

The Roles of Badges in the Computer Science Student Network

Ross Higashi, Robotics Academy, Carnegie Mellon University
Samuel Abramovich, LRDC, University of Pittsburgh
Robin Shoop, Robotics Academy, Carnegie Mellon University
Christian Schunn, LRDC, University of Pittsburgh

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Abstract: The Computer Science Student Network (CS2N) is an online learning environment which uses badges – displayable student achievements – in several different capacities. CS2N Small and Medium badges are designed to provide motivation and document progress. These motivational effects persist in testing, consistent with Achievement Goal Theory. Knowledge badges document significant learning milestones and can be laid out along visual Pathways to concretely illustrate curricular flow for all stakeholders, including teachers, students, parents, employers, and even content developers. Teaching badges certify instructors as proficient in pedagogy relating to a Knowledge badge topic, and grant limited administrative rights to approve student progress. High Performance badges leverage learner performance data to identify outstanding students and instructors. Industry badges represent recognized industry certifications and constitute meaningful end goals to each curricular sequence. We believe this framework will support the long-term growth of CS2N, and can serve as a worked example for other badging systems.

Introduction

Carnegie Mellon University’s Computer Science Student Network (CS2N) is a cloud-based learning-system architecture where students, teachers, and hobbyists can earn badges and certifications as they play with, compete in, and learn about computer science and STEM-related activities.

The CS2N badge architecture was recognized as a winner in the 2012 Digital Media and Learning Competition (DML) to develop a high-quality badge system for both Lifelong Learning and Teacher Learning. The badge architecture serves multiple critical functions in CS2N by providing motivation, articulating curriculum, and serving as lasting indicators of learners’ achievements.

This document represents a detailed description of the current state of CS2N’s badge system design, including both those features which have been implemented, and those which are forthcoming. It includes a description of our badge types, theoretical underpinnings, preliminary research, detailed examples, and an overall description of how the CS2N architecture supports multiple opportunities to learn. We believe that this worked example can both provide a gateway for others to integrate learning applications directly into CS2N or develop similar badging systems for other learners.

Badge Types

Table 1 shows the different types of badges in CS2N, differentiated by primary purpose and scope.







Small	Medium	Large – Recognition		
 <p>Small Badge Motivation</p>	 <p>Medium Badge Progress</p>	 <p>Knowledge Badge Content Proficiency</p>	 <p>Teaching Badge Pedagogy</p>	 <p>Industry Badge External Certification</p>
		 <p>High Performance Badge Empirical Excellence</p>		

Figure 1: Types of Badges in the CS2N System



Figure 2: A Sample Badge

Simple design elements like the shape and imagery on the badge in Figure 2 above allow viewers to quickly get a sense for what a badge means, and estimate its relative weight as a qualification.

Badges as Motivator: Motivation Theory and Preliminary Research

The CS2N architecture is built upon relevant learning science research as well as our own investigations. For example, recent literature suggests that badges may represent a new opportunity to combine motivational tools and assessment into a single construct (Antin & Churchill, 2011; Davidson, 2011). Consequently, when designing our badge architecture, one of the things we considered was how badge-based assessments might affect learner motivation.

Behaviorist learning science theories cite motivation to learn as originating extrinsically from the learner while constructivist learning science theories propose that the best motivation to learn emerges intrinsically within a learner (Greeno, Collins, & Resnick, 1996). However, the simple intrinsic-extrinsic dichotomy cannot fully explain the complexity within learner motivation regarding badges. Motivation and learning research has found it necessary to progress beyond simple intrinsic-extrinsic dichotomies to better explain learning outcomes, and a theory of badges should be rooted in that more modern theorizing. We choose to root our work in two well-researched and highly influential theories of motivation: Achievement Goal Theory and Expectancy Value Theory.

Achievement Goal Theory (AGT) identifies critical learning goals lying within a two-by-two matrix with Mastery and Performance on one axis and Approach and Avoidance on the other (Elliot, 1999; Elliot, Cury, Fryer, & Huguet, 2006). *Mastery approach goals* reflect a desire to master something based on self-interest in the subject or skill being learned. *Performance approach goals* reflect a desire to perform demonstrably better, while *performance avoidance goals* reflect the desire to avoid the appearance of underperforming. *Mastery avoidance goals*, reflecting a desire to preserve mastery in a skill or subject, exist theoretically but have yet to be identified in most real-world contexts. AGT has proven to be a good predictor of academic performance in various academic subjects (Pajares, Britner, & Valiante, 2000).

When viewing badges through an AGT lens, several connections are possible. Students could be motivated to earn larger, more meaningful badges based on adoption of *mastery goals*. However, students could also be motivated to earn any type of badge, no matter how small, by a *performance approach goal* orientation to have more badges than their peers. But there is also some risk: While a mastery goal orientation leads to a positive learning outcome and a performance approach goal could lead to learning, students could also have a negative learning outcome by adopting a *performance avoidance goal* of earning just enough badges to avoid being identified as a low badge earner.

Another highly relevant theory to badges is Expectancy-Value Theory, which can be applied to unpacking the role badges play in performance and identity. At the top level, there are two parts: an *expectancy* (how likely will the learner be successful) and a *value* (is the outcome valued). These two are multiplied such that a learner must have both a reasonably high expectancy of success and some reason to value the outcome in order to engage (Wigfield & Eccles, 2000).

Badges could impact students by increasing expectancies for success, via positive performance feedback throughout learning. However, this is not guaranteed: if the badges are perceived as too easy to obtain, then students might attribute the badge success as indicating the character of the badges rather than their own skill development.

Preliminary Motivation Results

Our own investigations have found that learners enjoy the introduction of badges into computer based learning applications. However, these preferences do not necessarily correlate with learning performance or with acquiring badges (Abramovich, Higashi, Hunkele, Schunn, & Shoop, 2011).

We are currently performing a quantitative analysis on learner performance for a trial run of a CS2N cognitive tutor. Our preliminary results indicate that our badging intervention reduced the levels of performance avoidance goals (that typically leads to students doing poorly). In addition, the number of badges earned by individual students correlated with drops in performance avoidance goals. In other words, our preliminary study indicated that the number of badges earned in an online learning tool predicted a decrease in negative learning goals.

We are continuing to pursue this line of research through future studies including an experimental manipulation of the presence of badges with monitored pilot groups in CS2N activities.

Badges as Curriculum Map: Pathways and Badge Maps

Badges are the key tool for organizing and understanding learning trajectories within CS2N. As students participate in CS2N activities, they progress down at least one Pathway, earning badges as they go. A CS2N Pathway is a curricular continuum from entry-level skills to industry certification or other formal recognition.

Each Pathway is developed in collaboration with the industry group or commercial partner who owns and controls the end-goal certification. A high-level Backward Design approach maps out important concepts leading up to the final goal, and Knowledge Badges are laid out to mark major content milestones. As it is the nature of Badges to be “earned”, these key points in the curriculum automatically become assessment sites.

Content modules from CS2N’s vetted pool of activities are chosen to deliver specific instruction aligned with these markers, and the Pathway is complete.

Pathways are illustrated using Badge Maps like the one in Figure 3. Each important learning milestone along the way is represented by its Knowledge Badge in the diagram. The current step is expanded to show Progress Badges as well. The student’s past and current progress are highlighted.

Badge maps provide clarity on the long-term value of student accomplishments, specify the “reward” outcome of a learning strand, illustrate a feasible progression toward it, and motivate students to continue pursuing it.

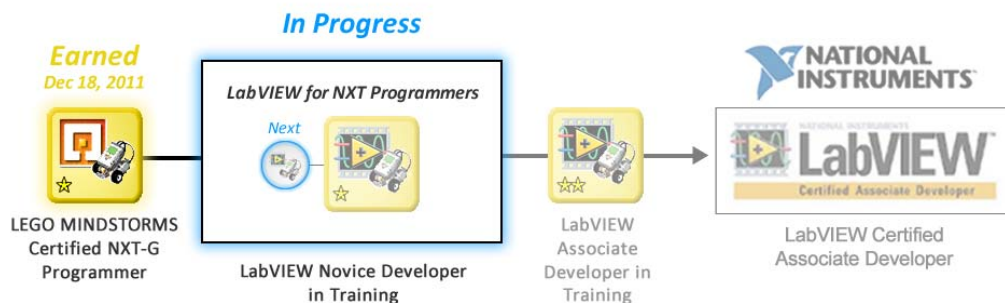



Figure 3: A Badge Map Illustrating a Curricular Pathway

Badges as Evidence Trail: Programming Badge Example

To unpack the processes which govern and moderate badge issuance, consider the badge in Figure 4 below (as viewed from the CS2N website):



LEGO MINDSTORMS Certified NXT-G Programmer
Master LEGO MINDSTORMS NXT-G programming concepts including Movement, Sensors, Program Flow, Logic, and Data Hubs.

Earned: 12/18/2011

Details ▾

Requirements:

- ✓ **(Bronze)** Complete the NXT-G Programming Mastery Exam with a final score of 90% or higher ([View exam](#))
- ✓ **(Gold)** Complete the NXT-G Build-a-Challenge Project and receive an instructor's approval ([View submission](#))

Approved by [D. Williams](#) on behalf of [LEGO Education North America](#)

Pathways: This badge is a step toward...

- 🔍 [LEGO Education NXT-G Accomplished Programmer](#)
- 🔍 [National Instruments Certified LabVIEW Associate Developer](#)

Valid through: This badge does not expire.

Figure 4: An Earned Badge Detail View

The badge's icon, name, date of issuance, and basic description appear at the top. A Details roll-down reveals additional information describing the badge's exact requirements, links to the Pathways in which it appears, and its expiration date if applicable.

Pathways

Clicking on a Pathway link in the Badge details shows the Badge Map for one of the Pathways that this Badge appears in (recall Figure 3 from earlier).

Earning Badges

CS2N encourages automated detectability and awarding of badges to enable self-paced learning whenever possible. The first Requirement listed for this badge is automated – completing a standard computer-administered online exam. Completing this exam satisfactorily earns the student a “bronze” level certification for this badge.

The second Requirement notes that a human instructor further approved credit for completing a specific challenge. Human instructors remain vital to effective content delivery in many settings, and CS2N has an entire top-level category of Teaching Badges dedicated to the development of their pedagogical capabilities. These same Teaching Badges grant instructors limited administrative rights within CS2N to approve a student's competency toward earning a content badge.

The Teaching Badge thus serves a dual purpose to promote the teacher's desirability as a candidate in a hiring decision: she will be both certified as capable, AND able to sign off on student progress for credit within the CS2N system. The system, meanwhile, benefits from added robustness against “gaming” by requiring human gatekeepers to sign off on key points in the process. A student who completes the additional requirements to procure this second, human-verified level of achievement is awarded a “gold” level certification.

Once a teacher earns her Teaching certification, she is able to approve badges “on behalf of” affiliate organizations which have authorized her to do so. This affiliation with a well-known issuing

organization or designated PD provider strengthens the badge's claim to legitimacy, and provides promotional incentive for the organization in the process.

Badges as Assessment

Traditionally, assessment of learning has been represented by the grades assigned in traditional schooling or through certification of skills by non-academic organizations. While assessment of learning is key to maintaining accountability in our education systems, it also comes with challenges. The design, difficulty, and frequency of assessments can have a large impact on learner motivation – especially for life-long learning (Boud, 2000). Repeated standardized exams have been found to have negative effects on student career goals and ambitions (Stiggins, 2002).

In several ways, Badges represent an opportunity to fulfill what advocates for assessment reform have desired: assessments that inform education stakeholders while also directly contributing toward a student's motivation to learn. Lorrie Shepard in her seminal address to the American Educational Research Association in 2000 called for assessments that are on-going, provide targeted feedback to the learner, are transparent, and support the creation of an assessment learning culture.

CS2N Badges are designed to preserve or boost motivational effects while also aligning with many of these assessment reform concepts. Regularly-spaced Motivation badges tied to micro-level engagement or content achievements provide on-going formative feedback. Mid-level, content-aligned Progress badges provide indicators towards mastery (i.e. targeted feedback) for individual learners. Knowledge Badges marking major achievements provide transparent assessment since their requirements are presented to all participants. Lastly, badges are highly shareable, and CS2N is committed to making its Badges part of the Mozilla Open Badge ecosystem, creating the potential for badge-based assessments to merge into a greater learning culture.

Badges as Feedback

When using CS2N's activities in a classroom, teachers and students register accounts in the system and associate themselves in a Class group. This structure naturally aligns with the teacher-student relationship, and allows CS2N activities to provide the teacher with appropriately privileged information for assessment.

The existence of this relationship within the system leaves CS2N uniquely situated to facilitate two additional methods of performance-based badging: automated statistical recognition and student-to-teacher recognition.

Automated recognitions are awarded for teachers who have statistically significant positive effects on their students. Algorithms sifting through users' progress within the CS2N system can, for example, identify teachers whose students perform significantly better on a quiz, compared to students without instructors. These teachers are automatically awarded a High Performance Teaching Badge by the CS2N system.

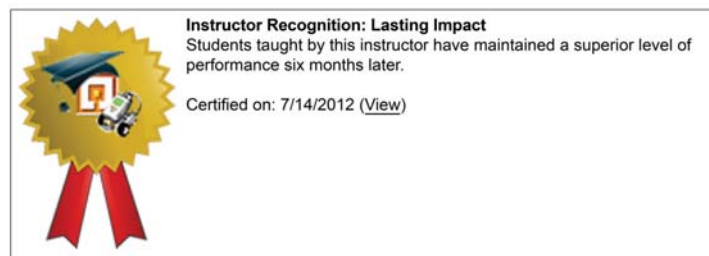


Figure 5: A High Performance Badge

Many other statistical and data interaction features are detectable and awardable: a teacher whose students maintain high rates of participation after six months (see Figure 5 above), a teacher who introduces a large number of new students to CS2N through his or her class, or a teacher who successfully guides a class through an activity after attending PD for it.

CS2N's awareness of the student-teacher relationship enables additional future channels for teacher recognition: by students and by other teachers. For instance, a student could choose to recognize a teacher for help given, awarding a small badge that includes the student's description of what helped. Alternatively, another instructor could note that a student is particularly well-prepared for a course, and credit that student's earlier teachers. CS2N would keep track of the number of times these small badges are awarded, and eventually confer larger recognitions (see Figure 6 below).



Figure 6: A Student-to-Teacher Feedback Badge, and a Larger Cumulative Recognition

Badges as a Global Design Document

Badges, by virtue of their high visibility and concretely defined requirements, inherently communicate expectations. This quality is valuable long before a single badge is awarded to a student or teacher. Badges in CS2N serve a critical communication and coordination role in bringing together organizations that collectively reach hundreds of thousands of teachers every year.

In order to reach as many learners as possible, CS2N collaborates with an extensive network of dissemination partners such as LEGO Education, FIRST LEGO League, the Boy Scouts, and Project Lead the Way. These organizations maintain professional development networks at scale that are already tuned to work with their particular content areas.

The end goal of the experiences these teachers train for and deliver is defined by the Industry badges that form the highest tier in the CS2N hierarchy. The idea of aligning content and delivery to industry needs is hardly new. However, the process by which they are connected in CS2N is aided by the very badges that will someday be offered to students.

Each badge forms a contract of sorts at the points where the various partners interact – the Industry badge is defined by industry partners and deconstructed by content partners to determine the best lessons and activities to use. Knowledge badges mark major learning milestones along the way, corresponding to major assessment points. Teaching badges align with the Knowledge badges, and allow dissemination partners to design appropriate curricula and professional development for their teachers. Teachers assess progress against the Badge pathway and use it to communicate expectations and progress to students and parents accordingly.

The Badge Map created during development may thus be the first time ALL stakeholders – employers, educators, administrators, education experts, parents, and students – will all be working from the same literal document in a form they can all understand.

Conclusion

Our immediate hope for this paper is that it serves as a high-quality worked example of a badge system to advance the discussion of badge-based systems at all levels. The design features described in this paper are under development by CS2N as of early 2012, and will be rolled out over the course of the following year, then iteratively improved throughout the system's deployment. Our initial design is geared toward Robotics and CS-STEM education, and we welcome collaboration with other STEM applications. But we also believe that the continued advancement of the system will be as much a result of interactions with the greater badge, gaming, and education communities as from lessons learned in our own pilot implementations. We see this paper as a way to share our own architecture and discoveries, as well as subject it to the critique within these communities that will be vital if badge architectures are to achieve widespread legitimacy as a valuable educational tool.

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