Depict: A Tool to Represent Classroom Scenarios[1]

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Depict is a web-based software tool for representing classroom interaction. Depict 1 is currently available in Beta version integrated in the LessonSketch environment (www.lessonsketch.org). This document discusses the theoretical and practical aspects of the design of Depict and is to be complemented with a technical description. The need for Depict is predicated on two fundamental ideas drawn from research on teaching and teacher education: (1) That professional knowledge of teachers is encoded and embodied in narratives of practice and (2) That the development of capacity to teach requires knowledge of practice as well as the practice of that knowledge (cf. Carter, 1993; Lampert, 2010).

Depict emerged as an idea and development project from project ThEMaT, which gave to it the in-house name, ThEMaT's Composer, with which Depict was referred in earlier presentations and draft versions of this document.[4] Project ThEMaT created cartoon based, animated scenarios of classroom interaction in mathematics and used those to confront teachers with problems of practice.[5] The internal work of the project, collectively developing the scripts for those stories, already suggested the need of a storyboarding tool that could facilitate the writer's use of the several modes of communication present in classroom interaction (not only voice but also written inscriptions, printed text, gestures, facial expression, body position and location, and body movement). But the data collected by the ThEMaT project, which showed how practitioners responded to animated scenarios by narrating alternative scenarios provided an even stronger suggestion: A composing tool could assist practitioners in representing those alternative scenarios. While simpler activities such as writing a dialogue could be used to precipitate and collect practitioners' stories, we hypothesized that a graphics-based lesson-depicting tool could provide some added value. To be specific, we made the following two hypotheses:

(1) Teachers' thinking about the tactical demands of classroom interaction could be stimulated with the assistance of a tool for modeling lessons as moment-to-moment conversations, and
(2) Teachers' thinking about the multivocality (intellectual diversity) and multimodality of classroom communication could be stimulated with the assistance of a tool that represented the many participants of classroom work using cartoon characters where humans were modeled in such a way as to enable them to communicate through some facial expressions and gestures as well as to represent some degree of individual difference.

The present document has three components. The first component describes briefly the character development project that we have done. The second component describes the software development that we have done and anticipates how this will enable ongoing work. The third

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[1] Revised and updated version of internal document titled "ThEMaT's Composer: Background, current state, and foreseeable goals" and dated November 2009.

[2] Contact: pgherbst@umich.edu

[3] Feedback from Chialing Chen is acknowledged.

[4] ThEMaT: Thought Experiments in Mathematics Teaching. Funded by the National Science Foundation, ESI-0353285, PI Patricio Herbst, co-PI Daniel Chazan.

[5] See those animated scenarios among the collection of lessons in LessonSketch, www.lessonsketch.org.

part gives details of a proposal of work that we made to agencies to continue this work. While the proposal was not funded it indicates the direction envisioned for this project.

I. Cast and Character development: ThExpians

Under the support of ThEMaT we have created five casts of characters and used them in representing scenarios of teaching.[6] These are all named "ThExpians" to allude to the notion that they are thespians (actors) playing in a thought experiment. Across each cast of characters one can observe different degrees to which the cartoon characters model the humans they represent. Within each cast of characters there are different degrees of individual differentiation. Thus the simplest (and more frequently used) cast is called ThExpians B and represents teacher and students as blue figures who only differ among themselves by the color of their vest. This character set has been used to create geometry classroom animations, slideshows, and comic books. The second cast is called ThExpians M[7] and it represents teacher and students as multicolored figures who differ among themselves by their skin color. This set has been used to create animations of algebra classroom interactions and comic book variations of those. Both ThExpians B and M have a limited number of facial expressions they can make by combining eyes, eyebrows, and mouth. They also can make some gestures by using their hands, though their arms and fingers are underdeveloped: ThExpians B have no arms, just hands with no fingers; ThExpians M have arms that don't flex at the joints and hands with fingers, but while the hands move, the fingers don't move independently. A third cast of characters is called ThExpians P and it represents teacher and students as humanlike plane figures endowed with fully articulated arms and fingers; they can also differ from each other by hairstyle, skin color, and shirt design. These characters were used in at least one comic book representation and an animation. They were also used by Charalambos Charalambous to create classroom scenarios that he used in his dissertation study, interviewing preservice elementary teachers (Charalambous, 2008). A fourth character set, ThExpians C, is built on same graphics (hence has the same human attributes) as ThExpians B but provides more resources for individual differentiation: Characters have four different skin colors and they can sport vests that indicate different trades as well as colors. This character set has been used thus far to produce three animations contracted by Vilma Mesa's "Teaching Mathematics in Community College" project but the characters themselves are a creation made by project ThEMaT. Finally, the character set ThExpians N has more resources for human movement, including hands with fingers that can move and arms and legs that flex. These characters also can have different skin colors and clothing. ThExpians N have been used thus far to produce two animations titled "A Number Rule" that were produced for NCTM. Figures 1-5 show shots of each of these character sets.[8]

[6] Some of the scenarios represented were commissioned by other projects, though the characters derived from the work of ThEMaT.

[7] ThExpians M were developed by Dan Chazan and Ronit Eisenbach at the University of Maryland.

[8] The project employed graphic artists Jack Zaloga, Travis Skindzier, Mindy Steffen, and Anthony Williamson to assist in developing the graphics.

FIGURE 1. THEXPIANS B

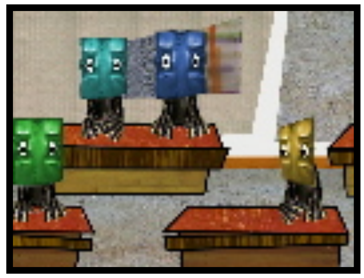

FIGURE 2. THEXPIANS M

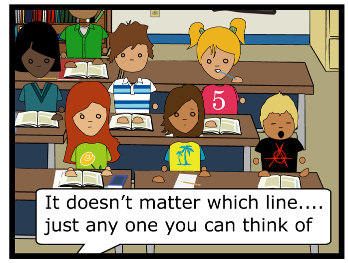

FIGURE 3. THEXPIANS P

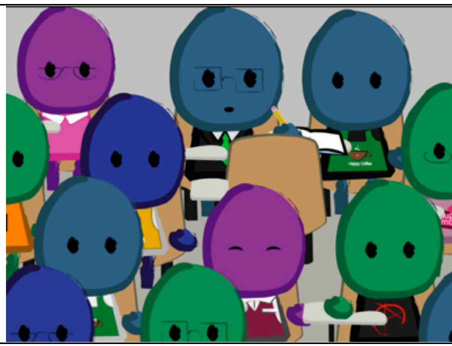

Figure 4. ThExpians C

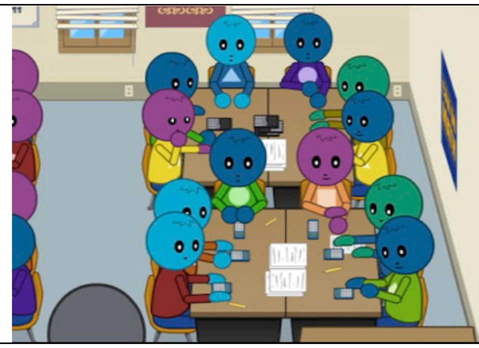

Figure 5. ThExpians N

We have done some research to compare the response of practicing and preservice teachers to the different characters. Preliminary analysis of responses to interviews based on stories narrated using ThExpians P has shown that, for inservice and preservice teachers alike, attention to mathematical features of stories correlates positively with awareness of possible alternatives in stories, while those two variables correlate negatively with participants' attention to human features of the characters. That is to say, participants who tend to observe the human like characteristics of cartoon characters tend to pay less attention to mathematical issues or to other possible development in stories. This small result along with the logistical difficulty in representing a story using ThExpians P has encouraged us to pursue the present development of the Depict software for ThExpians B and other cast of characters like them.[9]

II. Development of the Depict tool[10]

Depict allows the manipulation of a cast of cartoon characters and associated graphics (backgrounds, furniture, etc.) to compose graphic frames that represent moments in classroom interaction. The software allows different views (front, rear, left, right) of a character as well as the layering of different graphics including supplies (e.g., textbook, compass), character traits (e.g., hands at different positions, facial expressions), furniture (e.g., desk, chairs), and background images (e.g., boardwork[11]). This first version of Depict produces slideshows that

[9] This research has been done in collaboration with Chialing Chen, Wendy Aaron, and Anna Jacobson.

[10] The development of the Composer software has been done in collaboration with Vu Minh Chieu.

[11] To compose the boardwork, Depict allows users to either attach a file (png format) to a layer (e.g., the blackboard or wall) or to create a graphic using another web based tool, Inscribe. Inscribe permits users to draw shapes and write text.

could be either watched on a computer or exported and arranged in a comic book. The slideshows are entirely drawn by the user, by choosing stock scenes and modifying them or by building them from scratch by dragging and dropping the primitives noted above (e.g., teacher, students, supplies, furniture, etc.). We are interested in eventually improving the tool so that it can create a flip book animation based on the key frames designed by a user using actions like the ones noted above. Ultimately such flip book composer would allow the coordination of audio notes with key frames so as to create the impression of an animated scenario with voice over. For the time being Depict allows users to compose slide shows and have characters speak through speech bubbles and text comments instead of voice over. At the end of the ThEMaT grant we have a functional Depict tool that uses a graphics library based on the ThExpians B cast and that allows the drag and drop and layering of graphics, the input of formulas and diagrams on the board or papers, the attribution of speech using speech bubbles, and the edition of hand movements and facial expressions. This version also has basic navigation features and slide functions (e.g., zoom in, zoom out; cut, copy, paste object; duplicate slide, sequence slides; etc.). This version of Depict is integrated in LessonSketch in such a way that users can depict scenarios and use those depictions in their contributions to other LessonSketch activities. So users are able to participate in a LessonSketch forum (based on a LessonSketch lesson) not just by commenting via text, but also by attaching a slideshow of cartoon frames that depicts an alternative or possible continuation of the lesson. Similarly, users who participate in a LessonSketch experience may answer questions such as “what would you do next” by showing what they would do next through a depiction.

The concept behind the creation of Depict is that such a tool can help create a milieu for teacher learning (Brousseau, 1997): By having a depiction of a teaching scenario that a teacher learner can contribute to (altering, creating) as well as view and annotate, a feedback loop can be established where the play of a depiction at state 1 can afford opportunities for a teacher learner to anticipate instructional actions that they can depict turning the depiction to a state 2, and the viewing of the depiction at state 2 can provoke in the teacher learner associations with real scenarios where they have seen other things going with what is depicted. Thus a depiction can be the counterpart of the learner (that is, the depiction can be the milieu) in a situation for learning to teach. One must note here that if a depiction may act as a milieu for learning, it does so by eliciting and coopting the user’s sense of what a lesson usually has. To the extent that all teacher candidates have been students before, that elicitation is possible. But to the extent that most teacher candidates experiences as students may have involved them in apprenticing by observing unremarkable instruction (Lortie, 1975), the feedback that they may get from the milieu may not yet promote the learning of good teaching, but just the learning of teaching. So conceived, therefore, this milieu is not yet necessarily oriented to teach specific instructional moves or a specific kind of teaching. Those possibilities could be afforded through further specification of learning environments built on Depict, for example through the design of specific stories and their embedding in specific teacher learning activities as well as through pairing the Depict tool with other resources such as the ones we describe below. As described so far, however, we contend Depict does allow the learning of key elements of any kind of teaching: We contend however that seeing the moment by moment development of a story of instruction and seeing that such story involves a class of many students, can afford opportunities to learn about (1) the tactical nature of teaching, where the actions of teachers respond to the context in which they occur, for example in response to students’ actions; (2) the intellectual diversity that exists in a classroom, where different students can respond differently to teaching actions and (3) the multimodal nature of classroom interaction where participants use language, gestures, and facial expressions to transact classroom meanings.

To explore the viability of those contentions, a simplified, alpha version of Depict was developed and implemented using ThExpians P. This version of Depict was used in the dissertation research of Chialing Chen[12] to investigate the added value that the tool could bring to the process of anticipating a lesson (by a preservice teacher). In this version of Depict, users are able to create lesson slides by selecting classroom scenes from a provided library, creating board contents, and creating teacher-student dialogues. Although in this version individual students could not be moved from their seats, the user could add facial expressions and hand gestures to make them communicate in nonverbal modalities. Chen's analysis suggests that students who can anticipate a lesson using Depict achieve awareness and develop lesson details that differ qualitatively from those of students who only get to talk about what they anticipate their lesson to be.

We have used a participatory design approach for the development of later versions of Depict. Participatory design has been widely used in the research of user interaction of innovative software systems (Fuks, Pimentel, & Pereira de Lucena, 2006; Kensing & Blomberg, 1998). In participatory design, end users are involved as feedback participants in the design and development process of different versions of a product. Indeed, we have invited teachers, researchers, and teacher educators to use and give feedback on different versions of Depict so that we can improve its features and implement new features for the new versions.

The first version of Depict

As noted above, the main goal of the development of the first version of Depict has been to provide teacher users with a tool to create classroom stories in the form of slideshows, such as the use of the tool to anticipate classroom interaction in Chen's study described earlier. So, we created a simple version of a slideshow creation tool (like MS PowerPoint) in which we provided graphic templates, based on ThExpians P, to facilitate users' composition of slides that depict events of classroom interaction. Figure 6 shows a screen shot from this simple version.

This version provides the user with basic features for handling the sequence of the slides (see the moving menus at the bottom left of Figure 6), for creating and removing slides, for handling objects (e.g., arms, facial expressions, speech bubbles) in slides, for saving and editing stories (see the menus at the top left and top middle of Figure 6).

The user can insert one of ten templates (Figure 7) into each slide; there are front and back views, sometimes with a male or female teacher, sometimes with a zoom of the whiteboard. The user then can add arms and facial expressions (Figure 8) to each character of the current slide; they can also insert dialogue (Figure 7) and commentary captions into the slide. The drawing tool or Inscribe (Figure 9) allows the user to create whiteboard contents and attach those to the slides. Note that "My Library" (see bottom right of Figure 6) was designed to help users store their own graphics, but had not been implemented in this version.

Overall, the first version was still really simple but it did help pre-service teachers anticipate classroom interaction better than talking through a lesson plan (see Chen's work mentioned previously). From the development and evaluation of this version, we learned several important lessons for the design of the second version: (1) the use of ThExpians B, as mentioned earlier, may be better than that of ThExpians P because teachers may focus more on instructional practice and classroom interaction, but not too much on human-like characteristics of cartoon characters; (2) the user interface needs to be redesigned to provide more functionalities (especially the feature of dragging and dropping objects from the library onto the canvas) and to improve the usability of the tool; (3) users need to have a "Resources" space so that they can better handle their stories and graphics; (4) the user interface of the Inscribe tool must be improved or simplified.

[12] Chen, C. (in preparation). Learning to teach from anticipating lessons through comics-based approximations of practice. Doctoral dissertation in progress under the direction of Patricio Herbst. To be defended in December 2011.

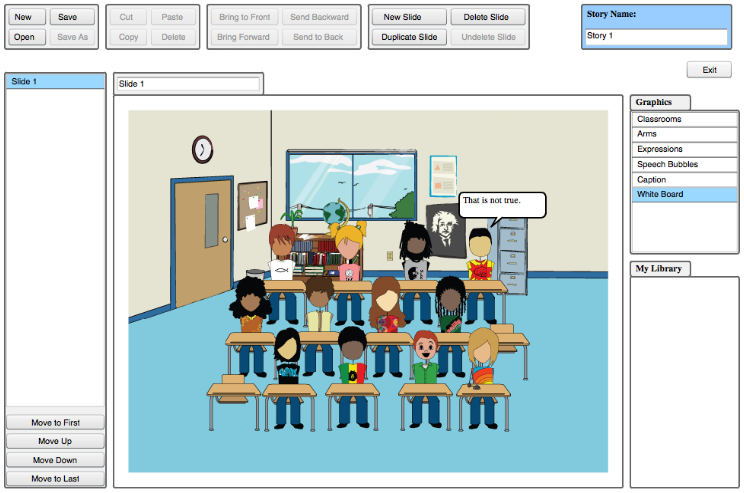

Figure 6. The first version of Depict

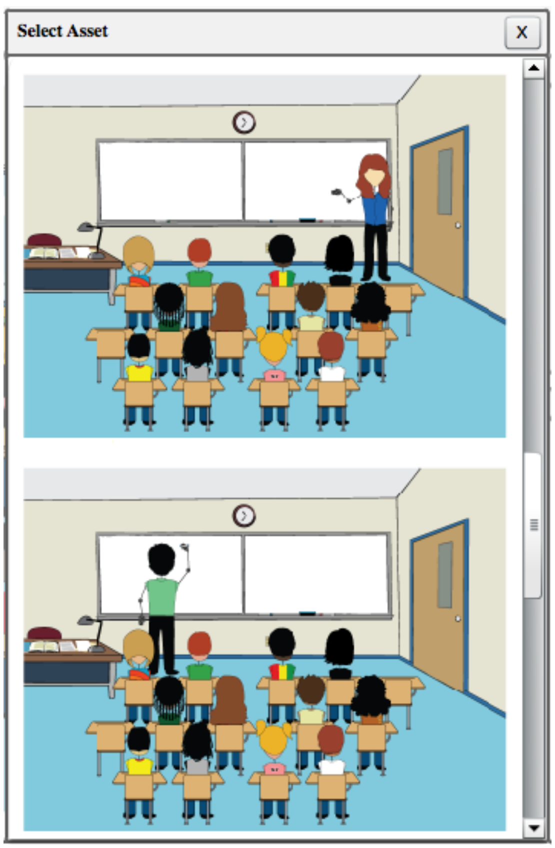

Figure 7. Classroom templates

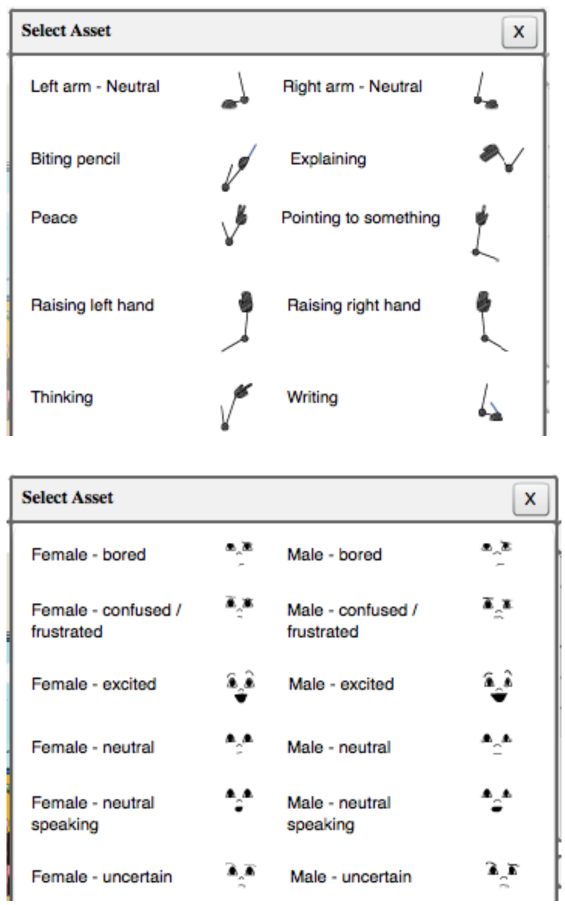

Figure 8. Arms and facial expresions

The second and current version of Depict

Our current funding[13] previews the incremental development of Depict to integrate a set of tools available for teacher educators to engage their students (preservice teachers) in composing teaching scenarios. Teacher educators will have access to a system of resources that includes Depict and that enable them to pose problems of teaching to preservice teachers. They will be able to use Depict to anticipate lessons as well as to respond to lessons created by others. Researchers can also use Depict to create depictions of instructional scenarios and attach them to questionnaires that they implement through LessonSketch.

The current version of Depict is a complete web-based application for composing classroom stories. It is integrated in a complex virtual setting (LessonSketch) in which all kinds of users (teachers, teacher educators, professional developers, researchers, etc.) can work collectively in different activities. Users can link the Depict tool with a "Resources" location, a web-based file manager where they store their work and documents, with Forums where they discuss their artifacts with other users, and with Experiences where they examine and discuss other kinds of representations of practice such as animations.

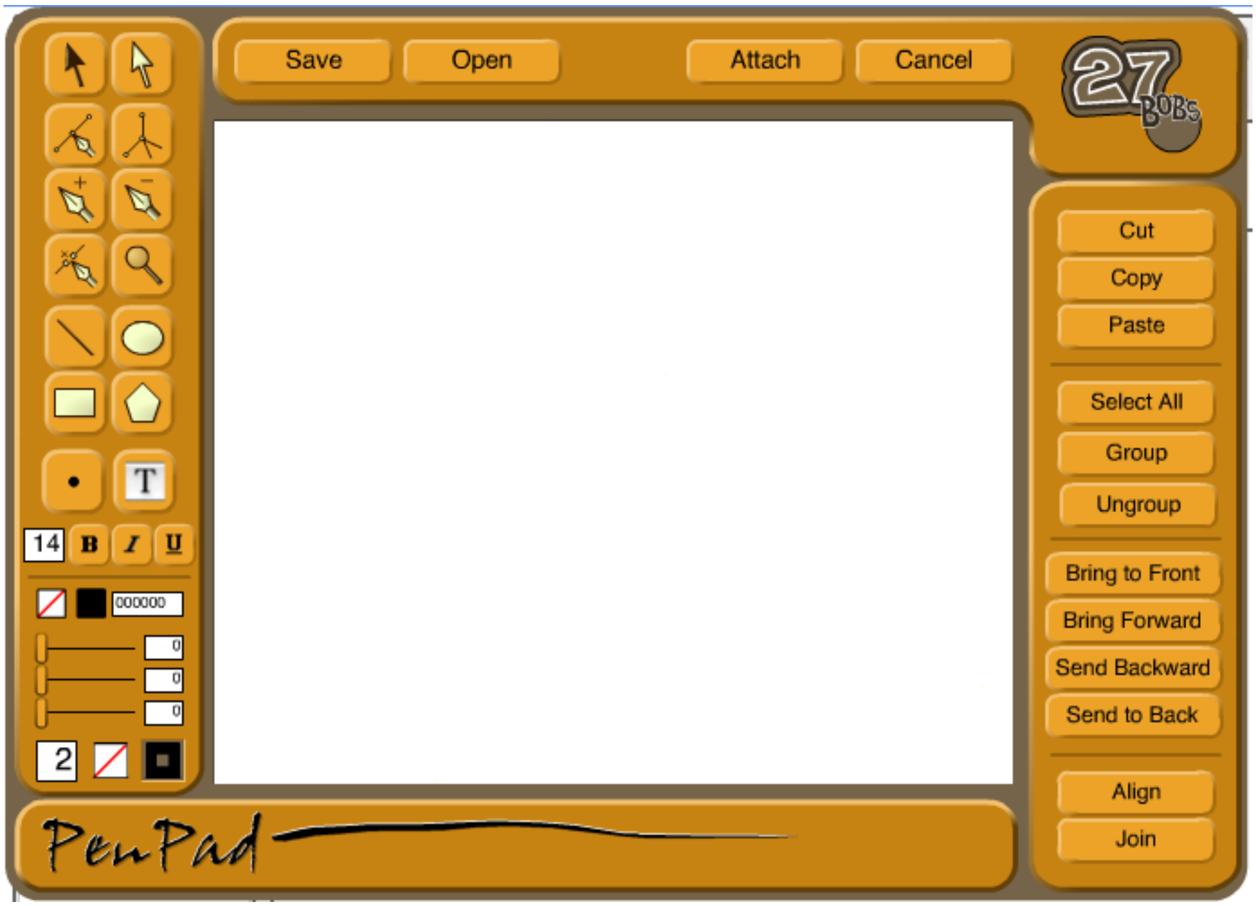

Figure 9. Screen shot of the Inscribe tool,
a drawing tool and boardwork editor associated with the first version of Depict

[13] This is through the project "Supports for learning to manage classroom discussions: Exploring the role of practical rationality and mathematical knowledge for teaching." Funded by the National Science Foundation, DRL-0918425. PI Patricio Herbst, coPI Daniel Chazan.

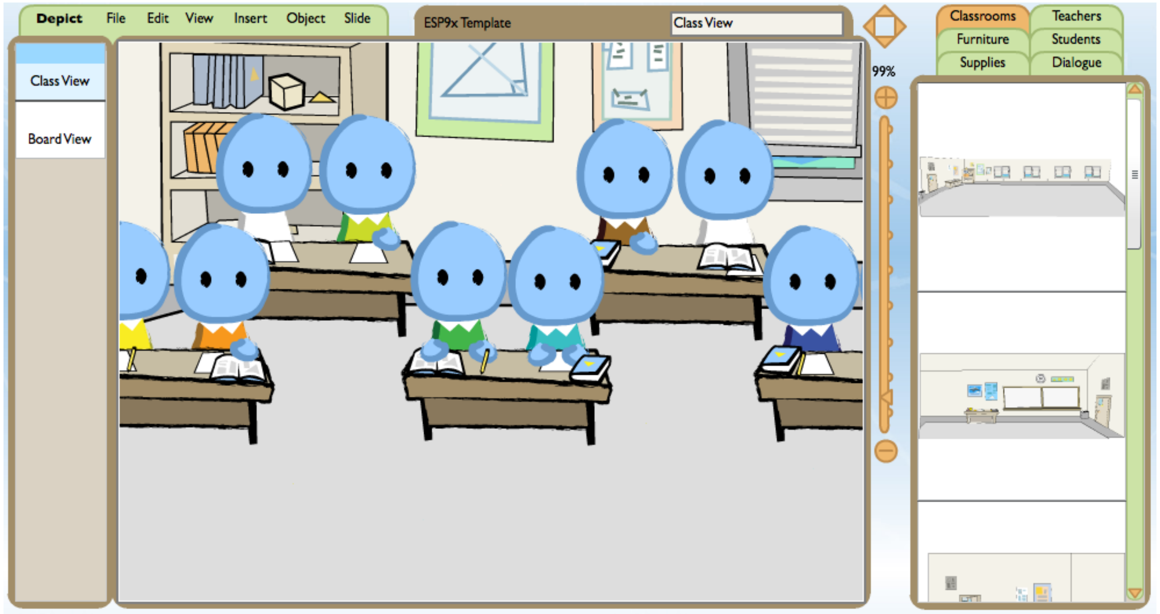

Figure 10. A screenshot of the second version of Depict.

Figure 10 shows a screen shot of the main user interface of the current version of Depict. The main functionalities of the new version can be summarized as follows:

- Graphics Library:
  - *Classroom backgrounds*: Five views are provided (class view, board view, door view, paper close-up view, and book close-up view). Users can use other backgrounds in the formats of PNG, JPG, and SWF from their computer or from Internet resources (they should be responsible for the copyright issues, see LessonSketch terms of use). Only one classroom background can be used for each slide, if a new background is inserted, the old one will be deleted.
  - *Classroom templates*: A number of slide templates created in advance by GRIP members can be used in lieu of classroom backgrounds—these already have a class of students sitting in rows. When users drag and drop a template (a PNG of the slide) from the classroom library to the canvas, users can piecemeal edit, add, and remove elements of the template. This is a big difference in comparison with the first version of Depict.
  - *Student characters*: Different student character views (front, back, left, right) are provided to compose student positions. Student characters may also be customized by changing the shirt color and style (about 30 different choices), adding eye and eyebrow expressions (12 choices, including ones that might be interpreted as confused, angry, etc.), adding mouth expressions (5 choices that include speaking, smiling, etc.), and adding left and/or right hands (5 choices for each hand: hand only, hand holding paper or book or pencil or compass). Same affordances are available for teacher character (except for the shirt colors, for which there are only three options).
  - *Furniture*: 7 graphics (horizontal desk, vertical desk, horizontal group desk, vertical group desk, front chair, back chair, and side chair).
  - *Supplies*: 7 graphics (front book, closed book, open book, horizontal compass, horizontal pencil, paper, and flat paper).

    - *Dialogue*: 4 choices (that can be interpreted as speaking, thinking, shouting, whispering). Dialogue boxes can be resizable and dialogue callout points can be movable.
    - Graphics format: Built-in library items consist of SWF (as vector image) files to maximize the effect of zoom in and zoom out. Imported graphics can be in the forms of PNG, JPG, and SWF.
- Object Selection:
    - When the user clicks on an object (a student character, a teacher character, a desk, etc.) the object will be marked as selected (a relatively dark blue rectangle that bounds the object appears). Multiple selections are not allowed for the time being.
    - When a new object is selected, the last selected object will be deselected (the bounded rectangle disappears).
- Object Movement:
    - Users can drag and drop object from Library onto Stage or within Stage (Stage is the canvas (640 x 480) in which the slide is composed.
- Slide Movement:
    - Users can drag and drop the background classroom or use a directional menu (see Figure 10) to move the current slide (left, right, up, and down).
- Slide Scaling:
    - Users can use a slider (below the directional menu in Figure 10) to zoom in/out the current slide. By default "Zoom" is 100%, users can zoom in up to about 900% and zoom out down to about 10%.
    - Objects don't scale independently, rather the ratio among objects in the same slide is constant. The slide zoom allows for close ups and wide angle shots.
- Slide Title:
    - Users can edit slide title of the current slide by using a text input.
- Slide Navigation:
    - Users can use a vertical slide navigation component to navigate slides. Title of slides appear in the navigation menu. When moving out of a slide, the thumbnail of that slide appears in the navigation menu (see the left hand side of Figure 10).
- Slide Selection:
    - Multiple slides can be selected simultaneously.
- Slide Layers:
    - Five layers are used to facilitate the management of graphics in a slide: (1) the bottom layer is the Background Layer in which only one classroom background image can be placed; (2) then followed by the Whiteboard/Wall Layer in which content of the whiteboard and wall images can be placed; (3) then followed by the Object Layer in which characters, desks, and so on are placed; (4) then followed by the Speech Layer in which dialogues are laid out; and finally the Caption Layer is on top for users to insert slide captions (the Caption Layer is always the same size regardless of slide moving or scaling). Graphics within a layer can be arranged so as to choose which graphics will be on top of which one. Additionally, users who have researcher accounts can add an "outer layer" so that the author and other users can insert comments to the classroom scene depicted in the slide as if spoken by an observer (see Figure 11).

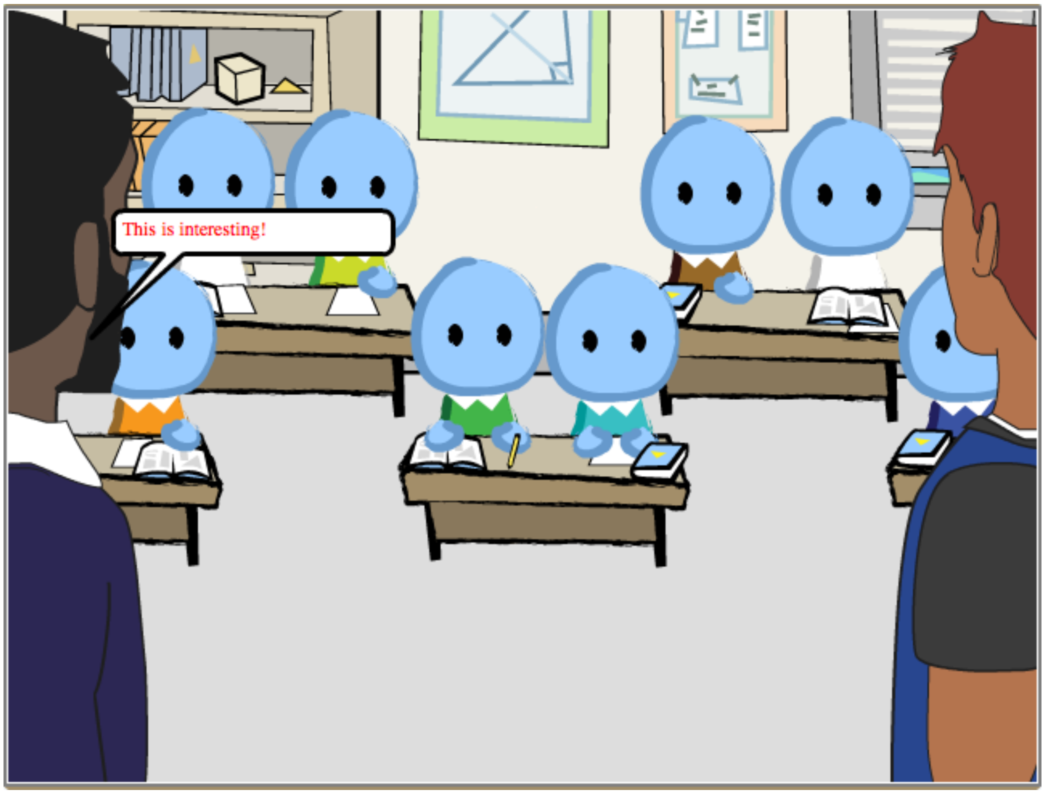

Figure 11. The outer layer of Depict

- Depict Menu:
  - *Close*: Close the tool. If the current slideshow/depiction is not empty, a save warning message pops-up so that the user can choose Save (the slideshow), Don't Save (the slideshow), or Cancel (come back to the tool).
  - *Preferences (only for researcher accounts)*: Users can turn on/off an outer layer so as to put observer comments on each of the slides.
- File Menu:
  - *New*: Create a new slideshow with a new name "untitled slideshow" by default. The first slide will be named "Slide 1" by default.
  - *Open*: Open a slideshow stored in Resources. When going to Resources to retrieve such slideshow only slideshow files (whose file extension is "depiction") are highlighted and can be selected.
  - *Save*: Save the slideshow in XML form to Resources, in a folder and with a file name chosen by the user (the file extension is "depiction"). Autosave is made every 5 minutes.
  - *Save As*: Similar to Save but save the slideshow with another filename and/or in another folder.
  - *Save and Publish*: Save the current slideshow and publish it in the form of a different kind of XML file. The file name of the published slideshow is the same as the file name of the slideshow (the users can change it if they want), the extension of the published slideshow is "published depiction," and the published slideshow is saved in the same folder of the slideshow file. Each slide in a published depiction is a PNG image (640 x 480), and the PNG images is stored in a secured place that the user can

not see. The XML published slideshow keeps information about the path to the PNG files. The slideshow player has a navigation component. The navigation component can be customizable. The full component includes a vertical list of slide thumbnails on the left hand side, a back button, a forward button, and a close button on the top right. When a slide is presented, the title is shown on the top left (see Figure 12). Published depictions allow faster viewing of slideshows than regular depictions because instead of creating each slide out of independent graphics objects it renders those slides into single graphics (PNGs). A published depiction is thus handier for viewing and annotating, while a regular depiction is needed for creating or editing a story.

- Edit Menu:
  - *Undo*: Undo the last action done within the current editing slide. The number of undo levels is 10. When moving to another slide, the undo function will be reset (the user could not undo actions done within the previous slide).
  - *Redo*: Similar to Undo but in the reverse direction. Undo and Redo features are really important in any authoring tool.
  - *Cut*: Cut the current selected object (if any) to the clipboard. The clipboard can be valuable only within a slideshow, but not through multiple slideshows.
  - *Copy*: Copy the current selected object (if any) to the clipboard.
  - *Paste*: Paste the object stored in the clipboard (if any) to Stage.
  - *Duplicate*: Duplicate the current selected object (if any) in Stage.
  - *Delete*: Remove the current selected object from Stage.
  - *Cut Slide*: Cut the data of the selected slides to slide clipboard.
  - *Copy Slide*: Copy the data of the selected slides to slide clipboard.
  - *Paste Slide*: Paste the slides in slide clipboard after the last selected slides.
  - *Delete Slide*: Delete the selected slides.
  - *Undo Delete Slide*: Undo "Delete slides," up to 10 levels.
- View Menu:
  - *Actual Size*: View the current slide in actual size (see Slide Scaling above).
  - *Zoom In*: See Slide Scaling above. Each menu click will zoom in the slide by about 110%.
  - *Zoom Out*: See Slide Scaling above. Each menu click will zoom out the slide by about 90%.
- Insert Menu:
  - *New Slide*: A new empty slide is added at the bottom of the slideshow.
  - *Duplicate Slide*: The selected slides are duplicated after the last selected slide.
  - *New Inscription to Whiteboard/Wall Layer*: Inscribe (a.k.a., the Drawing Tool) opens, and users create a new inscription and save/insert it to the whiteboard/wall layer.
  - *New Inscription to Object Layer*: Similar to the previous menu but inserting the inscription to the object layer.
  - *Inscription from Resources to Whiteboard/Wall Layer*: Insert an inscription file from Resources to whiteboard or wall. This is useful in case an inscription had been created previously and stored in Resources, as when the same board content is used across many slides.

    - *Inscription from Resources to Object Layer*: Similar to the previous menu but inserting the inscription to the object layer, which is useful, for example, in the case users want to represent students' work on the papers on their desks.
    - *Picture from Resources to Background Layer*: Insert an image from Resources (PNG, JPG, SWF, GIF, or a hyperlink to an image on the web) for the classroom background (the old one if any will be replaced).
        - These functionalities are important in order to create sophisticated inscriptions (e.g., mathematical graphs or symbols) that cannot be created using Inscribe. These inscriptions can be produced in client freeware software (e.g., GeoGebra, all sorts of graphs and diagrams) or web-based freeware (e.g., CodeCogs, all sorts of symbolic expressions), they can be saved to png format, uploaded to Resources in LessonSketch, then attached to a depiction.
    - *Picture from Resources to Whiteboard/Wall Layer*: Similar to the previous menu but insert an image to the whiteboard or wall layer.
    - *Picture from Resources to Object Layer*: Insert images to the object layer.
    - *Dialogue to Outer Layer*: Insert speech bubbles to the outer layer.
    - *Caption*: Insert a caption at the bottom center of a slide.
- Object Menu:
    - *Bring to Front*: Bring the selected object to the top their layer.
    - *Bring Forward*: Bring the selected object to a higher level in their layer.
    - *Send to Back*: Send the selected object to the bottom of their layer.
    - *Send Backward*: Send the selected object to a lower level in their layer.
    - *Manage*: Edit the selected object. If it is an inscription, it will be opened in the Inscribe tool so that users can edit it (when they save the inscription, the new one will be inserted to the slide to replace the old one and users are sent back to the slide composer). If it is a character, a popup menu will appear so that users can change facial expressions, hands, shirts, and views. If it is a dialogue, a popup menu will appear so that users can change the type of the dialogue (talking, thinking, shouting, whispering).
- Slide Menu:
    - *Move to First*: Move the current slide to be the first slide of the slideshow.
    - *Move Up*: Move the current slide one position up in the sequence of slides.
    - *Move Down*: Move the current slide one position down in the sequence of slides.
    - *Move to Last*: Move the current slide to be the last slide of the slideshow.
    - *Hide*: Hide the selected slides so that it will not appear in the published slideshow. A "HIDDEN" label will replace the actual title of the current slide in the navigation menu.
    - *Unhide*: Unhide the selected slides (restore it to the normal status).
- Contextual Menu:
    - When users right-click on an object, depending on the nature of the object, one or more or all of the following menus can be showed, for example, with a Student character: Cut Student, Copy Student, Duplicate Student, Paste Object (disabled), Delete Student, Bring to Front, Bring Forward, Send to Back, Send Backward, Manage Student (see above for the specification of those menus).

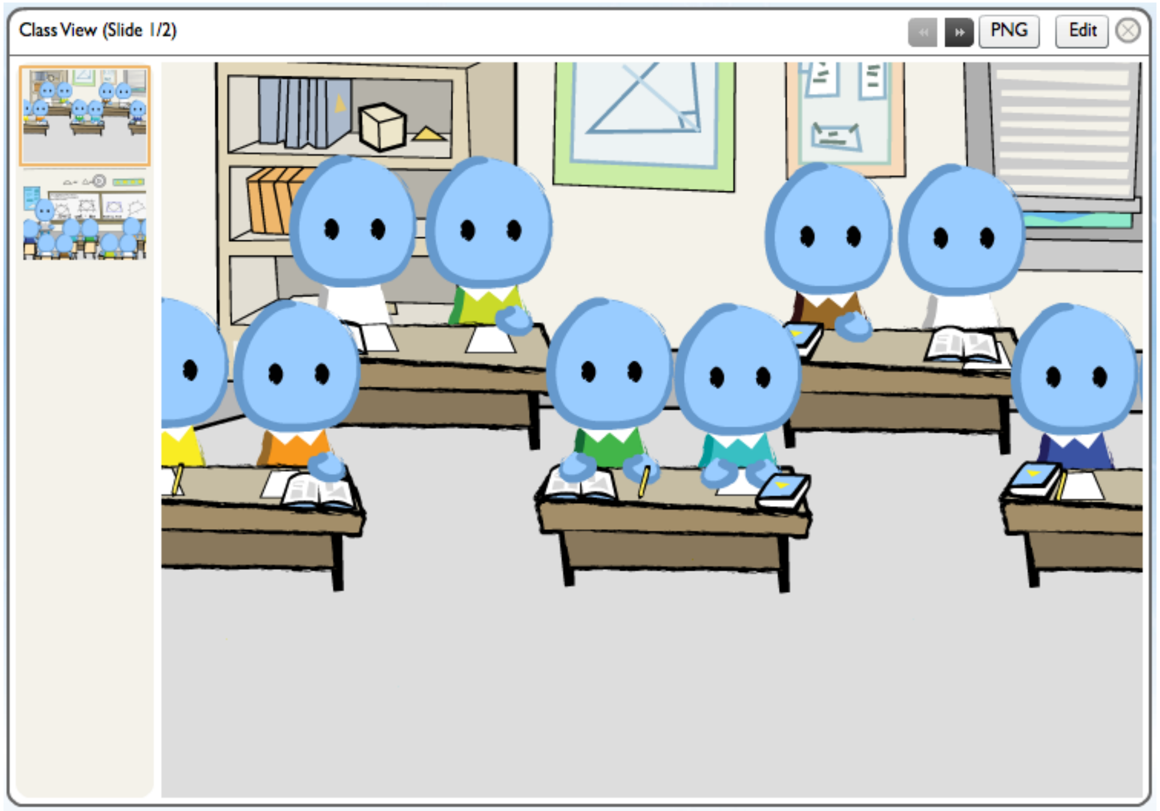

Figure 12. A screenshot of the Slideshow Player.

Overall, the current version of Depict is working relatively well. The tool is being heavily used in some teacher education classes that have provided good feedback on features and bugs. There has been positive feedback from end users. We continue to improve the reliability (fixing bugs) and the performance (publishing, opening, and saving depictions) of this version, these are especially needed when many users with limited Internet bandwidth use the tool simultaneously.

The future versions of Depict

We plan to preload graphics in the library to increase the performance of Depict. We also plan to add an important feature that allows users to record or attach audios to slides, as an alternative for text-based dialogs and narratives; this feature seems to be of interest by many users. Scaffolding will be considered and implemented as well. For example, we may provide the user with more editing modes such as script writing (see also CLOVER, DEMAIS, and iTell tools; Bailey, Tettegah, & Bradley, 2006; Bailey & Konstan, 2003; Landry & Guzdial, 2006).

Other activities with Depict can be envisioned. The next section describes projects that were envisioned around prospective enhancements of the tool, for example, the integration of resources modules such as instructional practices and student work. These are currently simmering, looking for funding opportunities.

III. A Storymaking Environment for the Professional Learning of Mathematics Teachers (a non funded[14] proposal to NSF in the Creative IT RFP)[15],[16]

The proposed project would study the design and added value of an IT (Information Technology) environment for representing and learning the practice of mathematics teaching in the form of cartoon story making. The project builds on a successful line of research on mathematics teaching spearheaded by Herbst and Chazan (2003a,b) whereby cartoon representations of teaching stories have been successfully used to prompt and ground conversations about decision-making and action in teaching among practitioners. The project posed two complementary questions: (1) What added value can a virtual setting for professional learning provide to usual teacher preparation activities such as reporting (composing), planning, role-playing, and (eventually) simulating lessons? And (2) What functionalities and supports does such a virtual setting need to have in order to enable prospective teachers to (a) engage with strategic and tactical demands of teaching, (b) use information resources that account for students' mathematical conceptions, and (c) process and respond to communication that is multivocal and multimodal (Koschmann, 1999; Kress & Van Leeuwen, 2001).

By posing a question on IT supports for the learning of teaching the project takes on a challenge to the long tradition of computer supported learning in that it considers a different kind of subject to be learned. The practice of teaching mathematics to children is qualitatively different than the academic fields usually considered in the ITS (Intelligent Tutoring System) and CSCL (Computer Supported Collaborative Learning) literature: Competent performance in mathematics teaching requires the creative, tactical and strategic management of interactions with live, self organizing counterparts (students or classes of students) and thus its learning requires mastering a subject with more complex but less well known representations. Furthermore, the professional, practical orientation of teaching attests to how different expert knowledge in and for teaching is from that of the academic disciplines: This craft knowledge is held in stories about practice rather than in abstract propositions (Clandinin and Connelly, 1996, 2000; Leinhardt, 1990). Recent developments on conceptualizing the nature of teacher knowledge (Ball, Lubienski, & Mewborn, 2001; Hiebert, Gallimore, & Stigler, 2002) as well as the nature of teachers' practical reason (Herbst & Chazan, 2003a) combined with developments in the use of rich media technologies to represent classroom interactions and promote deliberations about practice (Herbst & Chazan, 2006) suggest that it is timely to undertake the proposed work which in addition to its practical contribution can advance the modeling of expertise in teaching.

We will design and prototype a system of IT supports to three key activities of teacher preparation, all of which demand different kinds of story making and where we hypothesize that instructional technology can make a difference in meeting those demands. Such design exemplifies what a virtual setting for teacher preparation can be. It does so by leveraging intellectual resources for teaching, embedding those resources in an IT environment where prospective teachers can engage in scaffolded activities of professional learning. The story-making theme connects the professional activities of storing and communicating knowledge with the professional learning activities of describing, planning, role-playing, and (later on) simulating classroom practice. The story-making theme also stresses the creativity demands of the work of teaching, both on- and off-line, raising the question of how to design technology to accelerate and support the learning of a complex professional practice. This practice—teaching mathematics—is complex because it opens new problems as it proceeds and because its

[14] Rejected before review on the grounds that it exceeded the budget limits.
[15] Vu Minh Chieu and Christopher Quintana helped write the grant. Daniel Chazan, Deborah Ball, Nicolas Balacheff, and Vilma Mesa were going to be involved in the work had it been funded.
[16] Background for the proposal, research and development goals and specifications included. Excluded are timeline of work, research methodology, prior support, personnel, etc.

interpersonal nature imposes tactical demands that often conflict with strategic decisions. It is complex also because it requires a teacher to process simultaneous signals from many students, communicated in many modes of interaction. To do teaching a teacher needs to have access to intellectual resources and know how to use them timely. The problem is not just a nice challenge to the study and support of complex cognition; it has fundamental implications for the nation's capacity to meet its challenges.

Improving teaching by improving resource use: Teacher knowledge in practice

A crucial problem of American education is how to increase and improve the human resources needed in an economy increasingly dependent on science and technology (see Committee on Prospering in the Global Economy, 2007). The development of systemic capacity to teach mathematics and science to American students is paramount in that goal. Existing research on curriculum, teaching, and students' conceptions are important resources for teachers to meet those goals. Yet, as Cohen, Raudenbush, and Ball (2003) have argued, improvement of students' opportunity to learn hinges not so much on what resources are available, but on the kind of *use* to which those resources are put within instruction. Beyond the resources that a teacher has at her disposal, it is what the teacher does to set up and manage their students' intellectual environment with the resources available what makes a difference. It is therefore understandable why teacher preparation must be a centerpiece of attempts to improve mathematics and science instruction. It is also understandable that this preparation needs to center on improving teachers' use of intellectual resources in environments that replicate the intellectual demands of actual practice.

An important resource for teaching is teacher knowledge. It is widely believed that teachers' knowledge makes a difference on students' learning. Research on teacher knowledge has underscored the importance of focusing teacher preparation on knowledge in and for practice—that is, knowledge that can be used in doing the work of teaching (Ball & Bass, 2003). Knowledge of mathematics and of children's psychology are undoubtedly important pieces of the intellectual resources that teachers need for their work and that new teachers need to learn to use. This knowledge could be and has been represented in the form of academic knowledge for its consumption by future teachers. Yet studies linking traditional measures of teacher knowledge (e.g., mathematics courses taken and the academic knowledge gained in them) to student achievement have shown that representing and communicating such knowledge using traditional academic forms has a limited impact (Begle, 1972). In contrast, items that measure teacher knowledge for teaching (Hill & Ball, 2005; Hill, Rowan, & Ball, 2005) where mathematically relevant actions and decisions are contextualized in stories that involve students, teachers, and their settings, have shown correlations between teachers' capacity to answer questions satisfactorily and their students' achievement.

Knowledge about students' mathematical conceptions,[17] about the different ways—appropriate and erroneous—in which given concepts are present in students' mathematical work is one area in which research in mathematics education has produced considerable information. Whereas this information is a valuable resource for teaching, a current problem in the field of teacher education is how to educate teachers to use it (Crespo, 2000; Franke & Kazemi, 2001). Knowledge to use this resource is crucial in supporting the teacher's making of strategic decisions (e.g., what problem to pose at the beginning of a lesson to elicit students' prior knowledge relevant to the new material); it is also crucial to support the teacher's construction of

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[17] Following Confrey (1990) and Balacheff (1995; Balacheff & Gaudin, 2010) we use the word "conception" to refer to distinct manifestations of a mathematical concept in practice. For the concept of circle, for example, several conceptions are viable at different moments in schooling including "a round closed curve," "$x^2+y^2=r^2$," etc. Balacheff's model of conceptions is a bridge between educational modeling and computational modeling of students' knowledge and has been used in artificial intelligence approaches to learner support in geometry (Cobo et al., 2007; Weber et al. 2002).

tactical responses to students' contributions (e.g., what to see in and how to value an erroneous solution proposed by a particular student). To educate teachers in using knowledge of students' conceptions requires creating professional learning tasks where its use makes a difference and embed those tasks in learning environments where those intellectual resources can be accessed.

Researchers on teaching have demonstrated that complex knowledge of the practice of teaching is held in the form of narratives and stories of instruction. The notion of story serves to give to teaching a rational organization, albeit a different one than the preferred by academic representations of knowledge of the disciplines. This can partly be accounted to the fact that teaching is a practice oriented to addressing particular problems, contextualized, personalized, and temporal; it is reasonable that practitioners' craft knowledge be not only developed but also communicated and archived in the form of stories that help situate what is known in the midst of those circumstances (Carter, 1993; Doyle, 1997; Leinhardt, 1990; Connelly and Clandinin, 2006). The notion of practical rationality (Herbst & Chazan, 2003a) has been offered as a way to encapsulate the categories of perception and value that organize the stories in the teaching of a mathematics domain, such as geometry or algebra. Practical rationality includes the knowledge held explicitly by practitioners but also, and more importantly, the unspoken dispositions that regulate how they carry out their practice, how they make use of what they know.

An important question that arises is how to create expertise in the use of and in the implicit habits to use this important resource—knowledge of students' conceptions. How can learning to make creative use of intellectual resources in teaching be supported and accelerated? We propose to design and study a virtual setting for teacher education--a system of IT resources and intelligent supports with which prospective teachers have opportunities to learn knowledge of students' conceptions that exists intrinsically tied to the stories of instruction in which that knowledge could be used. We hypothesize that such setting may allow prospective teachers to confront problems of instruction, accelerating their acquisition of knowledge for teaching, and scaffolding their learning to make creative use of available intellectual resources. This proposal contributes to a larger agenda for teacher preparation focused on learning to do teaching, learning to use knowledge and other resources in teaching, in organizing and managing the intellectual environment where students can learn complex ideas (Ball and Forzani, 2005).

A virtual setting for teacher preparation in mathematics

The present proposal looks at the problems of teacher knowledge and teacher learning from an information technology perspective. Our goal is to design and investigate a system of information technologies suited for two related purposes (1) to record, archive, and access teacher knowledge of the mathematical conceptions of students represented in the form of instructional stories and (2) to scaffold and accelerate prospective mathematics teachers' learning about teaching by having them participate of activities that involve the creation and annotation of instructional stories. The IT that we conceive builds on an existing system, which we provisionally call ThEMaT's Composer (now renamed as Depict). Depict includes an array of graphics and a user interface with which a user can create multimedia representations of teaching in the form of slideshows. We propose to design a new version of the Composer, adding to the graphics a number of intelligent supports that can accommodate three key activities in teacher preparation: (1) composing and reporting stories of instruction, (2) planning a lesson; and (3) role playing the development of a lesson. In future work we expect to be able to take on the design of supports that simulate the learners' response to teaching in a highly interactive lesson. In general, we are envisioning a system of IT solutions that will help leverage the notion that classroom stories collect and trigger teacher knowledge. And we aim at outfitting such system with scaffolds and hints that permit novices to learn about mathematics teaching in a problem based environment, where the problems are problems of professional practice and the answers to those problems use cartoon story making as the means for representation.

Learning to teach: Why we need virtual settings

Practice is important to learn professional knowledge. But the argument for the centrality of practice in teacher education is not quite the same as the more established custom of placing prospective teachers in real school settings. Undoubtedly, by working as interns in schools and classrooms, prospective teachers can get access to real students and real educational problems. But the width of the complexity they encounter in real settings makes it unclear to what extent beginning teachers have opportunities to ponder, try, view, and evaluate alternative strategies and tactics, as opposed to merely replicate the instructional patterns that, according to received wisdom, "work" in each of those settings. Additionally, real settings can too easily shift the attention of beginning teachers to emergent non-instructional issues (such as student behavior or classroom policies). More protected and malleable settings are needed, where prospective teachers can learn to use their intellectual resources in instruction, to think about and rehearse how they would organize and manage students' learning environment, to practice instruction virtually--we call those *virtual* settings.

We argue that *virtual settings* can be designed to scaffold prospective teachers immersion into the practice of teaching; the amount of complexity into which the prospective teacher is immersed can be modulated and the amount of available resources and supports can be controlled. One can thus create problem-of-practice-based opportunities to learn in authentic but not overly complex contexts. Virtual settings include representations of classroom instruction that make use of a variety of rich media technologies to immerse an audience in the give and take of classroom interaction: in particular multimedia authoring tools, the internet (particularly Web 2.0 technologies), games, and simulations—all of which share the characteristic of enabling interactions with timelines and timely events. Our argument for the importance of virtual settings hinges on the need to educate and refine the *tactical sense* that teachers need to invest in the production of their practice. As Lin, Schwarz, & Hatano (2005) have argued, as a kind of problem solving, teaching demands quite a different kind of metacognition from the goal-oriented, strategic metacognition involved in the kinds of problem solving traditionally studied by psychologists. Practice is temporal in nature—the actions that compose practice *take* time, but also they can be *timely* or not; they depend on what happened before and constrain what can happen after (Erickson, 2004). Educating the tactical sense, the sense to do the right thing at the right time, the sense to seize opportunity, and to make good use of time is key in teacher education.

Much of what we are now able to envision comes from a rich history of engagement of the field of mathematics teacher education with video technologies. So it is reasonable to review what we have learned about professional knowledge and professional education that can and cannot be done with video technologies in order to value what we can do with a broader array of rich media technologies.

Virtual settings based on animated cartoons: Beyond what video records can do

Video records of instruction in real classrooms have been useful to bring to the fore the tactical-temporal entailments of practice. Teacher education materials have been developed around the investigation of video records of practice (e.g., Boaler and Humphreys, 2005; Seago, Mumme, and Branca, 2004). *Slate*, a multimedia environment created by Lampert and Ball (1998) provides an early illustration of virtual settings for the practice of instruction: It allowed beginning teachers to view video records of practice, annotate them, select clips, and assemble them into multimedia projects. More recently technologies like *Video Paper Builder* (Nemirovsky et al., 2005; Beardsley, et al., 2007), or LessonLab's *Visibility* platform (www.lessonlab.com; Santagata et al., 2007) have continued to enrich the set of tools with which teachers can experience and analyze available video records. There is an extensive literature that describes how engagement with videotaped episodes of teaching promotes the development of instructional capacity and important advances have been made to organize archives of video data and create experiences that permit teachers to view and comment video (Fishman, 2007; Jacobs & Morita, 2002; Sherin, 2007). Video has been good for several purposes, including recording complex events featuring learning or teaching, helping new teachers study accomplished teaching, identifying decision moments, justifying teacher choices, hypothesizing where students' ideas come from, and designing alternative teacher moves.

The work we propose is part of a larger agenda for research in mathematics teaching and teacher education that started from our use of videos to broker conversations among practitioners. Building on our research on classroom instruction, in algebra (Chazan, 2000) and geometry (Herbst, 2003, 2006) we started using video records of problematic episodes of instruction to elicit from experienced teachers the rationality they invest in teaching. Herbst and Chazan (2003a) have argued that video episodes have the potential to elicit and put to work the practical rationality of teaching because video episodes are not just *records* of events and *cases* of teaching, but also *artifacts* (i.e., reconstructions of events under recording and editing protocols that transform the "actual" events), and *probes* into teaching (i.e., catalytic of a *normative* response, like Rorschach's blots are). Video records of teaching (and the tools used to manipulate them) exemplify what a virtual setting for the practice of instruction is because they immerse their audience in a temporal organization of events that is similar to the temporal organization of events in real practice, thus making it possible to elicit from their audience contributions and reactions that are tactical in nature.[18] Yet video records are limited in their capacity to support activities of teacher learning.

In 2004, under the Teachers' Professional Continuum program, the National Science Foundation funded project ThEMaT—Thought Experiments in Mathematics Teaching (Herbst & Chazan, 2003b). With that support we have developed means to gather empirical data about the **practical rationality** of mathematics teaching—the system of dispositions that experienced practitioners put into play when they construct viable instances of practice. Instead of video records, we have used cartoon based stories, either animated or in the form of slideshows or comic books. Cartoons have allowed us to represent the same scenario for several "classes," or several scenarios in the same "class," allow us to sketch a story that may be hard to come by in reality, and to sketch alternative stories that branch from a common beginning. Thus cartoons have opened an avenue for experimentation in the study of the rationality of teaching through story telling. We used those animated cartoons in meetings of study groups of teachers involving dozens of teachers in conversations that total more than 100 hours. A main accomplishment of that ongoing project has been methodological. We have demonstrated the feasibility and the value of creating rich media artifacts[19] that represent mathematics instruction and appeal to practitioners: The practitioner exchanges that develop in reaction to those rich media artifacts, as teachers view or propose changes to those artifacts, attest to the existence and role of a practical rationality specific to the teaching of particular mathematical domains and that enables practitioners to notice and value particular actions or decisions. When these representations sketch scenarios that straddle the boundaries of customary practice, experienced teachers respond by producing alternative stories, stories that have happened or could happen in their own classrooms, thus disclosing information about the implicit norms that regulate their practice (see Herbst & Nachlieli, 2007; Miyakawa and Herbst, 2007a, 2007b; Weiss & Herbst, 2007). Since the media form imposes a temporal structure in the experiencing of each story, arguments about stories often focus on tactical decisions made by teachers. And since our representations use figural, two-dimensional characters, experienced teachers can easily focus their comments on the

[18] Along these lines, video episodes are very different than other representations of teaching used in teacher education to engage in practice such as written cases (e.g., Merseth, 2003; Stein, Smith, Henningsen, and Silver, 2000; Smith, Silver, and Stein, 2004).

[19] We use the expression "rich media technologies" to refer to technologies that permit the composition and display of created and captured images, texts, and sounds—including animations, graphic novels, slideshows, photographs, and video.

decision-making and rationality of the practice represented rather than on personal appearance of characters, the date of the episode recorded, or characteristics specific of the social context of the represented classroom (see McCloud, 1994; see also Mori, 1970).

The research agenda to which this proposal contributes builds on that ongoing work with rich media artifacts as data collection instruments. Encouraged by the nature of the interactions we have observed among the teachers that participated of our study groups, by the testimonies of individual participants, and by informal observations of prospective teachers' engagement with our animated stories we hypothesize that these cartoon-based representations of teaching can be repurposed to design an environment in which teachers can compose and experience teaching stories, learning knowledge in and for practice. This proposal seeks support for continuing and extending this research agenda, which can be articulated as the integration of the following three ideas, which our prior work has confirmed:

(1) Teachers' craft knowledge about practice is activated and stored in classroom stories,

(2) Interactive design environments can be developed where classroom stories are co-created, experienced, and modified, and

(3) Practitioners' engagement with classroom stories within computer-mediated story-making environments can elicit and develop the normative underpinnings of instruction.

A particular direction that we seek to take with the present proposal builds on an observation from the data gathered in project ThEMaT: Practitioners respond to the cartoon based instructional stories that we showed them proposing alternative stories, that they sketched using language, gesture, body movement, voice inflections, and improvised props (such as diagrams they would draw on an easel pad). We have recorded those emergent stories in our analysis and in some cases turned them into new animations or comic books using our cartoon characters. We hypothesize that a virtual setting that provided practitioners with design tools that allowed them to outline, compose, view, publish, and correspond about alternative stories of teaching could help develop interactions about practice that raise key questions of strategy and tactics in teaching. Interactions about the stories co-constructed by practicing and beginning teachers could contribute to educating the tactical sense of beginning teachers by immersing them in successive cycles of design and experience of classroom interactions. Obviously, educating the tactical sense in teachers requires not only having them notice moments in an episode in which something different could have been done, but also sketching what such alternatives could be and anticipating their possible developments over time. Video records lack the representational malleability to support this work: Whereas sampling from a large corpus of video records may help conceive of alternative moves a teacher could do in a given situation, video records are hard to tailor and manipulate for teachers to produce their own alternatives to a given scenario. Additionally, any one video case narrates one story too forcefully, depicts one physical setting in relatively high fidelity, and tends to foreclose any need to relay alternative stories that should have happened instead or could have happened in another setting. Animations or slide shows using cartoon characters are a more malleable medium and inasmuch as they only sketch stories, they invite the formulation of alternatives, the second-guessing of moves, and the projection of the circumstances and settings of viewers (Herbst & Chazan, 2006).

Toward a web-based composer of teaching

In line with the notion that to learn a practice, the learner (in this case, the beginning teacher) needs tools to create artifacts in the field of study (Papert, 1991), we argue that research and development should be directed to developing a virtual setting with tools (including graphics, software, resources, and interactive functionalities) that can engage teachers as producers and actors, not just as consumers, of instructional stories. We submit that the design of such virtual setting is key in advancing teacher education in mathematics and the sciences at all levels, including elementary, secondary, and undergraduate. We submit that such virtual setting for teacher education can help engage virtual communities of teachers around the production, share, and critique of teaching experiences. The centerpiece of our proposal is to explore two related questions about this virtual setting: (1) What added value can a virtual setting for professional learning provide to usual teacher preparation activities such as reporting (composing), planning, role-playing, and (eventually) simulating lessons? And (2) What functionalities and supports does such a virtual setting need to have in order to enable prospective teachers to (a) engage with strategic and tactical demands of teaching, (b) use information resources that account for students' mathematical conceptions, and (c) process and respond to communication that is multivocal and multimodal. To be achieved, this proposal requires a serious investment in instructional technology and artificial intelligence.

Designing a Composer of Instructional Stories

We want to design and research a virtual setting that can engage teachers in the composition and enactment of instructional stories, the identification of decision points, the creation of alternative courses of action and the annotation and analysis of stories of teaching. The notion that rich media and immersive technologies be used for learning is not new as it can be attested by a large corpus of empirical and theoretical writing (e.g., Gee, 2004; Mayer, 2005), some of which includes software for students to construct stories (e.g., Kar2ouche; Birmingham & Davies, 2001; Webb & Cox, 2004; see also http://nle.noe-kaleidoscope.org/resources/narrative.html). The novelty in what we are proposing is the development of rich media learning environments for beginning teachers and within a specific field of professional learning—learning *to teach* mathematics. In this sense, some precursors include professional simulators used to train physicians and the military (Isenberg, et al., 1999). Multiplayer games where one person plays the part of a teacher and others play the role of students, or simulators where intelligent agents are programmed to embody particular students' conceptions so as to pose instructional problems to whoever plays the teacher role, can engage prospective teachers in practicing teaching. Whereas teacher educators often use role play to have prospective teachers practice teaching (Megarry, 1981; Rose & Church, 1998), virtual settings where they could do it by impersonating characters and where they could record, replay, and annotate what they do could help build their capacity to reflect on the plausibility that the events they are co-creating could take place in a real class (cf. Kupperman, et al., 2002; Vincent & Shepherd, 1998). Multimedia composition tools could support a 21st century version of the "lesson plan form" where instead of using a form to sketch the segments of a lesson, teachers could use a timeline, graphics, text, and audio to demonstrate how a lesson might proceed over time, where the nature of the media helps the teacher attend to variables rarely considered in planning, such as the use of space or the anticipation of students' emotional or behavioral responses.

Depict is a system that we have begun to develop with our current funding from NSF. It enables a user to manipulate a system of graphics to construct a story of instruction and publish it in some temporal media (a slide show). Its graphics have been designed to enable users to implement different "theories" of individual differences as well as to represent communication using different modalities (including in particular gesture and facial expression).

The current Depict is thus far suited for one kind of activity—that of creating, viewing, and editing a story of teaching in a frame-by-frame mode. Teacher educators have used it to represent stories that prospective teachers are required to critique and suggest alternatives to. In such task the representation acts as an alternative to a transcript of verbal content, thus helping users come to grips with the multimodality and the simultaneity of events in classroom interaction (i.e., messages are conveyed through facial expression as much as by speech, when one person speaks others do other things), both of which are hard for prospective teachers to experience from interacting with transcripts. Whereas the present state of Depict already contains affordances for students to learn about teaching, it is far from providing the kind of learning opportunities that have been documented of tutors (Chieu et al., in revision; Koedinger & Corbett, 2006), simulators, or games (Rieber, 2005).

We surmise that the task of designing a virtual setting for the learning of mathematics teaching is more complex than that of designing a tutor of academic knowledge. Like in the latter a teacher interacts with people, but unlike the latter the means of interaction (e.g., examples given, lines of talk spoken) are open ended and the intelligence required to create interaction (e.g., anticipations of mistakes students may make, ideas of what problems to assign) depends on information which is hard to come by, store, and access. As we note at the beginning, the knowledge of practice which would be at stake in a setting like that is not codified in declarative sentences and action rules that could be used to design a cognitive tutor, but rather extant in stories of practice held by experienced practitioners. Thus the design of a virtual setting for the learning of mathematics teaching far from being an application of existing software design knowledge is a creative, interdisciplinary effort that can push the boundaries of information technology research. To articulate the goals we have for this design we start from the kinds of learning activities we would like to enable, then use those to envision modules for the IT system.

Teacher development activities where IT mediation could add value

We propose to explore the questions of what a virtual setting for teacher learning could look like and what its added value could be by using the teacher education activities listed in Table 1 which contrast what such activity looks like without technology support and what it could look like with such support. Each of these activities would require the development of specific aspects of the Composer.

Activity	Without Depict	With the envisioned Depict
Composing or reporting stories of teaching and learning	Teachers videotape actual lessons, write narrative descriptions of these lessons, or combinations of those. Made up stories are composed using text based vignettes or dialogues.	Teachers can use dedicated graphics along with text and symbols to represent the unfolding of an actual or possible lesson moment-by-moment and share the composition in a dedicated web space for it to be picked up by others. These might use same graphics to offer alternative (actual or possible) deployments of similar ideas.
Planning a lesson	Teachers use various text-based forms to either list strategic information (e.g., objectives, activities) or sketch temporal deployment (e.g., various segments of an anticipated lesson) or a combination of both.	Teachers navigate the various timescales of a lesson using different modes (outline, frame-by-frame) and various input forms (text, graphics) to create timelines and flesh them out as anticipated events. Tutorials and hints offer them possibilities for what they could do at the grain size of each timescale, helping them think back and forth between possible strategies and tactical demands.
Role playing the development of a lesson	Several teachers collaborate face to face in the real time enactment of a lesson where each of them plays different characters. Occasionally characters embody particular misconceptions.	Prospective teachers could collaborate in the design of a lesson using an online communication interface and means to control time, each of them plays different characters and with ready access to information on students' conceptions.

Those three activities are reasonable opportunities to learn about teaching regardless of whether an IT environment exists where they can be run. They have been used, to more or less a degree in teacher education courses and practicum assignments. The opportunity to learn in each of those three activities could also be boosted if these practices could be embedded in an IT environment: such an environment could offer the advantage of allowing a better control time in that the prospective teacher could stop and think, save where they are and come back to it later, even replay what has been done before and have it available actions for reconsideration and enactment. In terms of researching the design of a virtual setting for teacher education, we see those three activities not only as complementary developments of Depict but also as contributions to an ultimate goal of developing a teaching simulator that can be used in teacher education—a system where a prospective teacher interacts with a virtual classroom in real time (see Chieu & Herbst, 2011). The user research we propose would inform on what direction the development should be concentrated afterward. Each of the following sections sketches what kinds of IT systems are needed to carry out those teacher education activities and the studies proposed for each of them.

Composing and reporting stories of instruction in Depict

The activity of reporting (describing, portraying) episodes in teaching or learning is usually done through text composition, video or audio recordings, or a combination of both. In the foregoing discussion we noted negative aspects of both in regard to how the activity itself can be the locus of teacher learning. Animations and comic books afford a balance between those two extremes, with the latter being a media form that prospective teachers could aspire to produce, given recent developments in multimedia technology.

Adding to the existing ThEMaT's Composer (now Depict), the main development we foresee as needed to support the composition and reporting of lessons by prospective teachers consists of a user interface that enables a user to interact with a story in at least two levels of composition (which we call *outline* and *frame*), two levels of experience (which we call *view* and *edit*), and two levels of publication (which we call *correspondence* and *story space*). That is, unlike a comic strip, a lesson is a long event and could be composed using different timescales or grain sizes, say that of the episode (about 15 min in duration) or that of the utterance (about 1-10 seconds in duration; Lemke, 2000). At any of those levels of interaction with a story, a user may want to view the story continuously at a certain speed or view it making pauses to reflect and comment. Finally, the publication of a composed lesson at any stage of development can be seen as an invitation for someone else to view it and edit it as well as a contribution to a family of stories related by a common trunk from which alternatives have branched off. On account of this last consideration, part of the development includes creating a web based tool and a system of access and privileges that will allow users to create story spaces, contribute to them, and interact about them.

An added development needed includes what we call a Story Archive Module (SAM) to keep composed stories and their metadata in story spaces and allow searches within those stories. This archive includes records of classroom stories deployed in the form of animated movies, longer videos, slideshows, and comic strips. It would archive clips and story paths of our current representations plus all the stories that users would construct using Depict. Users would be able to draw from this archive to construct new representations (e.g., series of clips from one story that exclude one key event or replaces it with a new clip). A possible use of Depict is to record shorter multimodal events within lessons that embody students' mathematical conceptions. This application is key for another module for the Composer, described in the next section.

Planning a lesson as a slideshow using a library of student conceptions and a virtual planning coach

The activity of planning lessons is ubiquitous in teacher education programs and text based forms for lesson planning abound. Most lesson planning forms contain little support for users to anticipate the (multivocal and multimodal) response of students and to plan alternatives contingent on students' response. A graphics based media for planning supports multivocality (in that many speakers can be seen having the opportunity to provide input at any moment) and multimodality (in that in addition to speech, also facial expressions, gestures, writing, and postures, are available as semiotic resources for students to communicate their response to instruction). In tune with our argument about the need to educate prospective teachers in the use of knowledge about students' conceptions, it seems important to note that the opportunity to express students' response (afforded by the graphics) needs to be complemented with access to archival data on students' conceptions that allow prospective teachers to anticipate what students might actually say or do. Furthermore the kind of scaffolding to the activity of planning provided by a text based lesson plan format might be improved if more interactive scaffolding could be provided, in the form of IT based scaffolds and hints, leading eventually to a planning coach (Quintana, et al., 2004).

Two additional modules are envisioned to assist in the study of how Depict can be a virtual setting to learn teaching through lesson planning. These are a Mathematics Conceptions Module (MCM) and a Teaching Scaffolds Module (TSM).[20] The conceptions module is a relational database of web-based and open source materials containing the knowledge base for teaching and manipulated by a semantic-web system allowing semantic and contextualized searches of its contents (Devedzic, 2004). This database includes records and their semantics that are potentially useful representations of teacher knowledge of students' conceptions. In particular, one of those sets consists of artifacts of teaching, which could be in the form of scans of students' written work, short videos of students at work, or records of observations of individuals or groups of students doing specific mathematical work (these include, notably clips of the composed stories archived in SAM). The key idea here is to envision a system collecting and indexing the intellectual resources that a teacher may need to understand their students actions and responses vis-à-vis the content they are studying. Obviously the realization of a fully functional MCM is an effort that inasmuch as it demands a huge amount of coding of preexisting research and data entry, goes beyond the scope of what one could do with the resources of this grant. Our expectation is to construct the infrastructure and enter data from three key conceptual fields in mathematics (linear functions, properties of quadrilaterals, and fraction arithmetic). Our main work to build the infrastructure of MCM will include modeling how experienced practitioners connect these different representations of students' conceptions as they access them to do their work. In this sense the work proposed is more than a routine exercise on web 2.0 technologies but rather the development and study of a folksonomy of mathematics teaching (Golder and Huberman, 2005).

The second development consists of a Teaching Scaffolds Module (TSM). This is a system of intelligent agents that assists the planning of a lesson, by helping the user articulate purposes, allocate time, choose activity types, practices, strategies, and techniques, as well as providing rubrics, benchmarks, and demonstrations (by way of connecting to elements of SAM) for how each of those could be carried out. The work capitalizes on recent contributions to modeling the work of teaching and making a curriculum for teacher education (Boerst, Sleep, and Ball, 2007).

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[20] We now refer to these as the Students' Work Collection and the Instructional Practices Collection. They are in development.

Role-playing the development of a lesson using Depict and student profiles

A common practice in mathematics teacher education is to have prospective teachers experience new forms of instruction (such as problem-based instruction) from the perspective of the learner, then connect such experiences to what they could do to create similar experiences for their own students. Issues of communication, differentiation, discipline, identity, or misconceptions have also found their way into teacher education through practices like role-playing: some prospective teachers play specific student roles (e.g., a student for whom linear functions are proportions) and another prospective teacher plays the classroom teacher (e.g., presenting a problem that will cause cognitive conflict). We expect that Depict can help facilitate this kind of activity by giving tools for people to role-play a lesson at a distance, connecting students of teaching over the internet in role playing activities that are multimodal (namely, where characters can contribute to the interaction not just by speaking or inputting text, but also by making facial expressions, gestures, postures, and movements). Two additional developments are sought for Depict to support these activities.

A first needed development is a Profiles Archive Module (PAM) which contains representations of individual students (and perhaps also of individual teachers) by way of putting together characters across the stories archived in SAM (see above) or by tailoring characters to specific individual differences of relevance to teachers. We expect PAM to be used to model results of research on teachers' folk theories on students' identity, as well as to present in a manner that could be usable by teachers, characterizations of students' individual differences (along axes such as mathematical cognition, motivation, cultural or racial identity, class status, etc.). The idea here is to develop another folksonomy, this time of individuals. The assumption is that students' actions across stories might attest of modal ways of being a student in mathematics classrooms and that practitioners, particularly those with more experience in the field, might be able to recognize those profiles across stories. The profiles could then be used in role-playing activities where participants are assigned to enact different profiles as they co-construct a story.

A second development is technological in nature and requires creating a new user interface for Depict. This interface would enable different individual users to control different individual avatars (by adding speech, movement, expressions, etc.), for example by providing a dedicated screen where the user can close up on their avatar in addition to a common screen where the action of all avatars can be seen. The technology for such developments seems to be available from the gaming industry (Marino, 2004). Our interest is to explore the needs of users and to model the interactions between users by developing prototypes of this user interface. For example, one obvious issue to investigate is the role of time and timing in the role-play activity. Clearly, playing out a scenario brings the temporal demands of the scenario with it, establishing a preference for real time performance. On the other hand, role-playing a character, especially when that character embodies a profile which is important to master for future professional uses, establishes a preference for taking time out from interactions to study the character. The design problem seems to be how to capitalize on both imperatives in creating the controls available to the user to manage the way they relate the actions of their own avatar to the flow of actions of the rest of the participants' avatars.

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