

Narrative Tags In The Classroom: How Co-created Metaphors Facilitate Learning

Adam Lupu

Northwestern University

Narrative Tags In The Classroom: How Co-created Metaphors Facilitate Learning

Introduction

Computer programming is a highly sought after skill, and industry demand for software developers with extensive programming expertise continues to grow (Prabhakar, Litecky, and Arnett, 2005). Until recently, aspiring programmers looking to fill this demand had two options: learn on their own or study at a college or university. Learning on one's own can be quite challenging, but learning in a university can be worse. Many students in undergraduate computer programming classes suffer from poor grades, frustration, and mental fatigue (Braught, Wahls, and Eby, 2011; Murphy, Fitzgerald, Hanks and McCauley, 2010). Additionally, at least one third of students enrolled in a college-level introduction to programming course will either fail or drop out (Bennedsen and Caspersen, 2007). Unfortunately, students who continue and graduate with degrees in computer science often lack necessary skills for employment, including communication and collaboration (Begel and Simon, 2008).

Perhaps in response to these findings, a third educational option for novice programmers has emerged. Commercial organizations like Code Academy and General Assembly offer training programs that teach a modern programming language and professional software development skills to beginners. Organizations like RailsBridge seek to entice women, who in 2009 received only 18% of undergraduate computer science degrees (NCWIT, 2011), into the software development industry. Yet, to date, there are no existing studies analyzing the learning that takes place in these organizations.

With computer programming education expanding beyond universities and do-it-yourself manuals, there is a growing opportunity for the development of more effective pedagogical practices. I decided to investigate the learning that takes place in one of these organizations. I set

out to examine how people learn in a classroom of adult, novice web developers. My main question was: What forms of learning occur? What learning objectives does the organization intend? What do students actually learn and why? While I discovered several learning events that I will describe and analyze in future papers, one specific form of learning seemed uniquely relevant to this particular organization and this particular setting. I found that while attempting to learn web development knowledge, skills, and practices, students and their instructors co-create common verbal references that serve to bundle learned concepts and behaviors, maintain classroom norms, and generate a sense of cooperation and community. These verbal references, referred to in this paper as *narrative tags* have their origins in shared stories, metaphors, and analogies. They are either intentionally deployed or naturally emergent, and their use and meaning can evolve over time.

Methodology

I conducted my observations at a recently created local academy for aspiring entrepreneurs and web developers. My ongoing observations began in August 2011. I gathered the specific data from which this paper draws during the months of January and February 2012. I spent 20 hours per week for two months gathering data in the form of field notes, formal and informal interviews, and audio and video recordings. The primary setting was a classroom in a downtown office building; interviews and observations also took place at a satellite location, as well as nearby cafes and eateries. I had two roles when I was on site. I was enrolled as a student in the class, and I served as the Learning Architect for the organization. As a student I participated in classroom lectures, discussions, and labs. I also attended social gatherings, professional networking events and meetings, and held informal conversations in and beyond the

classroom. As a Learning Architect I conducted formal interviews, video recordings of paired student labs, and surveyed student's for classroom feedback. I also collaborated with the instructor and teaching assistants and attended staff meetings.

I interviewed several students who participated in the class. I interviewed the lead instructor and the school's founders. I also informally interviewed the teaching assistants and other staff members. My closest collaborators were the lead instructor, and two students who were particularly informative and helpful. In addition to helping me with my research they also were quite curious about learning in general and how I might be able to help advise them in getting the most out of the class.

I began coding my field notes and interviews using an open coding format. After identifying nearly fifty unique codes, I eliminated about half of them as irrelevant to the research topic and grouped the rest into three main categories. They were 1) verbal exchange, reflection, and refinement, 2) Artifact creation and use, 3) Professional language use and practices. Through the process of coding my field notes and reducing my codes to three main categories two things became clear. First, I realized that identifying all of the learning events that occurred for these students was impossible, and even a robust and fairly complete accounting was beyond the scope of a single paper. Second, as I looked at the three general categories that emerged, each of them either emerged from, or was significantly influenced by, the shared dialogue that I observed among the participants in the classroom. This led me to look more closely at what was occurring during these conversational interactions. Whether they were lectures, class discussions, or casual hallway chatter, a few linguistic tools emerged as unique to this classroom and to their ability to communicate learned concepts and practices in only a few words.

Results

I found seventeen distinct narrative tags used in the classroom and I coded these narrative tags using eight separate categories on four different dimensions (two categories per dimension). Narrative tags were assigned to at least four categories (one in each dimension), and in some case a narrative tag appeared to demonstrate properties of both categories in a dimension. I will describe these dimensions and the categories I assigned to them, and then I will discuss examples of these multi-dimensional narrative tags.

The Dimension of Longevity

Narrative tags appear to vary in the number of times students reference them and the duration of their use. Some narrative tags were used for only a single day during a single class discussion. Others lasted weeks and were referenced by students and/or the instructor several times per class period. In order to distinguish between the narrative tags that appeared temporary and the ones that evolved over time, I created the dimension of longevity with the two classifications of “enduring” and “fleeting.” I define enduring narrative tags as those that students referenced more than a week after their first use. Their particular use may have changed over the course of weeks or even months, but as long as I could trace present uses to past origins over more than a week’s time, I classified them as “enduring.” For instance “No Laptops!” began as “Avoid laptop use” and went through several iterations (e.g. “Refrain from using your laptops” and “Close laptops”) over the course of the first six weeks of class.

By contrast, “fleeting” narrative tags lasted less than one week (often only existing for a single discussion) and were rarely, if ever, brought up later. An example of a narrative tag that I coded as “fleeting” is the calculator analogy the instructor introduced on the first day of class. I

recorded one additional reference to it during a discussion between two students two days later, however, it did not resurface during future discussions.

The Dimension of Origination

How narrative tags begin also seems to vary by tag. In some cases the instructor created them intentionally. In other cases, a student was the first person to use the verbal phrase that seemed to “stick.” Sometimes there appeared to be a specific pedagogical purpose to the narrative tag, for others the value to student learning emerged over time and use. In order to distinguish the nature of the origin of each narrative tag, I defined the dimension of origination with two distinct classifications, “intentional” and “emergent.”

An intentional narrative tag is one that the instructor, a teaching assistant, or a student intentionally brought to the class’s attention for an specific pedagogical purpose. The calculator analogy above is an example of an intentional narrative tag. The meaning and use of a narrative tag may not be bound to how it was intended, but if I could discern that the initial purpose was to facilitate learning a new concept, skill, or behavior, I coded the narrative tag “intentional.” In contrast to an intentional narrative tag, an emergent one appeared to originate during a group discussion or classroom activity as a result of conversational interactions rather than a specific individual’s clear intent. For instance “self dot” (which refers to the programming command ‘self.’) emerged during a conversation in the classroom. Consider the following excerpt from my field notes on 2/12/2012.

The instructor described how a programmer could use the command ‘self.’ to refer to the application model he or she is working on. Then Jarod, a student in the class, said, “wait, can you explain that again?” Before the instructor had a chance to respond, another student called from the back of the room, “Jarod, you

have to use self dot focus.” Several students in the class began laughing loudly, the instructor smiled and laughed with them. Jarod blushed and said smiling, “You got me!”

In this episode a student in the class applied the metaphorical comparison of programming a self-referential expression into a computer with using the same command to remind oneself to focus on what the instructor was saying. The student intended it as a joke, however, many additional metaphorical uses of the phrase “self dot” started to emerge during class discussions and side conversations. No original pedagogical intention seemed evident from any single individual, the metaphor appeared to emerge naturally from this humorous interaction and became a jovial way for students to prompt each other’s behavior. I therefore coded this narrative tag as “emergent.”

The Dimension of Value

Throughout my investigation of narrative tags, I repeatedly asked what value they serve to a student’s learning process. I have provided a couple examples of how narrative tags begin and how long they can last. To understand their value, we must unpack their content. In defining a narrative tag’s value dimension, I identified whether a tag suggested appropriate learning behaviors or classroom norms, whether it prompted the recall and application of a specific concept, or appeared to serve both of these tasks. Narrative tags that served to encapsulate conceptual information (i.e. professional knowledge and understanding) I applied the code “conceptual.” For example, a TA brought the following comic to the class’s attention during a discussion concerning database management.

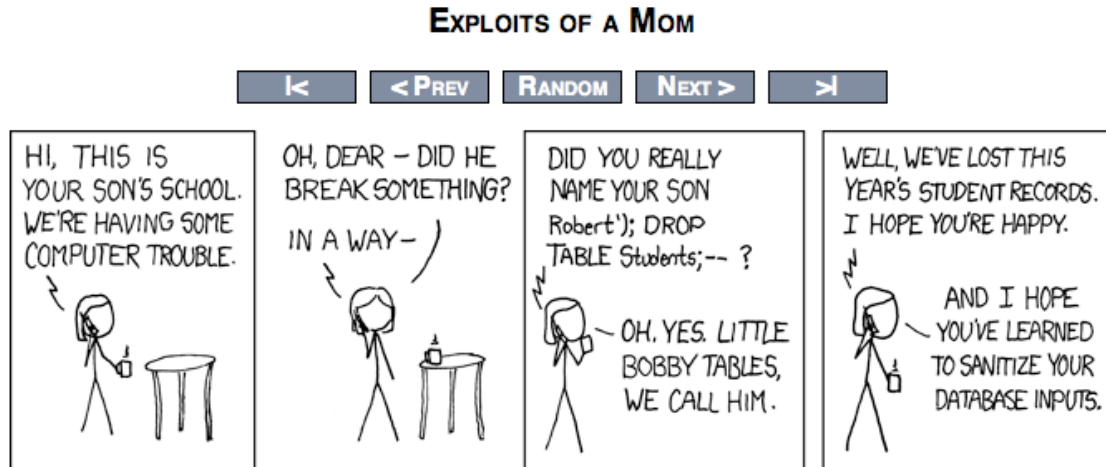


Figure 1 – An XKCD.com comic strip depicting a mother who knows how to teach her child’s school an important lesson about database management.

This comic depicts a mother who goes to great lengths to educate her son’s school about database management. The conceptual reminder it offers students is that databases can be altered by user inputs unless certain precautions are taken. “Remember Little Bobby Tables” became a conceptual reminder to students in the class that they needed to sanitize all database inputs before committing them.

For narrative tags that served as recommendations or reminders of appropriate professional practices or specific classroom behavioral norms, I applied the classification “behavioral.” One example of a behavioral narrative tag is the phrase “Sleep with it under your pillow.” Consider the following excerpt from an observed lecture on 1/23/2012:

The instructor said, “If you memorize nothing else, memorize this!” as he held up a sheet of paper containing the Rails naming conventions for routes. He continued, “So do whatever you have to do... look at it every day, sleep with it under your pillow, whatever you need to do. Just memorize this one sheet!”

And from one week later on 1/30/2012:

“So I know you’ve been sleeping with this under your pillow, right? So I can test you on it now right?” The instructor looked at the class, holding the same sheet of paper between himself and the students. There was no reply.

And finally from an interview with a student on 2/24/2012:

We sat down to begin the interview and I noticed a sheet of paper had been left behind on the desk. It was the naming conventions for Rails routes. I asked Rick if he was familiar with it. He replied, “Well, I’ve been sleeping with it under my pillow.” We both laughed.

“Sleep with it under your pillow” became a behavioral reminder to memorize this specific information. The phrase itself referred not to the conceptual information on the paper, but to the practice of memorizing that which the instructor (a professional in the field) deemed important enough to spend time memorizing.

Several narrative tags appeared to prompt both conceptual reminders and behavioral actions. These tags seemed to be the most valuable to student learning and also seemed to endure and develop over time. I will describe one of these (“It’s not magic.”) in detail below. To inform this description, I would first like to introduce the dimension of community.

The Dimension of Community

If learners of a craft, such as web development, seek access to a community of practice, such as the professional software development industry, they must learn to communicate with existing members of that community (Lave and Wenger, 1991). Some narrative tags seemed to serve this purpose quite well, introducing students to the language they would need to understand to hold professional conversations. I classified these tags as “inclusive” because of their ability to help students feel included in the professional web development community. Through learning

about, interpreting, and utilizing these tags, students gain access to the conversations that occur amongst professional web developers (those who Lave and Wenger would refer to as “Old-timers.”). Thereby inclusive narrative tags offer opportunities to connect with professional communities of practice.

For example, “DRY it up!” and “What’s the MVP?” were two of the most commonly referred to narrative tags. In the professional software development industry, DRY stands for Don’t Repeat Yourself and represents the professional practice of keeping one’s code “clean” by writing commonly used sets of commands only once, then referring to those commands when needed, rather than repeating them several times in other files. Students would prompt others to “DRY it up!” whenever they saw repeated code, effectively using social pressure to drive each other to practice developing software like professionals. MVP stands for Minimum Viable Product. In the industry, it represents the minimum set of features a software release can have while still serving its core product function. “What’s your MVP?” was a way of initiating a conversation with one’s peers while simultaneously reminding them to stick to the basics and code software that works rather than adding more features.

In contrast to an inclusive tag, an “exclusive” narrative tag is one that cannot be easily interpreted or understood by someone who does not participate in the class. It could be an inside joke like “Accidental Troll” (which refers to a student who’s so vocal about their opinions that they unintentionally offend people) or a phrase that has carries more weight with class members than it would with outsiders, like the “No Laptops!” narrative tag mentioned above. Exclusive narrative tags might contribute to a sense of community for the members of the class, but they also may serve to isolate students from others through an internally shared, but externally unintelligible vernacular. For instance, the word “zebra” has a specific meaning that emerged out

of a classroom discussion. If someone outside the class were to hear students referring to “zebra variables” they would not understand the reference or its true meaning. Only through a narrative description of the emergence of “zebra variables” in this class would an outsider gain access to a conversation that referred to them. I will discuss the “zebra” narrative tag in greater detail below.

The following table depicts the seventeen narrative tags I identified during my field observations and the eight classifications I used to distinguish each tag. I placed at least four codes on each narrative tag, one for each dimension described above. In a few rare cases, narrative tags demonstrated properties of two classifications within the same dimension due to the evolution of their use (e.g. emergent and intentional or inclusive and exclusive).

	Tag Classification							
	Longevity		Origination		Value		Community	
	Enduring	Fleeting	Intentional	Emergent	Conceptual	Behavioral	Inclusive	Exclusive
Accidental Troll		x		x		x		x
Little Bobby Tables	x			x	x	x		x
Tivo back	x		x			x	x	
"It's like using a calculator"		x	x		x			x
NO Laptops!	x		x	x		x		x
Open-source	x			x	x	x	x	
Script Monkey		x		x		x	x	
Error-Driven Development	x		x		x	x	x	x
"Don't forget to rake"	x		x	x	x	x		x
"self dot"	x			x	x		x	x
Demo Day	x		x			x		x
"Sleep with it under your pillow"	x		x			x	x	
Panda		x	x		x			x
Zebra	x			x	x			x
"It's not magic."	x		x	x	x	x		x
DRY it up	x		x		x	x	x	
"What's the MVP?"	x			x	x	x	x	

Table 1 - Narrative Tags and their Classifications

Rather than describe every narrative tag I discovered, I have selected three specific tags to describe in depth. I believe the following three tags serve to illustrate the functions narrative tags serve and their applications to classroom learning. For each tag, I describe its origins, what functions it serves, and how it evolved (or diminished) over time and use. I also argue why each one captures some part of the learning process specific to this domain and this group of learners.

“Zebra” Variables

In computer programming, some variables can be defined by the programmer, while others are specified by the specific programming language being used. While first introducing this concept to students during one day’s lecture, the instructor said the following:

“We can make this anything we want. We could call it Zebra...” In the place where the expression “:landmarks” was, he types in “:zebra” then continues. “...if we wanted to. We can call it anything as long as it has that colon in front and we remember that that’s what we decided to call it. But I’m not going to remember which one I called zebra, so let’s make it landmarks.”

Here the instructor is creating a list of Chicago area landmarks, and he chose to refer to this list as “:landmarks,” but he let everyone know that that was his choice not a result of the conventions of the programming language. Later a student asked:

“So can we make that zebra?” referring to another instance of the use of the word landmark (this time capitalized and without the plural ‘s’). “No,” the teacher responded, “In this case, Landmark refers to the class we created when we first generated the model. It has to remain “Landmark.”

When programmers can assign their own names to symbols and variables and when they have to obey programming conventions requires a complex appreciation of programming and how it works. Novice programmers do not yet have the discipline to easily scan lines of code and pick out which names are required and which ones can be changed. If students use their own name when a conventional name is required, something similar to the following episode may result.

A student waves his hand in the air and lets out a sigh. The instructor comes over to his computer where he is working with a fellow classmate. Instructor: “What’s

wrong?” Student: “I don’t know, it keeps saying undefined local variable landmarks” [the student is pointing at an error message on the screen]. The instructor says, “OK let’s take a look at your code... [The student switches windows to reveal the code] “...ah, yes. OK, so remember how we said some things we have to worry about what we call them and others we can call whatever we want?” The student says, “you mean the zebra thing?” Instructor: “Yes, the zebra thing, exactly. Well this is not something we can just call zebra, this is a reference to the class we created called Landmark. So capital L, no s, [he changes the code] and that should do it...” The instructor switches back to the browser window and reloads the page. It appears without errors.

In this episode the instructor asks the student about the previous lesson on naming conventions, the student responds by invoking a narrative tag referring to “the zebra thing.” Through this shared reference the instructor then repeats the lesson and demonstrates how to fix the student’s coding error. This narrative tag served as a conversational reference to the lesson (invoked by the student) and provided an opportunity for the instructor to positively validate the student even as he corrected him (“yes, the zebra thing, exactly.”)

Several other references to the term “zebra” were invoked in future class discussions by both the students and the instructor. Several weeks later a student suggested we play “spot the zebra” and the term evolved into a learning activity which later became a game.

The instructor ran the cursor over each word in the twelve lines of code as the students looked on. “What’s this one?” he said. “Zebra!” a few students called out. “And this one?” he asked. “Not zebra!” called a few more. The class

continued like this until we had gone through each word in the code and decided whether it was ours to name or not.

Zebra was an enduring, conceptual tag whose use evolved through classroom interaction. This narrative tag’s value to student learning increased as it evolved, until it became an almost daily reference, reminder, and shared verbal queue.

“It’s like using a calculator!”

Unfortunately, not every tag was as powerful or enduring as zebra. One particular tag that helped me understand programming, but did not seem to have a lasting influence on student learning in general was a calculator analogy the instructor introduced on the first day of class.

“If you’ve ever used a calculator, you’re already a programmer. When you’re using a calculator you’re feeding instructions and data into a processor and getting an output.” Using the overhead slides [shown to the right] the instructor demonstrates how the buttons that initiated mathematical operations are the “input” and the numbers are the “data.” He describes the calculator itself as a “processor” and the screen as the vehicle for the “output” when operations are completed. He concludes the lecture by repeating, “Programming is like using a calculator.”

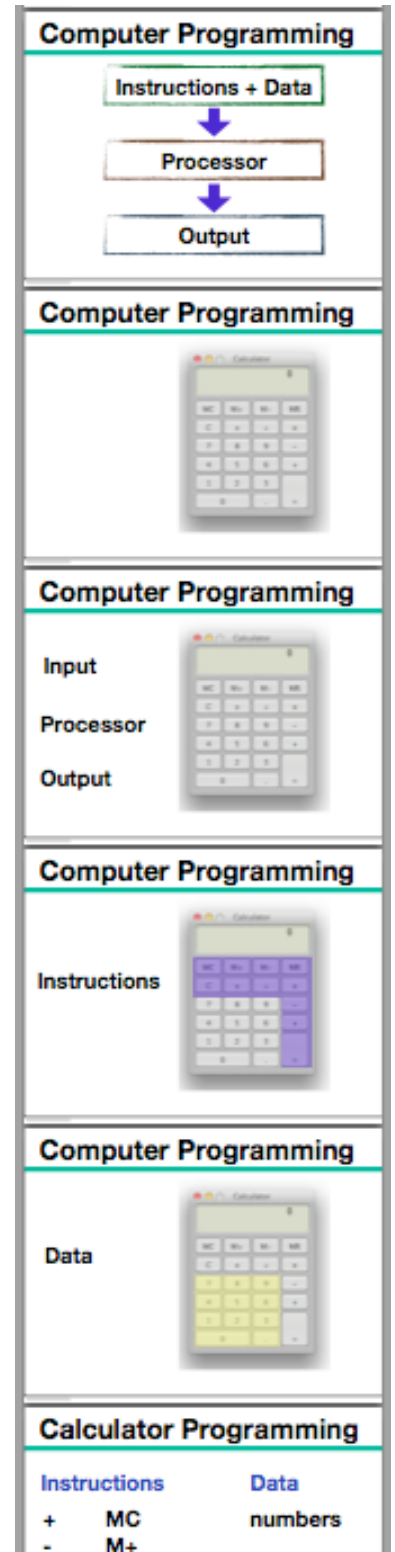


Figure 2 - The Instructors Calculator Presentation

This is an example of how a narrative tag, in the form of an analogy can bundle information, in this case a basic description of computer programming, into a common experience the entire student body is likely to share: using a calculator. I therefore coded this as a “conceptual” narrative tag. I also coded it as “intentional” since the instructor introduced it to explain a larger concept (how computer programming works) and help students relate to upcoming programming tasks.

In the following class I overheard one additional reference to the calculator analogy. While trying to explain how to program the computer to display a list of sports teams to their lab partner, one student said, “it’s like the calculator, the ‘puts’ [referring to a Ruby programming command] is the instructions, the math, and the team is the data, the numbers.”

Clearly, this student was borrowing from the analogy introduced during the previous class and using it to explain one of the first exercises in computer programming that students were asked to perform. I observed no additional references to calculators, and therefore coded this narrative tag as “fleeting.” However, there were two instances where students asked the instructor to identify which section of code referred to “instructions” and which referred to “data” indicating some evidence that the language introduced through the analogy remained in conscious use, if not the analogy itself.

“It’s not magic.”

The narrative tag that appeared to influence student learning the most originated from the instructor but also acquired emergent meanings through student use. It bundled both conceptual knowledge and suggested a lasting behavioral practice. And it offered a form of inclusion with the professional development community, while simultaneously creating the exclusivity of a shared classroom reference.

During the first week of class, the instructor said that one of his “pet peeves” is when people think of Rails (the framework being taught in the class) as magic. “No! It’s not magic. It kills me when people say it’s magic.” He articulated this sentiment twice that day. Two days later, after fixing an error by entering a single line of code, the instructor asked, “So why did that work?” A student gasped, “It’s magic!” The instructor laughed, several other students laughed, and a narrative tag emerged.

For the first few weeks students would cry “It’s magic!” whenever they didn’t understand something. This became a form of requesting help from fellow students. On three separate occasions, I observed a student say something equivalent to “it’s magic” either in conversation with another student or quietly to themselves. On each of these three occasions another student in ear shot would insert themselves into the conversation, saying “can I help?” or simply, “what’s magic?” The inquiry always prompted a discussion.

During the seventh week of class I noticed two instances of the phrase “nothing’s magic.” These were delivered in conversation as I was passing by or overheard across the room. This phrase was different than the requests for help mentioned above. This phrase seemed almost like a form of resignation. One student even said it with a sigh and a shake of his head. The narrative tag seemed to evolve from a request for help to an acknowledgement of how programming really works. “Nothing’s magic.” This shift corresponded with a change in attitudes amongst myself and my classmates. We were more overwhelmed now, more aware of all the stuff we did not know, but would have to learn in order to become truly competent programmers. Consider the following episode from the eighth week of the class.

Me: “Did you understand that talk about databases?”

Rick: [letting out a sigh] “I’m still trying to understand Javascript.”

Jim: "I'm still trying to understand Rails!"

Jim smiled and Rick laughed. I felt a sense of catharsis wash over me. It seemed I was not the only one that was struggling to keep up.

Me: "What are we even learning anyway?"

Jim: "Magic."

The "magic" narrative tag evolved from the instructors "pet peeve" to a student's request for help to a summary of everything we were learning in this classroom. It symbolizes the journey students took throughout the course. We grappled with and eventually demystified the "magic" of web development and came to appreciate both its depths and its usefulness. It seems only fitting to me that this narrative tag be referred to as "magic." For it reminds me of Jung's "Hero's Journey" (Jung, 1939) and represents a true narrative unfolding of my "learner's journey" through my education in this field.

Discussion

Since "narrative tags" is a phrase I assigned to the co-created metaphors I observed in this class, it has no other references in the literature. However, there are some similar concepts referred to in other works. For example, Sherin, Azcevedo, and diSessa (2005) describe conversational "landmarks," verbal phrases or physical artifacts representing conceptual information, which a teacher might return to in conversation with students. Certainly narrative tags display this characteristic. However, one key distinction we might draw is that landmarks represent fixed points in a conversation and their verbal references are meant to hold the place of specific meaning. Sherin et al. councils teachers to restrict their use to conform to intentions, saying, *Teachers might productively think about the properties of landmarks—for example, their proximity to a pathway and/or their relations to important conceptual issues—and then use them*

instrumentally. A teacher has less control over how students use landmarks, although she might subtly encourage productive landmarks and discourage those that have little productive function.

(Sherin, Azcevedo, and diSessa, 2005, pg. 349) Alternatively, narrative tags evolve over time and use to represent a set of meanings usually because of the way students transmit and transform them. Indeed, some of the inherent value to learning comes from the students being free to alter and adopt them through repeated use.

As alluded to earlier, we can also examine narrative tags through the theoretical framework of Legitimate Peripheral Participation (Lave and Wenger, 1991). Professional web development requires practitioners to perform computer-programming tasks, apply software engineering practices, and employ domain specific collaboration techniques. To accomplish these three objectives novice web developers must learn the knowledge and skills already available to experienced professionals. One form in which this learning occurs is through the interactions between novices and experts, or “new-comers” and “old-timers” (Lave and Wenger, 1991). The interactions between the instructor and the students in this class mimicked this dynamic and several of the narrative tags help students gain access to professional development conversations, concepts, and practices. As I noted at the beginning of this paper, such practices need to be encouraged in order to improve the practice of educating future software developers.

Conclusion

The continued study of narrative tags in classrooms could lead to a better understanding of how they serve to transfer information and professional practices to newcomers. With a better understanding of their value and power, teachers and professors could deliberately design specific narrative tags and be sure to reference them in future classes, tracking their transformations through the student body and seizing on the ones that naturally emerge as

pedagogical tools to further student learning. In order to make this possible, future investigation of narrative tags and their influence on learning will need to account for the following limitations of my current research.

Since I began with a very general observational perspective and happened upon narrative tags several weeks into the class, I was not necessarily looking for each instance of their use and may have missed several appearances of the narrative tags I have cited here and/or overlooked whole narrative tags altogether. Future studies designed to decode a classroom's narrative tags and their value to learning should examine them from the beginning and endeavor to capture each instance of their use for comparisons. Additionally, the definition of narrative tags I offer here for consideration serves only to initiate a continuing conversation. A more robust definition and discussion of narrative tags and their dimensions of classification is needed.

The next step, therefore, is to study the use and evolution of narrative tags in multiple classrooms, across multiple domains, identifying any patterns that emerge within domains or across domains. Are narrative tags a natural occurrence in other classrooms? Do they exist in other learning environments outside the classroom? What learning outcomes do they serve (or hinder) and how effective are they? The exploration of narrative tags has just begun. I invite others to join me in discovering what these verbal queues, these shared metaphors, analogies, and evolving stories tell us about learning.

References

- Begel, A., & Simon, B. (2008). Struggles of new college graduates in their first software development job. *Proceedings of the 39th SIGCSE technical symposium on Computer science education*, SIGCSE '08 (pp. 226–230). New York, NY, USA: ACM. doi:10.1145/1352135.1352218
- Bennedsen, J., & Caspersen, M. E. (2007). Failure rates in introductory programming. *SIGCSE Bull.*, 39(2), 32–36. doi:10.1145/1272848.1272879

- Braught, G., Wahls, T., & Eby, L. M. (2011). The Case for Pair Programming in the Computer Science Classroom. *Trans. Comput. Educ.*, *11*(1), 2:1–2:21. doi:<http://doi.acm.org/1921607.1921609>
- Jung, C. G. (1939). The integration of the personality.
- Lave, J., & Wenger, E. (1991). *Situated learning: legitimate peripheral participation*. Cambridge University Press.
- Murphy, L., Fitzgerald, S., Hanks, B., & McCauley, R. (2010). Pair debugging: a transactive discourse analysis. *Proceedings of the Sixth international workshop on Computing education research, ICER '10* (pp. 51–58). New York, NY, USA: ACM. doi:[10.1145/1839594.1839604](https://doi.org/10.1145/1839594.1839604)
- Prabhakar, B., Litecky, C. R., & Arnett, K. (2005). IT skills in a tough job market. *Commun. ACM*, *48*(10), 91–94. doi:[10.1145/1089107.1089110](https://doi.org/10.1145/1089107.1089110)
- Sherin, B. L., & Azevedo, F. S. (2005). Exploration zones: A framework for describing the emergent structure of learning activities. *Everyday matters in science and mathematics: studies of complex classroom events*, 329.