

Source Academy

A Web-based Environment for Learning Programming with SICP

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ABSTRACT

The Source Academy is a community-built immersive online environment for learning computing with the book *Structure and Interpretation of Computer Programs* (SICP). An interactive version of the textbook is integrated into the system, and the programming environment of the Source Academy allows learners to focus on SICP-specific sublanguages of JavaScript (Python and Scheme versions in preparation). The environment includes tools to support SICP's mental models for computational processes and data, including a stepper that animates the substitution model of Chapter 1, a data visualizer that supports the box-and-pointer diagrams of Chapter 2, and a visualizer for the environment model of Chapter 3.

The system is web-based (no software installation required) and supports dynamically loadable plugins (modules) for programming with graphics, audio, image, and video processing. An extension called Source Academy @ X provides Learning Management System features such as the management of programming assessments and their manual and automatic grading. Source Academy @ X includes gamification components such as achievements, contests, levels, and a game that offers a narrative to contextualize the assessments.

The 45-minute demo provides CS educators with an overview of the Source Academy, including its tools, modules, and textbook integration, the Source Academy @ X extension for course management and a preview of Python and Scheme versions.

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1 OVERVIEW

The core of Source Academy is a web-based development environment that lets learners write programs in an editor and run them interactively. Along with the usual syntax highlighting, refactoring, and navigation features, the program editor of Source Academy visualizes the scope of name declarations, which comes in handy when teaching the rules of JavaScript's block scoping. Immutable permalinks to programs facilitate communication among learners and instructors. The editor features collaborative sessions where a

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user can invite others such that they can jointly develop programs, a useful feature for small-group learning. The extension Source Academy @ X provides Learning Management System (LMS) features such as the management of programming assessments and their manual and automatic grading and includes gamification components such as achievements, contests, levels, and a visual-novel-style game that offers a narrative to contextualize the assessments.

Both Source Academy [9] and its extension [10] are free software built by the community of learners and course facilitators of the course CS1101S, the CS1 course required for computer science undergraduates at the National University of Singapore (NUS). Details of this community-based approach are covered in [2].

2 BASE SYSTEM

Sublanguages

The first two editions of SICP used the minimalist language Scheme in their programming examples and employed only a carefully selected subset of Scheme's features. Similarly, SICP JS [1] only uses a small subset of JavaScript. The JavaScript sublanguage that includes only the features needed for SICP JS Chapter 1 is called Source §1, the sublanguage for Chapter 2 is called Source §2, etc.; see [3] for details on this JavaScript-sublanguages approach.

To support this approach, Source Academy allows learners to choose the sublanguage they wish to focus on, including full JavaScript and HTML5, with customized syntax highlighting and error reporting. Source Academy @ X lets instructors specify which sublanguage is to be used for a specific programming assignment.

Tools for mental models

The environment includes a stepper [7] that animates the execution of programs written in Source §1 and 2 according to the substitution model described in SICP Chapter 1. The stepper features small-step and larger-step execution, redex highlighting, and explanations.

A data visualizer allows learners to display box-and-pointer diagrams for pairs and lists as introduced in SICP Chapter 2.

The central mental model for program execution in SICP is the environment model. Source Academy includes an environment model visualizer that displays environment diagrams consistent with the graphical notation presented in the book. Learners can use the visualizer to view the diagrams that depict the environment structure up to a specified break point. Data structures (pairs and arrays) are displayed using box-and-pointer diagrams.

Media and robotics

To take advantage of the media-rich world of web programming, Source Academy supports dynamically-loaded modules for audio

processing (for details see [6]), 2-D graphics following [5], 2-D and 3-D curves, constructive solid geometry (CSG), and video processing. LEGO Mindstorms robots can be programmed with Source Academy @ X by registering the robot wirelessly with an integrated message queuing service (for details see [4]). After supplying suitable access credentials, learners can run their programs on the robot using the familiar programming environment of Source Academy @ X and with the same collaborative editing option.

Textbook integration

SICP JS is integrated in the Source Academy. The programming examples are clickable and allow casual interaction and experimentation without distracting from the flow of reading. Permalinks let learners and instructors easily refer to textbook paragraphs.

3 EXTENSION SOURCE ACADEMY @ X

The Source Academy as described so far is a single-page application that doesn't require a backend, apart from the web server that hosts it, such as the canonical deployment on GitHub pages, available at [9]. The LMS extension of Source Academy—Source Academy @ X—comes with a backend for storing and grading learner programs and for managing the gamification components. Like Source Academy, this extension is free software. To use the canonical deployment of the extension, available at [10], interested instructors are invited to create an administrator account and register students.

Assessment management and grading

Source Academy @ X includes a management component for programming assignments that allows administrators to upload assignments in XML, configure their opening and closing times, and specify their manual and automated grading process. The system includes a dashboard to monitor the status of assessment grading that allows administrators to identify facilitators who need reminders of the importance of timely feedback.

Game

An optional visual-novel-style game integrated with Source Academy @ X supplies a playful context for homework assignments of a course. The game follows a coherent course-long plot to which the homework assessments refer. Provided that learners can muster sufficient suspension of disbelief, they derive an additional sense of meaning, urgency, and accomplishment from the game. It features conditional control of game chapters, forks and loops in the plot, and extensive support for developing and testing the game plot and assets. All game assets (scenes, avatars, collectibles, etc) are original and designed by NUS undergraduate students.

Achievements

Source Academy @ X can be configured to display learner achievements and to allow instructors to incentivize learners for excellence, consistent effort, and improvement relative to past performance with badges and awards. A system of achievement levels provides learners with continuous additional motivation. Instructors can review the achievements record of learners.

Contests

As outlets for learner creativity and for the occasional comical relief, Source Academy @ X includes facilities for setting up programming contests, for letting users cast their votes for the most popular entries, and for identifying the winning entries based on popularity and program size. (Contest entries are penalized by a factor that grows exponentially with their length.)

4 STRUCTURE OF DEMO SESSION

The audience gets a detailed overview of the most important system features and a clear idea how these features benefit learners and instructors. The system is free software, built by the community of learners and instructors who use SICP in their classes. The demo shows how interested developers can use the Source Academy infrastructure to support programming languages other than JavaScript and will include prototypes of Source-Academy-based environments for Scheme and Python. For those who would like to get involved in the Source Academy and SICP community [2], the demo concludes with details of the structure of the community, the repositories managed with the GitHub organization source-academy [8], and the available documentation [11].

5 PRESENTATION APPROACH

I will prepare a short demo invitation and work with the SIGCSE TS organizers to make the invitation accessible to symposium participants. In the invitation, I will ask how I can make the demo accessible and comfortable for all attendees, giving them the opportunity to express any needs or preferences via email, ahead of the demo. The demo will provide opportunities for audience interaction for asking questions using a microphone and an electronic channel.

REFERENCES

- [1] Harold Abelson and Gerald Jay Sussman. 2022. *Structure and Interpretation of Computer Programs, JavaScript edition*. MIT Press, Cambridge, MA. adapted to JavaScript by Martin Henz and Tobias Wrigstad with Julie Sussman.
- [2] Boyd Anderson, Martin Henz, and Kok-Lim Low. 2023. Community-driven Course and Tool Development for CS1. In *Proceedings of the 2023 ACM SIGCSE Technical Symposium on Computer Science Education*. ACM, Toronto, Canada, 7. <https://doi.org/10.1145/3545945.3569740>
- [3] Boyd Anderson, Martin Henz, Kok-Lim Low, and Daryl Tan. 2021. Shrinking JavaScript for CS1. In *Proceedings of the 2021 ACM SIG-PLAN SPLASH-E Symposium (SPLASH-E '21), October 20, 2021, Chicago, IL*. ACM, Chicago, IL, 87–96. <https://doi.org/10.1145/3484272.3484970>
- [4] Boyd Anderson, Martin Henz, and Hao-Wei Tee. 2021. Ruggedizing CS1 Robotics: Tools and Approaches for Online Teaching. In *Proceedings of the 2021 ACM SIG-PLAN SPLASH-E Symposium (SPLASH-E '21)*. ACM, New York, NY, 82–86. <https://doi.org/10.1145/3484272.3484969>
- [5] Peter Henderson. 1982. Functional Geometry. In *Conference Record of the 1982 ACM Symposium on Lisp and Functional Programming*. ACM, New York, 179–187. <https://doi.org/10.1145/800068.802148>
- [6] Martin Henz, Shang-Hui Koh, and Samyukta Sounderraman. 2021. Teachable Moments in Functional Audio Processing. In *Proceedings of the 2021 ACM SIG-PLAN SPLASH-E Symposium (SPLASH-E '21)*. ACM, Chicago, IL, 65–70. <https://doi.org/10.1145/3484272.3484967>
- [7] Martin Henz, Thomas Tan, Zachary Chua, Peter Jung, Yee-Jian Tan, Xinyi Zhang, and Jingjing Zhao. 2021. A Stepper for a Functional JavaScript Sublanguage. In *Proceedings of the 2021 ACM SIG-PLAN SPLASH-E Symposium (SPLASH-E '21)*. ACM, Chicago, IL, 71–81. <https://doi.org/10.1145/3484272.3484968>
- [8] Source Academy. 2023. <https://github.com/source-academy>.
- [9] Source Academy. 2023. Source Academy. <https://sourceacademy.org>.
- [10] Source Academy. 2023. Source Academy @ NUS. <https://sourceacademy.nus.edu.sg>.
- [11] Source Academy. 2023. Source Academy Documentation. <https://docs.sourceacademy.org>.