scupelli 2016b], which may suffer from the lack of personal connection.

## Reinforce the Growth Mindset




**Context:** Students are asked to answer math problems on an online learning system to help them understand a topic they recently learned.

**Problem:** Students with a fixed mindset often give up when they struggle to solve a problem.

**Forces:**
- *Lack of persistence*. Students may give up when they are unable to solve problems after a few attempts.
- *Learned helplessness*. Students who repeatedly fail to solve similar types of problems may believe that they will be unable to solve the same or similar problem in the future.
- *Fixed mindset*. Students who believe that their intelligence is innate and will not improve regardless of what they do are less likely to persist.

**Solution:** *Therefore, provide students with motivational messages that promote the growth mindset when they fail to answer a problem*. Students with a growth mindset believe that they can acquire skills as long as they invest time and effort to learn it, while fixed-mindset students do not. Motivational messages that promote the growth mindset may help change the way fixed-mindset students think about their intelligence and encourage them to persist. Some examples of motivational messages may be: "Did you know that when we learn something new our brain actually changes? It forms new connections inside that help us solve problems in the future. Pretty amazing, huh?", "I think that more important than getting the problem right is putting in the effort and keeping in mind the fact that we can all be good at math if we try.", and "When we realize we don't know why that was not the right answer, it helps us understand better what we need to practice." [Ostrow et al. 2014]. Motivational messages may be shown with explanatory feedback when students struggle to solve a problem so they remember why it is important to persist. Motivational messages may be presented in different ways such as textual messages, audio messages, videos, or animated pedagogical agents. Avoid overusing motivational messages so students do not get bored or annoyed by it. For example, show messages only when the student submits an incorrect answer on the second attempt and only in every other Math problem.

**Benefits:**
- Motivational messages can encourage students to devote more time and effort that can help them solve the problem.
- Students' self-efficacy and confidence may improve when they receive motivational feedback, decide to persist in solving difficult problems, and eventually answer problems correctly
- Motivational messages can help students change the way they think about their own intelligence especially after they experience the benefits of persistence.

**Liabilities:**
- Some students may get annoyed after getting too many motivational messages especially if they sound repetitive.

- Persistent or motivated students may get distracted from unnecessary motivational messages.
- Motivational messages may not be very effective if students have not developed a certain level of "rapport" with the system.

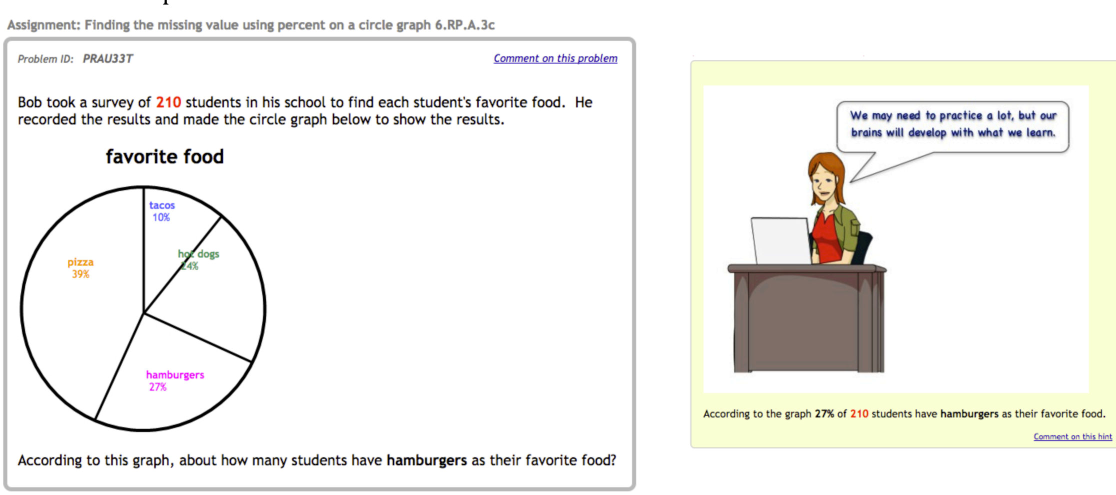
**Supporting Theories**

- According to Dweck [2006], students often approach learning tasks with a *fixed* or *growth* mindset. On one hand, students with a fixed mindset believe that their intelligence is innate and additional effort or practice will not improve it. Students with a growth mindset on the other hand believe that devoting time and effort to learn can help them improve or acquire new skills.
- Students who struggle with learning activities are more likely to benefit from motivational messages [Ostrow et al. 2014].
- Students' mindset may be altered using different strategies such as praising processes that lead to success, sharing articles and studies about the growth mindset, or contextualizing the growth mindset in the current learning situation [Cimpian et al. 2007, Dweck 2007, Yeager & Dweck 2012].

**Known implementations:** Several research used growth-mindset interventions to help various student populations such as high school students, community college students, charter school students, and students from large institutions [Yeager et al. 2013]. In one study, students read an article about the brain's ability to restructure itself with continued effort and applying better strategies to promote the growth mindset. The activity was reinforced by asking students to summarize the article and to give advise to a hypothetical student who thought he was not smart enough. The impact of the results might have varied, but generally students benefitted from the intervention.

More recently, motivational messages were used to support students learning math in the ASSISTments online learning system. Experimental results suggested performance improvements in students struggling with math problems who received motivational messages [Ostrow et al. 2014].

The following figure illustrates an example of a motivational message shown by the ASSISTments online learning system. A pedagogical agent conveys the motivational message when students request hints to help them solve a problem. Specifically, the agent says, "We may need to practice a lot, but our brains will develop with what we learn."




Problem Hint

**Related Patterns:** The **Reinforce the Growth Mindset** design pattern can be used when students are asked to practice skills they learned such as what is described in the **Try It Yourself** design pattern [Bergin et al. 2012]. It can be used with the **Build and Maintain Confidence** design pattern [Bergin et al. 2012] to encourage students to persist despite experiencing learning difficulties. The pattern can also be used to provide positive reinforcing comments in the **Feedback Sandwich** design pattern [Bergin et al. 2012] not only to encourage students, but also to emphasize that persistence helps them learn better.

## 5. SUMMARY AND NEXT STEPS

The paper presented three patterns for designing learning support for math problem solving activities in online learning systems: **Animation-Enhanced Hints**, **Personal Video Hints**, and **Reinforce the Growth Mindset**. Online learning system stakeholders can use these patterns to help ensure the quality of learning support provided to students, which may be more likely to help improve their performance.

The patterns presented in this paper are part of a Pattern Language for Math Problems and Learning Support that is currently under development. Design patterns from the pattern language as well as related design patterns have been uploaded to an online design pattern repository (http://www.learningenvironmentslab.org/openpatternrepository) to make them publicly available and foster collaborative pattern mining, pattern writing, pattern evaluation, and pattern refinement as described in [Inventado and Scupelli 2015a].

## 6. ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under DRL-1252297. We would like to thank Ryan Baker, Stefan Slater, and Jaclyn Ocumpaugh from Teachers College Columbia University, and Neil Heffernan, Eric VanInwegen, and Korinn Ostrow from Worcester Polytechnic Institute for helping us analyze the data and gain insights for developing the methodology. We thank members of the Learning Environments Lab namely Alexandra Merski for her help exploring the existing math problems, design of revised math problems, and help setting up the randomized control trials, Rachael Chang for her help with the randomized control trials and visualization of the 3D2P process, and Sharris Francisco-Inventado for her help with the visualization of the Pattern Language for Math problems and Learning Support in Online Learning Systems. Finally, we would like to thank our shepherd Prof. Takashi Iba and members of the Vanguard writer's workshop group—Jason Yip, Christian Köppe, Clifton Kussmaul, Alberto Francisco Kummer Neto, Arisa Kamada, and Rina Kato—for their support and feedback to help us improve the paper.

## REFERENCES

Allen, E., and Seaman, J. 2015. Grade Level: Tracking Online Education in the United States. Babson Survey Research Group and Quahog Research Group, LLC.

Arnold, A., Scheines, R., Beck, J. E., and Jerome, B. 2005. Time and attention: Students, sessions, and tasks. In Proceedings of the AAAI 2005 Workshop Educational Data Mining (pp. 62-66).

Baker, R., Walonoski, J., Heffernan, N., Roll, I., Corbett, A., and Koedinger, K. 2008. Why students engage in "gaming the system" behavior in interactive learning environments. Journal of Interactive Learning Research, 19(2), 185.

Bergin, J., Eckstein, J., Völter, M., Sipos, M., Wallingford, E., Marquardt, K., Chandler, J., Sharp, H., and Manns, M.L. 2012. Pedagogical patterns: advice for educators. Joseph Bergin Software Tools.

Bloom, B. S. 1974. Time and learning. American psychologist, 29(9), 682.

Carlsson, D. 2004. A categorization of HCI patterns. Department of Computing Science, Umea University, Sweden.

Cimpian, A., Arce, H. M. C., Markman, E. M., and Dweck, C. S. 2007. Subtle linguistic cues affect children's motivation. Psychological Science, 18(4), 314-316.

Clark, R. C., and Mayer, R. E. 2011. E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. John Wiley & Sons.

Cummins, S., Stead, A., Jardine-Wright, L., Davies, I., Beresford, A. R., and Rice, A. 2016. Investigating the Use of Hints in Online Problem Solving. In *Proceedings of the Third (2016) ACM Conference on Learning@ Scale* (pp. 105-108). ACM.

Cunningham and Cunningham Inc. 2014. Keep it Simple. Retrieved from http://c2.com/cgi/wiki?KeepItSimple.

D'Mello, S. and Graesser, A. 2012. Dynamics of affective states during complex learning. Learning and Instruction, 22(2), 145-157.

Dearden, A. and Finlay, J. 2006. Pattern languages in HCI: a critical review. Human Computer Interaction, 21(1), 49-102.

de Koning, B. B., Tabbers, H. K., Rikers, R. M., and Paas, F. 2010. Attention guidance in learning from a complex animation: Seeing is understanding?.*Learning and instruction*, *20*(2), 111-122.

Dweck, C.S. 2006. Mindset: The new psychology of success. Random House

Dweck, C. S. 2007. The perils and promises of praise. Kaleidoscope, Contemporary and Classic Readings in Education, 12.

Guo, P. J., Kim, J., and Rubin, R. 2014. How video production affects student engagement: An empirical study of mooc videos. In *Proceedings of the first ACM conference on Learning@ scale conference* (pp. 41-50). ACM.

Harashima, Y., Kubota, T., and Iba, T. 2014. Creative education patterns: designing for learning by creating. In Proceedings of the 19th European Conference on Pattern Languages of Programs (p. 7). ACM.

Heffernan, N. T., and Heffernan, C. L. 2014. The ASSISTments Ecosystem: Building a platform that brings scientists and teachers together for minimally invasive research on human learning and teaching. International Journal of Artificial Intelligence in Education, 24(4), 470-497.

Iba, T., Ichikawa, C., Sakamoto, M., and Yamazaki, T. 2011. Pedagogical patterns for creative learning. In Proceedings of the 18th Conference on Pattern Languages of Programs (p. 28). ACM.
Inventado, P.S. and Scupelli, P. 2015a. Towards an open, collaborative repository for online learning system design patterns. eLearning Papers, 42(Design Patterns for Open Online Teaching):14-27.
Inventado, P.S. and Scupelli, P. 2015b. Data-driven design pattern production: a case study on the ASSISTments online learning system. In Proceedings of the 20th European Conference on Pattern Languages of Programs (EuroPLoP '15). ACM, New York, NY, USA, Article 14, 13 pages.
Inventado, P.S. and Scupelli, P. 2015c. A Data-driven Methodology for Producing Online Learning System Design Patterns. In Proceedings of the 22nd Conference on Pattern Languages of Programs (PLoP '15). ACM, New York, NY, USA.
Inventado, P.S. and Scupelli, P. 2016a. Design Patterns for Math Problems and Learning Support in Online Learning Systems. In Proceedings of VikingPLoP 2016.
Inventado, P.S. and Scupelli, P. 2016b. Design Patterns for Helping Students to Learn to Visualize Math Problems in Online Learning Systems. In Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP '16). Koedinger, K. R., Kim, J., Jia, J. Z., McLaughlin, E. A., and Bier, N. L. 2015. Learning is Not a Spectator Sport: Doing is Better than Watching for Learning from a MOOC. In Proceedings of the Second (2015) ACM Conference on Learning@ Scale (pp. 111-120). ACM.
Köppe, C., Niels, R., Holwerda, R., Tijsma, L., van Diepen, N., van Turnhout, K., and Bakker, R. 2015. Flipped Classroom Patterns - Designing Valuable In-Class Meetings. Proceedings of the 20th European Conference on Pattern Languages of Programs, EuroPLoP'15. Irsee, Germany.
Large, A. 1997. Computer animation in an instructional environment. Library & Information Science Research, 18(1), 3-23.
Mor, Y., and Warburton, S. 2015. Practical Patterns for Active and Collaborative MOOCs: Checkpoints, FishBowl and See Do Share. eLearning, 48:48-56.
Ostrow, K. S., and Heffernan, N. T. 2014. Testing the multimedia principle in the real world: a comparison of video vs. Text feedback in authentic middle school math assignments. In *Proceedings of the 7th Int Conf on EDM* (pp. 296-299).
Ostrow, K. S., Schultz, S. E. and Arroyo, I. 2014. Promoting growth mindset within intelligent tutoring systems. In Sergio Gutiérrez Santos, Olga C. Santos (Eds.): Proceedings of the Workshops on The Non-Cognitive Factors and Personalization for Adaptive Learning (NCFPAL) held at Educational Data Mining 2014, London, United Kingdom, July 4-7, 2014.
Rieber, L. P. 1990. Animation in computer-based instruction. Educational technology research and development, 38(1), 77-86.
Shibuya, T., Seshimo, S., Harashima, Y., Kubota, T., and Iba, T. 2013. Educational patterns for generative participants: designing for creative learning. In Proceedings of the 20th Conference on Pattern Languages of Programs (p. 24). The Hillside Group.
Warburton, S., and Mor, Y. 2015. A set of patterns for the structured design of MOOCs. Open Learning: The Journal of Open, Distance and e-Learning, 1-15.
Yeager, D.S., and Dweck, C.S. 2012. Mindsets That Promote Resilience: When Students Believe That Personal Characteristics Can Be Developed, Educational Psychologist, 47:4, 302-314
Yeager, D. S., Paunesku, D., Walton, G.M., and Dweck, C.S. 2013. How can we instill productive mindsets at scale? A review of the evidence and an initial R&D agenda. In white paper prepared for the White House meeting on "Excellence in Education: The Importance of Academic Mindsets," available at http://homepage.psy.utexas.edu/HomePage/Group/YeagerLAB/ADRG/Pdfs/Yeager et al R&D agenda-6-10-13. pdf.