Supporting Individual and Collaborative Authoring of Interactive Narrative in Creative Coding

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Creative coding is a type of computer programming that facilitates self-expression and creativity through media computation. In this paper, we explore storytelling using text-based programming for creative coding. In particular, we compared individual and collaborative approaches to storytelling in an introductory computer science class with 49 students using *p5.js*. Results show that students preferred working on the individual over collaborative coding because they feel more ownership over the story and can focus on applying the learned coding concepts without worrying about communication or coordination. Students, however, preferred reading collaboratively authored narratives as they found them more interesting than the individually authored narratives. We provide a qualitative analysis of the narrative structures produced by the collaborative coding, to explain the potential reasons behind this preference. We also contribute a set of design implications and recommendations to improve the administration of and experience with individual and collaborative storytelling with text-based programming.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: collaborative storytelling; interactive narrative; creative coding

ACM Reference Format:
Anonymous Author(s). 2021. Supporting Individual and Collaborative Authoring of Interactive Narrative in Creative Coding. *J. ACM* 37, 4, Article 111 (August 2021), 22 pages. https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

Creative coding (also known as media computing [18]) is a "type of computer programming in which the goal is to create something expressive rather than functional" [41]—with visual graphics as a common example of its product. The traditional approach to teaching introductory programming concepts relies heavily on text-based calculation problems where the only output is text output in the programming environment console. In contrast to the traditional approach, creative coding engages students in creative tasks, such as creating games [4] and manipulating pixels of an image to create their own filters [41]. In other words, students learn programming in a much more media-rich way, making programming more interesting, relevant, and engaging [17, 38, 49] and helping to broaden participation and diversity in computing by appealing to students who enjoy creative activities and find the traditional programming focus on math and engineering problems overwhelming and/or difficult to relate to [38, 46, 47]. One type of creative coding is storytelling. Storytelling is an activity that has been shown to allow students to exercise their creativity [5] while practicing their coding skills. Prior work (e.g., Kelleher [20], Wolz et al. [46]) has shown that coupling storytelling with programming on block-based programming platforms (such as Scratch [26, 31]) can motivate students and help them build more confidence and positive attitudes towards computing. However, Scratch is aimed primarily at children and adolescents

0004-5411/2021/8-ART111 $15.00
https://doi.org/10.1145/1122445.1122456

(ages 8 to 16) [26, 45]. For older students, Reas and Fry [32] introduced *Processing*—a text-based programming language that uses the same language conventions and syntax as Java but allows one to create visual, interactive programs like in Scratch [32]). For the creation of web-based interactive graphics, *p5.js*, a JavaScript library offering the same functionalities as *Processing*, was also developed [29]. Students use these languages and libraries to quickly and easily create visuals and interactive graphical programs. In the process, they learn about the syntax and conventions of the programming language as well as the standard programming concepts that are typically taught in introductory programming courses [18].

Little is known about how to support collaborative storytelling when using these text-based programming. In collaborative storytelling, individual authors have to add part of the story following pre-defined constraints (e.g., theme, actions)—which requires some level of sacrifice in their creativity—in order for the parts, when presented as a whole, to form a coherent story. Finding a proper balance between design constraints for story coherency and individual's creative freedom is an important research question that has been studied in many collaborative storytelling contexts where stories have been authored in English [13, 22, 25]. But how is this handled when stories need to be authored with text-based programming? How do we balance design constraints and creative freedom in this context? How do design constraints impact creative freedom and the collaborative authoring experience? There are many unanswered questions.

Our work aims to fill this gap by exploring two types of authoring procedures—individual and collaborative—for creating stories with code, using *p5.js*. In particular, we deployed a series of creative coding assignments to an introductory computer science class with 49 students. Results show that students preferred the individual over collaborative coding because they can take ownership of their stories and focus on applying the learned concepts without concerning themselves with communication and coordination. However, students preferred to read collaboratively authored narratives as they found the collaboratively authored narratives more interesting. We provide a qualitative analysis of the narrative structures produced by the collaborative coding, to explain the potential reasons behind this preference. We also contribute design implications and recommendations to improve the collaborative coding experience.

2 RELATED WORK

2.1 Collaborative Storytelling

Design Dimensions of the Collaborative Authoring Process. Collaborative storytelling is mediated through a diverse set of tools, settings, and environments [1, 10, 22]; they influence how collaborative processes are designed, administered, and experienced. Thus, collaborative storytelling approaches can be characterized—and distinguished—along several dimensions: (1) what the story was authored in (e.g., text, code); (2) how the collaboration was done— Were stories created with authors adding stories in relays or without following a particular sequence? Did authors collaborate synchronously, semi-synchronously, or asynchronously? Were the authors collocated or remote from each other when collaborating ?; (3) what format the resulting story had (e.g., text/multimedia-based, interactive/non-interactive, branching/non-branching); (4) whether collaborators contributed part(s) of a story or an entire story; (5) how many storylines were generated.

Collaborative authoring processes can be characterized as either linear or nonlinear [24, 25]; the differentiating factor has to do with whether a next contributor has to add to an existing story (linear) or edit anywhere in the story (nonlinear). A few nonlinear authoring approaches (also referred to as hypermedia approaches [22, 25]) exist. In one type of nonlinear approach, authors individually work on the part(s) of a story at their preferred time; their contributions are later

combined to form a coherent story. For instance, Désilets and Paquet developed WikiStory which adopts a Wiki model. It allows members to write or edit anywhere in the story on their own time, enabling nonlinear collaborative storytelling [14]. With One Million Monkeys Typing, each story has three possible paths and a writer can intervene at any time to write along an established path or create a new path [39]. The linear approach, on the other hand, has authors work in sequence where authors add scenes one after the other. In Folding Story [43], each writer takes a turn and contributes a line of a story (120 words or less) by looking only at the previous writer's line. Fabulate [42] is a collaborative book project, with each writer expanding on the story by adding up to 500 words to where the last published entry left off. While writers are free to introduce new characters and situations, they are asked to sustain the overall theme of the book. In StoryMash, each writer can submit a chapter and have anyone pick up the story from there [28]. Antle reported the development of Storybuilder, a comix-style version of the add-a-sentence-to-a-story activity [1]. The resulting story, however, was rather similar to interactive narratives we explore in this study as it featured one scene at a time with readers able to flip through to see next scenes as opposed to traditional comic book style where more than one panels (scenes) are presented in one page.

Each approach to collaborative storytelling has its strengths and weaknesses [15, 22]. The nonlinear approach is convenient for authors as they can work at their own pace when it is convenient for them. However, they need to work with some constraints that may limit the authors' freedom and creativity; these constraints are necessary because if authors freely create stories of varying lengths with different themes, combining story contributions to form a single, coherent story becomes difficult, if not impossible. The linear approach, on the other hand, does not have constraints with regard to coherency formation and can achieve coherency more easily as authors work together or take turns to expand the story. The main story theme and storyline are more likely to have been shared or discussed between the authors. Thus, authors building on the story would not make as significant a change as those in nonlinear approaches where the exchange between the authors may not be as guaranteed. This obviously results in the need for coordination among the authors [22]. For instance, when authors work on the same script or design simultaneously, they need to communicate with each other in real-time. If co-located, the authors can simply discuss; if authors are authoring remotely, they need a system that supports real-time communication or other mechanisms to coordinate turn-taking.

The Challenges of Structuring Collaboration. Collaborative storytelling is known to require a compromise between creativity and story coherency [13, 19, 25]: authors cannot fully exercise creative freedom when operating under design constraints, such as a predefined story theme or storyline, for a coherent story. Prior work has shown that some level of constraints are inevitable to ensure that collaborative storytelling yields a coherent story [22, 23]. Kim et al. explored different constraints and approaches to administer these constraints [22]. They tested a collaboration model in which authors are separated into leading and supporting roles; the lead author decides on the constraints for the supporting authors and supporting authors contribute their ideas within those constraints. Specifically, the system that embodied this idea had lead authors use prompts to define the constraints and goals for supporting authors. For instance, the prompt may ask supporting authors to contribute a paragraph describing how two characters met; the lead author then decides what to do with those ideas. An issue with this model is that the lead authors take on too many responsibilities. As a result, the model does not scale and lead authors can create bottlenecks. As we will explain in more detail in the rest of this paper, we had to conceive a model that guarantees a bottleneck-free collaborative writing process and equal roles for all students. Our work expands upon prior work on interactive narrative and collaborative storytelling as we explore collaborative storytelling in the context of creative coding and propose collaborative authoring processes that can be administered in this context.

In our study, students are tasked with using programming to create an interactive story. This adds another layer of complexity to the predominant form of collaborative storytelling in which students typically write in their natural language (e.g., English), which is much easier. While Burke and Kafai's work also involved authoring with programming, the significant difference is that they used Scratch, which, as a block-based language, allows syntax-error free experience. Students using text-based languages to create interactive graphics, as in our case, faced a number of additional challenges: memorizing JavaScript conventions and syntax, understanding how to use *p5.js*, and debugging syntax and logic errors. Thus, our work contributes methods for supporting collaborative storytelling in a more challenging context of creative coding.

2.2 Creative Coding

Context and Domains. Framing computer science in a familiar context is a popular instructional technique [41]. Some of these contexts include games/animation [31, 48], music [6], storytelling [7], physics-based simulations, robots [36], and art [17, 18]. Students use programming to create music, manipulate objects in simulations, develop games and stories, draw visualizations, control robots, and design animations. Prior work shows this contextualization approach [3] facilitates meaningful learning, motivates students about programming [20], improves retention [37], is more accessible to students [17], and encourages collaborative learning [27].

Storytelling in Creative Coding. One of the well-known research projects that explored storytelling as a means to encourage and motivate computer programming is Storytelling Alice [20]. While both Alice and our work engage learners in storytelling with programming, they are different in that Alice was a drag and drop code editor that leveraged block syntax to remove syntax errors—this was because they were targeting students in K-12 [20]. Also, Alice engaged learners in creating 3-D animations as opposed to 2-D interactive narratives; this requires extensive software development and maintenance—its development recently stopped and the software is no longer supported. On the contrary, developing 2-D interactive narratives with creative coding libraries (e.g., *p5.js*) can now be done much more easily and quickly.

Burke and Kafai [7] explored how creative coding using Scratch, a block-based programming language, can help middle school students develop their storytelling and creative writing skills. Wolz et al. [46] had middle school students create news stories using Scratch and found the activity helped them develop positive attitudes towards computing. Fields et al. [16] explored a way to make interactive storytelling using Scratch a "collaborative" experience by allowing children to receive feedback from the Scratch community on their draft before finalizing their stories. Our work differs in that the aim is to understand the differences between collaborative and individual storytelling using a text-based (instead of block-based) programming language.

3 CASE STUDY

We conducted a case study at an introductory computer science course at an R1 university in North America, where students were given individual and collaborative storytelling programming assignments. We used both quantitative and qualitative methods to analyze the impact of the different authoring procedures on the experience and generated products (i.e., stories) of collaborative storytelling using text-based programming. Our inquiry is grounded by two research questions:

- **RQ1:** What are students' experiences with the individual vs. collaborative authoring of interactive narratives in creative coding?
- **RQ2:** What kinds of interactive narratives did students produce under the constraints of the individual vs. collaborative authoring process?

Below, we describe the course setting, storytelling assignments and how they are designed, our data collection instruments and data analysis methods, and results.

3.1 Course

At XYZ [1] university, students in the Digital Arts Program are required to take two introduction to computer science courses (I & II). While open to any non-CS student, these courses were designed primarily for Arts students. The course employs a creative coding approach in which students use *p5.js*, a JavaScript library for creative coding. Students in this course learn the fundamentals of computer programming by creating games, animations, and interactive graphics such as interactive narratives.

Courses at XYZ university are 13 weeks long and this study took place during the Spring (Jan-May) semester of 2020. This course had eight assignments, which counted for 24% of the final course grade, and students could drop one assignment. The storytelling assignments (A6, A7 and A8) were administered as the last three assignments in the course, beginning in week 6.

3.2 Participants

Among a total of 49 students who took the course, 42 students answered our post-study survey. 41 students (15 M, 26 F; no student chose Non-binary) permitted the use and analysis of their survey responses, labs and assignment submissions, and grades for research. Most of the students were in Arts (28), and the rest were in Science (9) and Health Science (4). Most students were undergraduate students in their first and second year (18 First, 15 Second, 4 Third, 3 Fourth), with the exception of one graduate student from Health Science who was returning for a post-degree program. The majority of students said they were taking the course to meet degree requirements (28), while the rest (13) were taking the course out of interest in learning programming. Half of the students (21) were retaking the course, whereas the other half (20) was taking it for the first time. In terms of their experience with programming prior to the course, most students had limited experience (15 No Experience, 18 Several Hours/Days, 8 Several Weeks/Months). Students were evenly split in terms of their interest in learning programming prior to the course (15 Not Interested, 16 Interested to a certain degree, 10 Highly Interested). Prior to the course, a little more than half of the students (25) regarded learning programming as "difficult," while some number of students (14) regarded it as "manageable" and very few (2) "easy."

One of the authors was an instructor for this course. Therefore, following ethics guidelines, we had another author, not affiliated with the course, manage the administration and collection of survey responses, as well as consent forms, which asked students whether we could use their data for research purposes. Also, to ensure no undue influence, we emphasized that students' decisions regarding consent would not impact their grades and would not be known to the instructor until *after* their final grades had been submitted.

3.3 Design Considerations

During the course, students were given three storytelling assignments—assignments 6 (A6), 7 (A7), 8 (A8)—where they were required to create stories in the form of interactive narratives using text-based programming and within a tight timeline (i.e., within a week). In addition to authoring a story, students (who are novices learning how to program) needed to ensure their programs ran without bugs and satisfied implementation requirements. These unique circumstances led to the following design considerations in how we structure the authoring processes that students are asked to follow for each assignment:

[1] Anonymized for review

D1: Minimize coordination with other students (i.e., allow students to author their stories at their preferred time). Given the tight timeline, it is difficult to require students to wait for other students. If students are asked to write in relays, this can lead to a bottleneck situation when a student fails to add their story on schedule or leaves the program in a broken state, making it necessary for the next student to debug their mistakes. Writing in relays can create scheduling conflicts, an additional overhead that can make the experience frustrating. Thus, we needed to develop an authoring process that allows students to work at their preferred time.

D2: Minimize the influence a student's error has on another student. Text-based programming presents significant challenges, especially for non-CS students, as they are prone to writing code with many syntax and logic errors. Even for individual assignments, students can get stuck and require interventions from an instructor or teaching assistant. Having multiple students code at the same time not only increases the probability of creating a program with bugs, but also can complicate the debugging process. Taking these into account, we needed to try to minimize the impact that students' errors can have on others.

D3: Ensure a coherent storyline. Achieving coherency in a collaboratively authored story is a common goal in collaborative storytelling [13, 22, 25]. Achieving coherency can be more challenging with multimedia-based stories, compared to text-based stories, because multimedia-based stories need to keep background and interaction mechanisms consistent and sensible across the scenes. Thus, we needed to create structure in the assignment to help students achieve this consistency.

D4: Maximize creative freedom. In addition to ensuring a coherent story, maximizing creative freedom is important for optimizing the collaborative storytelling experience. As mentioned above, creative freedom can negatively impact story coherency. While we cannot guarantee complete autonomy as in individual assignments, we needed to ensure a reasonable amount of creative freedom for the students.

3.4 Storytelling Assignments

All storytelling assignments focused on the application of the learned concepts up to that point. Fig. 1 shows the Processing IDE (right) and the browser (left) rendering the code in Processing. At a high level, in all three storytelling assignments, students were asked to download the basic starter code (i.e., a template for the interactive narrative), open it with the assignment-specific IDEs, update the starter code, and submit the updated code. What differs between the three assignments is the authoring procedure that the students are asked to follow.

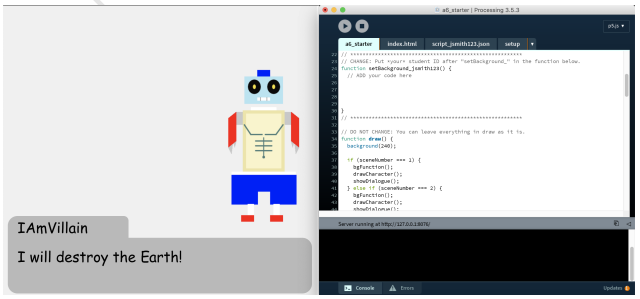
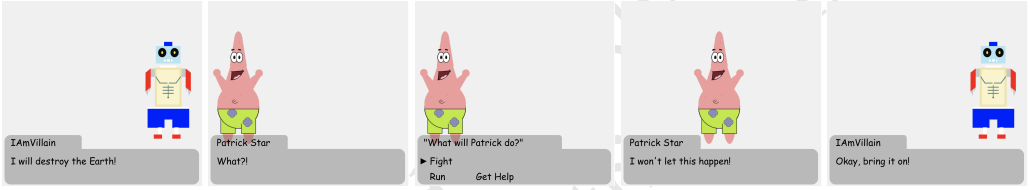


Fig. 1. Browser (left) and Processing IDE (right), showing the starter code for assignment 6

In assignments A6 and A7, students followed an **individual** authoring process where they created narratives independently. In assignment A8, students followed a **collaborative** authoring process where they worked in relays to construct the story. The main difference between A6 and A7 is that in A6, students' individual stories were assembled by the instructor to form a larger narrative

that remixed different story components (e.g., character, background, theme, dialogue). Though working individually, as shown in Fig. 3, students in fact collectively authored a single narrative with multiple story lines. In order to combine narratives from different authors and ensure story coherency even after scene remixes, it was necessary to impose certain constraints (e.g., on the length or theme of the story) that students were asked to follow. In A7, students also constructed narratives independently, but without the design constraints imposed in A6. For conceptual clarity, we refer to A6 as individual storytelling with high constraints and A7 as individual storytelling with low constraints.

Individual Storytelling with High Constraints (A6). In A6, students created stories independently [D1] (and were graded independently [D2]) and the instructor subsequently combined the individual stories into a collective whole. The story featured a "hero" structure common in many narratives [8], with three characters—protagonist (hero), antagonist (villain), and protagonist's friend. The scenario has a villain character threatening to destroy the Earth (Fig. 2a-2b), the protagonist (Patrick Star) choosing an action among three options—fight, run, or get help (Fig. 2c), followed by scenes depicting aftermath or reaction to the chosen action (Fig. 2d-2e).



(a) Pre-branch (b) Pre-branch (c) Branch (d) Post-branch (e) Post-branch

Fig. 2. Five-scene interactive narrative template–(a) to (e)–on which students were asked to add their own story, characters, background, conflict, and actions. The story progresses from left-to-right, with (c) representing the branching point. Students were asked to create post-branch scenes and dialogues accordingly, depending on the chosen action (Fight, Run, or Get help) at (c).

Students were provided with templates with the characters, script (i.e., dialogue), and theme (question & action choices) included and the background empty. To enable maximum creativity [D4], students were asked to update three components of the story: background, dialogue, and characters. Students were instructed to create three new characters (to replace the characters provided in the template): protagonist, antagonist, and protagonist's friend. For this, students were given a URL link to a website where they could use an interactive program to remix exquisite corpse submissions (created by students in the class for an earlier assignment) and download them as image files. There were 42 submissions so they could select one combination from 74,088 possible combinations (42 head * 42 torso * 42 leg). Then they updated a script file in JSON (which specifies the dialogue), added code to set the background, and optionally filled in the empty `mousePressed` and `keyPressed` functions to add interactivity to their story [2].

The motivation behind A6 was to remix individual stories to create a coherent collective story with multiple storylines, as illustrated in Fig. 3. To enable remixing and to maintain story coherency [D3], we imposed a number of constraints: all stories must use the three action choices [fight, run, get help], branch at scene 3 ($b = 3$), and have 5 scenes ($k = 5$). Fig. 2 shows the general structure of the narrative consisting of 5 scenes with branching occurring at scene 3 and offering 3 possible choices. The story setting is introduced in scenes 1 and 2; the story reaches its peak (narrative arc)

[2]https://anonymized-for-review.GitHub.io/

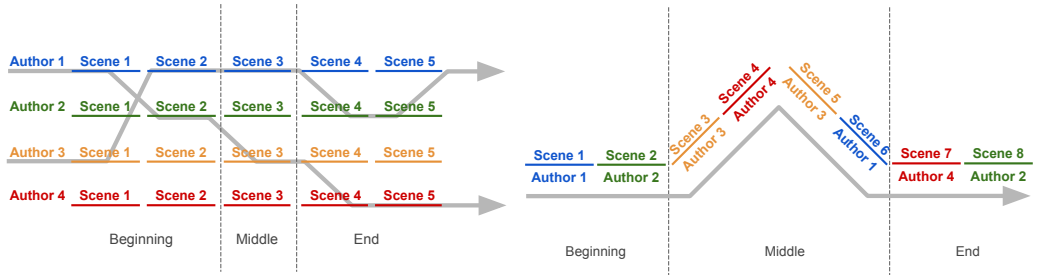
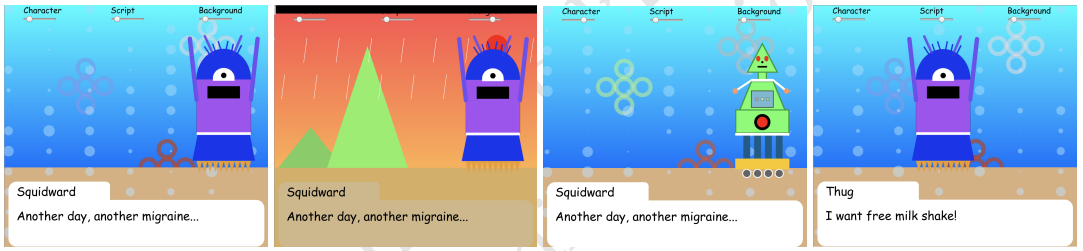


Fig. 3. The individual (high constraints) authoring process used in A6 (left) allows authors to write entire stories on their own, which can be later combined with other stories. This is in contrast to the collaborative authoring process used in A8 (right), where authors work in relay to add their scenes.

at scene 3 (e.g., What should Patrick do? Decisions: [Fight, Run, Get Help]?); the story shows the aftermath of the peak (release of tension) in scenes 4 and 5 [11]. Having all stories branch at scene 3 based on the same question and a common set of action choices ensured that the remixed story has a consistent theme and is reasonable.

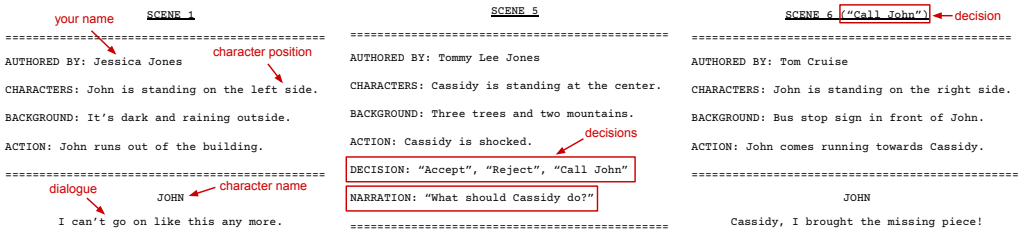


(a) Original Story (b) Change: background & interactivity (c) Change: character (d) Change: script

Fig. 4. The remixed story.

Figure 4 shows a few sample screens from the collective narrative, created by remixing different students' 5-scene interactive narratives. By manipulating the sliders in the top region, readers can change the narrative components: background and interactivity (b), character (c), and script (d). Since there were 21 submissions, a story could be selected from 9,261 possible combinations (21 backgrounds * 21 characters * 21 scripts). The remixed story was shown to students a week after students' A6 submission and before students started working on A7.

Individual Storytelling with Low Constraints (A7). In Assignment 7 (A7), as in A6, students were asked to update characters, background, and dialogue in the same manner (hence fulfilling [D1,D2,D4] as well). Different from A6, the goal of A7 was not to remix the stories in the end, but to have students produce individually authored stories. This means stories were internally coherent (satisfying [D3]), but could not be remixed with one another, thus not meeting the criteria to be considered as a collaborative story. As such, students were given a minimal set of constraints. The design constraints in A7 were that they needed to create at least 8 scenes and 2 backgrounds. Students could decide when stories branched, and they could also decide the story theme, i.e., conflict and decisions. The instructions did not explicitly require a branching scene.



(a) Pre-branch scene (b) Branch scene (c) Post-branch scene

Fig. 5. Assignment 8: Part I - script template for each scene type (pre-branch, branch, post-branch). Students took turns with their group members to add scripts for each scene on Google Doc.

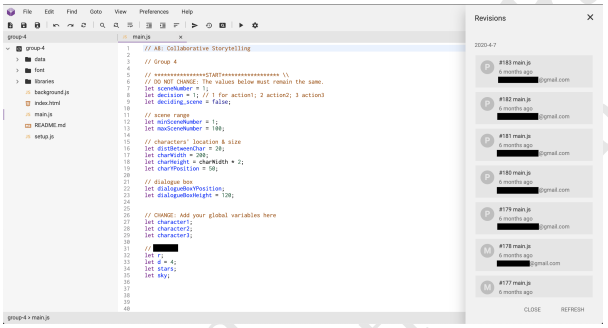


Fig. 6. Assignment 8: Part II - Screenshot of the CodeAnywhere platform students used to implement the script in Part I. Black boxes are inserted for anonymization.

Collaborative Storytelling (A8). In contrast to A6 and A7, A8 involved students working in groups to tell a story in relays, as illustrated in Fig. 3. We divided 48 students (1 student dropped the course before A8) into groups of four to five. This gave us 10 groups—2 groups with 4 students and 8 groups with 5 students. Students worked together as a group to create a story.

A8 was done in two parts. Part I required students to write a story in English using Google Doc, using the script template shown in Fig. 5. Each student was required to add at least two scenes; the scenes, however, could not be consecutive—this was to ensure a mix of creative scenes. Each scene contained information about the characters, background, and dialogue, as shown in Fig. 5. If the scene was a pre-branch scene (Fig. 5a), students added information about character(s), background, and dialogue. For a branching scene (Fig. 5b), in addition to characters and background, they described the question and action choices. The script for post-branching scenes was similar to pre-branching scenes but needed to specify which action choice it was following, as shown in Fig. 5c.

Students were asked to implement their scenes for Part II. In Part II, students implemented the story (script) from Part I using a real-time pair programming platform called CodeAnywhere (shown in Fig. 6), which allows the saving of revision history for analysis purposes and should allow for easier coordination between students [D1]. Its low constraint nature fulfills [D3,D4] in a similar manner as A7. Lastly, each student was assigned a group mark (to encourage the student to check their group's code works) and an individual mark (so that they are not too affected by other students' errors) [D2].

4 FINDINGS

The goal of this study was to understand how authoring processes of creating stories in creative coding impact students' experience and the generated narratives. As our study was conducted in the context of a course, there are many possible confounds that are difficult to control for, including the timing of the assignment, group dynamics, diversity of student abilities, etc. As such, we seek to draw insights based on qualitative and quantitative data that support the same conclusion. To ensure anonymity, we refer to students as S1, S2, ... S41. We specify groups in A8 as G1, G2, ... G10.

4.1 What are students' experiences with the individual vs. collaborative authoring of interactive narratives in creative coding? (RQ1)

To address this question, we administered a survey at the end of the class, which has two sets of questions—one for individual storytelling assignments (A6 and A7) and one for the collaborative storytelling assignment (A8). In each survey, we asked for students' general experience with the assignment ("How do you feel about the assignment?") and whether they would recommend that the assignment be administered in the same course in the future. Then we asked specific questions, such as whether the assignment was fun, interesting, and engaging. To understand the perceived benefits and challenges, we also asked students to explain what they liked/disliked about the assignment, and elaborate on their responses to the general experience and recommendation questions.

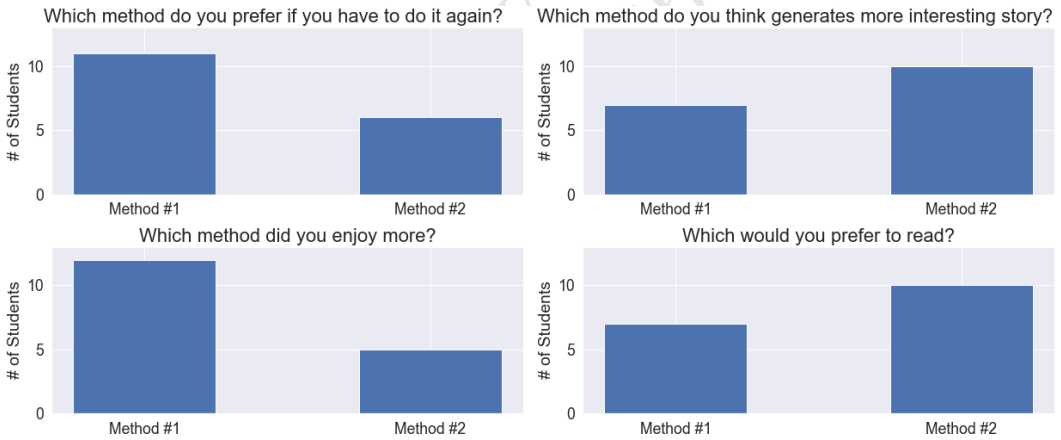


Fig. 7. Comparison of individual and collaborative assignments

4.1.1 Rating of Overall Experience. In this analysis, we used only the data of 17 students who completed all 3 assignments for a direct comparison between the individual and collaborative assignments. The analysis revealed that students, on average, found both individual and collaborative assignments fun, interesting, and engaging while rating individual assignments more positively (fun: 71% vs. 65%; interesting: 82% vs. 65%; engaging: 82% vs. 59%). More students reported having spent extra time on the individual assignments (65%) than on the collaborative assignment (47%) because it was fun or engaging. Similarly, more students were satisfied with their individually authored interactive stories (82%) than with the collaboratively authored stories (47%). A paired T-test revealed that students gave significantly higher ratings when asked how they felt about the individual assignments (M=4.6/7, SD=1.3) as compared to the collaborative assignments (M=3.4/7,

SD=1.5), $t(16)$=2.7, p=0.01. The Wilcoxon rank-signed test also showed that these students are much more likely to recommend the individual assignments (10 Yes, 6 Maybe, 1 No) for future iterations of the course than the collaborative assignment (3 Yes, 9 Maybe, 5 No). This analysis is done by mapping Yes to 2, Maybe to 1 and No to 0, yielding T=5, z=-2.5, p=9.2e-3, with a higher median for recommendation ratings of individual assignments (Mdn=2.0) than collaborative assignment (Mdn=1.0).

Interestingly, the comparative analysis (Fig. 7) shows that although students enjoyed individual assignments more and preferred to do them if they had to do it again, they thought collaborative storytelling resulted in more interesting stories. Even though students preferred the individual assignments over the collaborative assignment in the context of completing them, they preferred the collaborative assignment as a reader (i.e. they thought it produced more interesting stories and preferred to read those stories over the individually authored stories). In RQ2, we provide an in-depth analysis of the narratives produced through individual vs. collaborative authoring process to describe potential reasons behind this.

4.1.2 Key Differences in the Experience with Individual vs Collaborative Storytelling. For an in-depth analysis of the factors that influenced their experience with individual and collaborative assignments, we analyzed the qualitative data from the students who completed either the A6 or A7 individual storytelling assignments (N=35) and the A8 collaborative storytelling assignment (N=40). To clarify which individual assignment(s) (A6, A7 or both) students likely had in mind when commenting, we tagged onto the subject ID a subscript to indicate which assignments they worked on (e.g., $S39_6$, $S39_7$, or $S39_{6,7}$), or 0 if a student did not work on any individual storytelling assignment ($S39_0$). Our analysis is based on the rationale that students provided for the two open-ended questions in the survey, namely (1) What did you like/dislike about the assignment? and (2) Would you recommend [individual storytelling assignments] in future CS105 classes?

Communication & Coordination. Some students faced several challenges as they worked on the collaborative assignment. Notably, they ($S10_{6,7}$, $S14_7$, $S17_7$, $S18_{6,7}$, $S40_{6,7}$) had difficulties communicating and coordinating with other group members ($S21_{6,7}$, $S23_6$); for instance, for $S10_{6,7}$, their group members did not communicate with each other and did not do their parts till the very end. For $S9_{6,7}$, their group members did not implement their scenes in Part II, leaving "the overall project broken and not running smoothly." $S40_{6,7}$ also noted lack of ownership in a group project—a common problem in group work [35], saying "everyone just thinks that someone else is going to do it". While students like $S26_0$ were lucky to be "put into a good group who managed their time well and got [their] respective tasks done on time," other students like $S10_{6,7}$ and $S27_{6,7}$ were put in teams with students who did not work to a pre-defined schedule and/or did not communicate well. This posed challenges to these students.

Opportunity to Learn from/with Others. Students also highlighted benefits and positive experiences with the collaborative storytelling. While some students ($S31_7$, $S38_7$, $S39_6$) simply enjoyed the collaborative nature of the assignment and it being a nice "change from the usual assignment" ($S15_7$), many students recognized it as a good "chance for students to work together" ($S31_7$) and learn from others. Particularly, they saw it as an opportunity to learn "different coding styles" ($S7_7$), "thought processes" ($S26_0$), how to code and collaborate with others ($S8_6$, $S29_7$, $S40_{6,7}$), and important "programming and life skills" ($S19_{6,7}$). $S7_7$ also pointed that their group provided an access point for help; they shared that their group members "helped each other when [they] were stuck[, which then] motivated [$S7_7$] to do the work."

Creative Freedom & Design Constraints. Interestingly, all three assignments were seen as providing enough creative freedom—even A6 which we see as imposing high constraints. Many students ($S5_{6,7}$, $S7_7$, $S15_7$, $S18_{6,7}$, $S20_{6,7}$, $S22_{6,7}$, $S24_{6,7}$, $S31_7$, $S34_{6,7}$, $S39_6$, $S40_{6,7}$) praised the creative

freedom with the individual assignments. $S15_7$ said that "they give students a chance to show off their abilities in a fun and creative way." $S5_{6,7}$ noted that these storytelling assignments required him "to use both the left (logical thinking, coding) and right side (creativity, writing story) of the brains." $S7_7$ said, "I liked the flexibility and freedom we had with this code opposed to the other assignments, I had a lot of fun showcasing what I learned and being creative."

Several students ($S10_{6,7}$, $S26_0$, $S29_{6,7}$), on the other hand, stated that the collaborative assignment allowed more creative freedom than A6 and A7. $S10_{6,7}$ said, "I liked the creativeness of [individual assignments] but disliked the limitations that were placed... I liked that [the collaborative assignment] was less limiting and we could change things around more."

4.2 What kinds of interactive narratives did students produce under the constraints of the individual vs. collaborative authoring process? (RQ2)

We seek to understand the effects that authoring processes have on the generated narratives. Are there any differences between the stories produced through individual storytelling and collaborative storytelling? If so, what are these differences? To investigate this question, we present an analysis of both students' self-reported responses to the survey and stories constructed by them. For the narrative analysis, we examined the diversity and complexity of and creative uses of narrative components: narrative structures, inspiration sources for stories, question & choice sets, interactions, and background scenes. In analyzing each component, we present our analysis and end with a summary of their implications and any discrepancy observed between the individually and collaboratively authored narratives. This narrative analysis approach builds on prior work that analyzed narrative components for creativity assessment in stories [33] and for comparing the individually and collaboratively authored stories [34].

4.2.1 Survey Responses. Our individual and collaborative storytelling authoring process imposes different types of constraints on the students, and constraints, as we mentioned in related works, have a direct impact on creativity. To assess whether students were able to use the individual or collaborative storytelling activities to express their creativity, we asked, "Were you able to be creative in the assignment?" and "Did the assignment encourage you to be creative?" For this analysis, we included the response of the students who completed each assignment—21 and 31 students for individual assignments A6 and A7, respectively and 40 students for the collaborative assignment A8.

As shown in Fig. 8, most students positively rated ("Moderately," "Very," "Extremely") the individual and collaborative assignments as being approximately equal in its capability to enable and encourage creativity. For the first question, "Were you able to be creative in the assignment?", the

(a) Enabling Creativity (b) Encouraging Creativity

Fig. 8. Relationship between authoring of interactive narratives and creativity. A6 and A7 are individual assignments while A8 is collaborative.

positive response rates are 67% (A6), 58% (A7) and 60% (A8) respectively. For the second question, "Did the assignment encourage you to be creative?", the positive response rates are 71% (A6), 65% (A7) and 60% (A8) respectively.

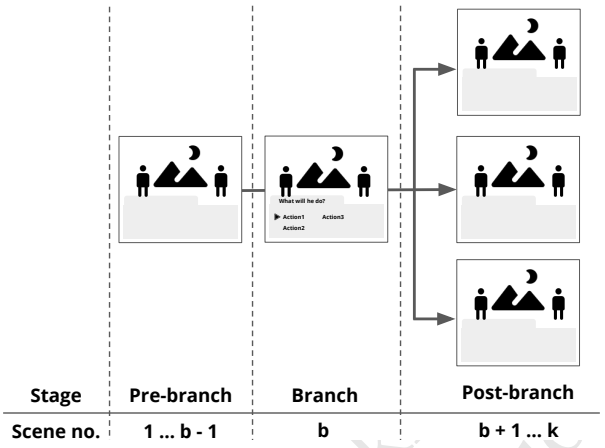
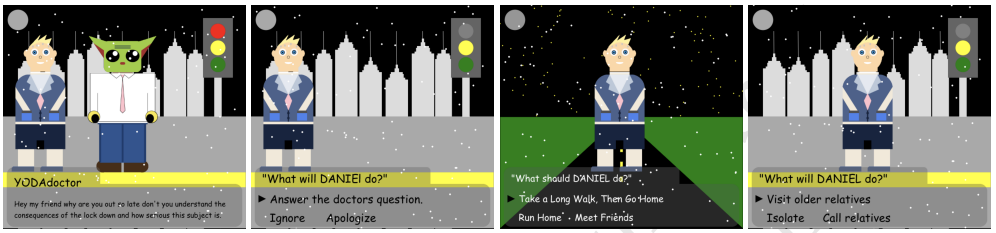


Fig. 9. General structure of Choose-Your-Own-Adventure storyline ($b \geq 2$ and $k \geq 3$). Pre-branch introduces a background and conflict in the story. The narrative arc reaches its peak in the branch stage and readers decide what action to take. Post-branch scenes depict a scenario following this decision.

4.2.2 Narrative Analysis. The programs generated by students are a form of *interactive narratives* called *Choose Your Own Adventure* (CYOA) [40]—a form of storytelling that allows readers to make choices, which then reveals different story lines and endings depending on these choices [44]. As shown in Fig. 9, CYOA has a branching stage in which readers—as the story's character or narrator—make decisions; the decision influences the direction and outcome of the story. Here, we describe the type of stories that were generated from the storytelling assignments, highlighting some of the differences in the stories produced through individual vs. collaborative storytelling.

Sources of Inspiration. The stories authored both individually (N_{ind}=32) and collaboratively (N_{col}=10) were diverse, portraying scenes, characters, and situations from Movies (N_{ind}=5; N_{col}=1), Novels (N_{ind}=1), TV Series (N_{ind}=1), A6 (N_{ind}=3; N_{col}=1), Recent Events (N_{ind}=3; N_{col}=2), and Others (N_{ind}=19; N_{col}=8). Submissions that depicted—or were inspired by—movie scenes included stories such as "Thanos coming to destroy the Earth" (*Avengers*), "Terminator going back in time to kill Sarah Connor and asking where she is" (*Terminator*), and "Gollum reciting a riddle" (*Lord of the Rings*). One submission portrayed a boy stuck in a chocolate river, a scene in the novel *Charlie and the Chocolate Factory*. Another submission described an episode from a popular TV series *The Office* where Jim asks Dwight to open the door. Submissions based off of the story in Assignment 6 used, for instance, the same protagonist name (Patrick) while just changing the antagonist name to Villain and Badguy from Alien. Submissions reflecting recent events included one about movie director Joon-Ho Bong receiving an Oscar, and stories based on coronavirus, such as a story with a character deciding whether to meet friends or self-isolate and stay home. The remaining submissions categorized as "Others" depicted stories we could not find any ties to; we believe they have been generated by the students. For instance, they included stories such as "Mom catching Lia skipping classes", "Jeff forgetting to do their homework", "Alicia denying having eaten Enrique's burger", and "Boxy asking for mashed potato at a pizza place but finding out they do not have any".

Overall, the diversity of stories—coupled with the fact that a significant number of them were based on the elaboration of their imagination or experiences (Others + Recent Events: N_{ind}=68.8%; N_{col}=80%) as opposed to copies from existing stories (i.e., Movies, Novel, TV Series, A6)—suggests that both the individual and collaborative authoring of interactive narratives supported creativity, allowing students to easily create stories based on their current interests. While the collaborative process resulted in slightly more stories from students' experiences or imagination—which, according to Rubegni et al. [33], correlate to creativity support, the small difference suggests that no significant difference exists between the individually and collaboratively authored stories in terms of their capacity to support storytelling.



(a) Pre-branch (b) Branch #1 (c) Branch #2 (d) Branch #3

Fig. 10. A story from A8 with three branch scenes.

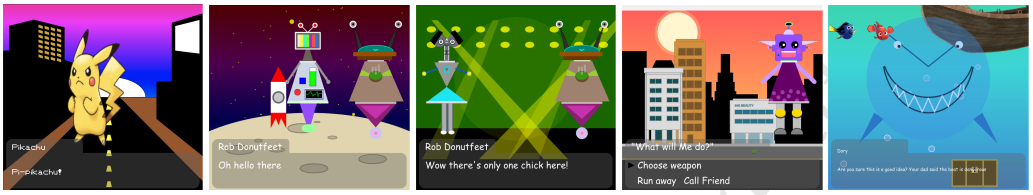
Branch Scenes. Most of the branch scenes in both individually (N=29/32) and collaboratively (N=8/10) authored stories followed the "What will [character] do?" format (from A6), focusing on the action a character should take. The examples include "What will Iron Man do?"and "What will Willy Wonka do?" This type of prompt resulted in choices describing actions such as "Wash hands, sanitize, drink water". Three students ($S18_{6,7}$, $S27_{6,7}$, $S37_{7}$), in the individually authored stories demonstrated creative use of the question & choices set: $S27_{6,7}$ had a story where Gollum is reciting a riddle—he presents a set of characteristics of something ("Voiceless it cries," "Wingless it flutters," and more) in the pre-branch stage and then asks "What am I?" This prompt results in possible answers to this riddle and asking for hint: "Wind!", "A baby", "I don't know! Help." $S18_{6,7}$ used "What will Boxy eat?" asking a reader to decide what Boxy should eat since the restaurant does not have the mashed potatoes that she asked for; the choices were food: "Almonds", "Sushi", "Watermelon." $S37_{7}$ showed two robots meeting at a park and asked"Where will they go?" The choices described places they could go: "Hill", "Lake."

Interestingly, we found that one of the two collaboratively authored stories that did not follow the A6 format was also written by $S18_{6,7}$ who demonstrated a creative use of the branch scene in the individual assignment. For the other two students with creative branching in A6 ($S27_{6,7}$, $S37_{7}$), their A8 groups used the same A6 format in their stories. By analyzing the scripts, we found that these two students did not get a chance to write the branch scene; other members added a branch scene before they did, reusing the A6 format. It is unclear whether the two students, if given a chance in A8, would have used a different format like they did in A7. This shows that while the collaborative authoring process provides an opportunity for collaboratively authored stories to be creative, it can also limit the creativity of some students. While it is unclear whether and how much this influenced their experience, $S27_{6,7}$ and $S37_{7}$ were among the five students who recommended against using the collaborative assignment in future semesters. One possible explanation is that these students felt they could be more creative working on their own.

While none of the stories in A7 have more than one branch scene, G2 authored a story with three branch scenes. As shown in Fig. 10, the story is about the COVID lockdown, and three decision

scenes center around whether the character should listen to the doctor and stay inside. G9 also created a story with two branch scenes.

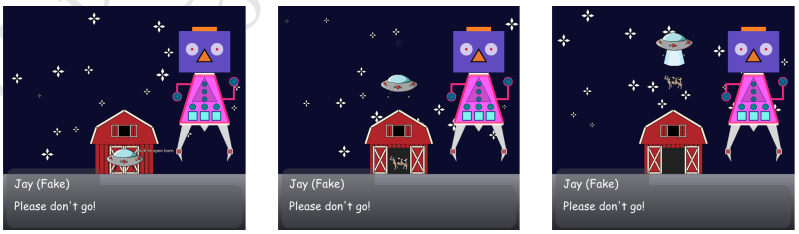
This, coupled with the fact that the collaboratively authored stories in A8 had more scenes than individually authored stories in A7 (M_{col}=11.9 vs. M_{ind}=8.7), suggests that collaboratively authored stories are longer and more structured. This finding is in line with prior work by Rutta et al. [34] who found collaboratively authored digital narratives to be longer, more structured, and richer with meaning compared to those authored individually.



(a) Pokemon (b) Space (c) Club (d) City (e) Nemo

Fig. 11. Examples of background scenes from three storytelling assignments: A6: (a), A7: (b)-(d), A8: (e). The scenes are interactive and have animation running in the background.

Interaction & Background. Many students worked hard to create aesthetic scenes. Fig. 11 shows some examples of background scenes students developed. Fig. 11(a) shows a city background with Pikachu standing on the road; the student used one-point perspective to add dimension and quality to the scene. Fig. 11(b) shows the space scene. While it is hard to see from the image, the scene has stars flying across the space in the background. Fig. 11(c) shows a club scene, with the lights oscillating back and forth like in a typical dance club. Fig. 11(d) shows a city with buildings and cars moving across the road. The scene also uses a gradient to depict the sunset. Finally, Fig. 11(e) shows a scene from the movie *Nemo* in which he chases after the boat; the scene has water bubbles moving around in the scene to accurately portray life underwater. These examples display the creativity and effort students put in to improve their stories. Moreover, they demonstrate how authoring interactive narratives motivated some students to put in extra effort.



(a) Hovering mouse (UFO) close to barn door reveals text "click to open barn"

(b) Opening barn reveals cow inside barn.

(c) Placing mouse (UFO) above barn initiates cow abduction.

Fig. 12. An interaction example where a user can use the mouse to (1) move the UFO, (2) click to open barn, and (3) place it in a hidden spot to initiate abduction.

While some students and groups did the minimum work (students could earn full marks for simply using the required programming concepts, even if they demonstrated no particular connection

to their stories), many others went beyond and used programming concepts in a creative way to enhance their stories. Fig. 12, for instance, shows a scene where a UFO is kidnapping a cow. In the scene, the UFO follows the mouse and when a user hovers a mouse (UFO) near the barn door (Fig. 12a), the scene displays the text "click to open barn." When a user clicks the mouse, the barn door opens and reveals a cow inside the barn (Fig. 12b); finally, when a user places a mouse (UFO) above the barn, the UFO flashes a beam and the cow starts to rise up towards the UFO (Fig. 12c). Other stories also used the same concept to implement interactions in creative ways: hovering over the enemy's torso area discloses the enemy's weak point; putting a mouse cursor on a light switch and clicking it turns off the light—the scene turns black. One student ($S22_{6,7}$) and one group (G3) asked the instructor how to import a sound file into their project—which was not part of the curriculum—in order to enhance their stories. The student used the Pokemon soundtrack for a battle scene with Pokemon characters (Fig. 11a), while G3 used the school bell sound for their story.

Overall, from our analysis of interactions and backgrounds in the narratives, we did not find any noticeable, significant differences between the individually and collaboratively authored narratives in terms of these narrative components; those produced through individual and collaborative authoring processes were equally creative, detailed, and well-designed. We also did not find much evidence of collaborative coding having a statistically significant impact on students' coding patterns (e.g. type and frequency of usage of constructs like loops and conditionals).

Narrative Structures. We examined narrative structures (i.e., the branching patterns) of the stories generated through the individual vs. collaborative storytelling process. We first turned narrative structures and patterns into graphs, which are a common representation for narrative analysis [2, 21, 30]: a node represents a scene; an arrow signifies the flow of the narrative; a path through the graph indicates a possible story line that readers can experience. We clustered similar graphs (narrative structures) together to identify narrative patterns. We based our analysis on the framework introduced by Carstensdottir et al. [9], and found that the narrative structures from students' submissions across A7 and A8 (A6 narratives are not analyzed because they all use the template structure) have two of the narrative structures proposed by Carstensdottir: *Broom* and *Foldback*, as well as a hybrid of the two (*Foldback-Broom*).

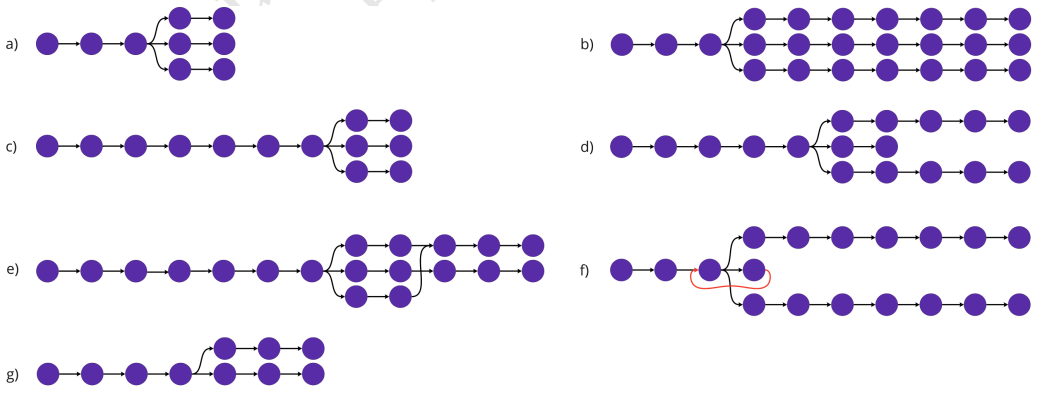


Fig. 13. Examples of Broom-shaped narrative structures. (a) is the structure of the provided template, (b) is a Broom-shaped narrative with more post-branch scenes, (c) has more pre-branch scenes, (d) has post-branch scenes of unequal lengths, (e) has two branches sharing some of the same post-branch scenes, (f) has an unequal Broom structure with a loop (shown by the red arrow), and (g) has post-branch scenes from two choices.

The Broom structure is shown in Fig. 13, and is categorized by a number of linear *pre-branch* scenes followed by *post-branch* scenes in distinct branches that do not rejoin. Formally, we represent a Broom structure using N-Broom(M, M, M), where N=3 is the number of pre-branch scenes and M is the number of post-branch scenes in each branch. In the template provided to students in the assignments, the narrative (Fig. 13a) has a 3-Broom(2,2,2) structure, because it has 3 pre-branch scenes and 2 post-branch scenes in each of the 3 branches. Other variations of Broom structures found in submissions are shown in Fig. 13b-g.

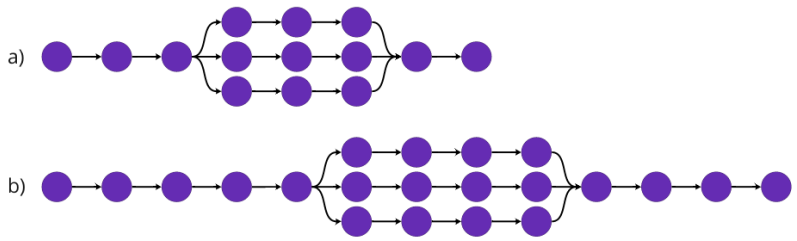


Fig. 14. Examples of narratives with Foldback structure. (b) has more pre-branch, post-branch and rejoin ending scenes than (a).

The second structure observed has the Foldback shape (Fig. 14) where all branches ultimately rejoin to a single storyline. Formally, we represent a Foldback structure using N-Foldback(M, M, M)-S, where N=3 is the number of pre-branch scenes, M is the number of post-branch scenes in each branch, and S is the number of scenes in the single merged story line. Fig. 14a is a 3-Foldback(3,3,3)-2 structure, because it has 3 pre-branch scenes, 3 post-branch scenes in each of the 3 branches, and rejoin to a single storyline with 2 scenes.

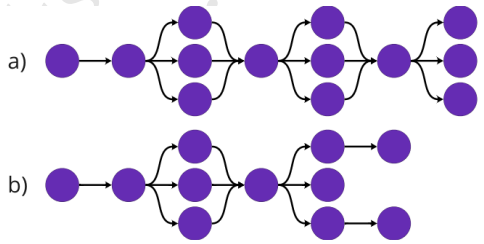


Fig. 15. Examples of narratives with Foldback-Broom structures, (a) branches out 3 times and (b) branches out 2 times. Narratives with Foldback-Broom structures were only observed in A8.

The third structure is the Foldback-Broom structure, which is a hybrid of Foldback and Broom. For example, Fig. 15b is a hybrid 2-Foldback(1,1,1) + 1-Broom(2,1,2) structure.

We examined whether stories were a variant structure of the template narrative, i.e., 3-Broom(2,2,2), or a novel structure. For A7, more than half of the stories (64.5%) were variants of the template structure N-Broom(M,M,M) with the number of pre-branch scenes N ranging from 3 to 11, and the number of post-branch scenes M ranging from 2 to 7. More than a quarter (25.8%) were narratives with a N-Foldback(M, M, M)-S structure, with the number of pre-branch scenes N ranging from 3 to 5, and the number of post-branch scenes M ranging from 2 to 6, and the number of scenes in the merged story S ranging from 1 to 8. The remaining (9.7%) were non-branching narratives—this may be due to the A7 instructions not explicitly requiring the use of a branching scene.

What is interesting is that a significant number of narratives (25.8%) had a novel Foldback structure. Students also changed the template structure in various ways for their narratives. Fig. 13d, for instance, shows a varying number of post-branch scenes in each branch—i.e., 7-Broom(5,2,5) instead of 7-Broom(5,5,5). Fig. 13e shows a clever use of a loop mechanism to enhance their narrative; when a user chooses "Run away" as opposed to "Fight in the city" or "Fight outside the city," the story switches back to the decision scene to nudge the user (hero) to not "Run away" but "Fight" (to save people). Also, while the same structures from A7—template variant, Foldback, and non-branching structures—were also observed in A8, we found that an additional narrative structure, Foldback-Broom (Fig. 15), appeared twice in A8 (G2, G9). This occurs when a narrative has more than one branch scene. For instance, Fig. 15a—equivalent to Fig. 10—branches out three times, resulting in 2-Foldback(1,1,1)-1-Foldback(1,1,1)-1-Broom(1,1,1). Fig. 15b branches out twice, yielding 2-Foldback(1,1,1)-1-Broom(2,1,2).

Interestingly, out of the 3 students in G9 who completed A7, 2 used a Broom structure and 1 used a Foldback structure for their A7 submission. We could hypothesize that students combined the two structures to create the hybrid structure. However, a detailed analysis of the script suggests that a more likely explanation is that this happened because of the collaborative authoring process in A8. Since multiple students with different ideas contributed to the storyline, the narrative diverged—additional branch scenes are a result of this. This can be observed in G2 and G9 who authored stories with more than one branch scene. G2 had three branch scenes, as shown in Fig. 10. The 3 branch scenes were added by 3 different students. G9 also used 2 branch scenes, these two branch scenes were also added by two different students.

In summary, while the introduction and use of novel structures in both individually and collaboratively authored stories suggests that students were able to exercise creativity in both processes, a close analysis revealed that the presence of multiple authors in the collaborative authoring process led to students adding more than one branch scene and yielding a more complicated narrative structure (Foldback-Broom), providing an explanation for why the collaborative authoring process is more likely to return stories that are longer, diverse, and more complicated in structure.

5 DISCUSSION

Individual vs. Collaborative Storytelling. The findings revealed that both individual and collaborative authoring processes allowed students to use text-based programming (*p5.js*) to author creative, interesting interactive narratives about their experiences, imagination, and existing stories. Many students went beyond the minimum required work to create interactions, background, and question & choice sets in creative ways to enhance their narratives. The findings also revealed the different impact that individual and collaborative storytelling had on students' experiences and narratives. While both individual and collaborative storytelling were recognized as an opportunity to show their abilities in creative ways, some students felt they could be more creative when completing the collaborative assignment. This was complemented by our narrative analysis where we found that collaboratively authored narratives are generally longer and more complicated in structure. We also observed, as students noted, that collaborative storytelling can allow students to learn from each other in various ways (e.g., by seeing how others make creative use of branch scene, interactions, background, etc.). Collaborative storytelling, however, also revealed that it has more challenges—e.g., in the areas of communication and coordination—to overcome than individual storytelling, which led to key differences in students' experience with individual vs. collaborative storytelling and ultimately to students favoring individual storytelling even though they regarded collaboratively authored stories to be more fun to read. Collectively, our work lends further support to prior work that found collaboratively authored stories to be longer, more structured, and richer in meaning compared to those authored individually [34].

Design Implications. Our findings have several design implications for designing and administering collaborative authoring of interactive narratives with text-based programming. Individual and collaborative authoring approaches each have different benefits and challenges: individual approaches allow students to focus on demonstrating their skills and telling their own story, while the collaborative approach provides an opportunity for students to learn from others and benefit from others' creative ideas, but requires students to communicate and coordinate well in order for it to be successful. Thus, when designing tools or systems to support these approaches, they should focus on minimizing the problems and amplifying the benefits of each approach. For instance, while students need to come up with stories and code on their own in individual approaches, in the collaborative approach, students can work with others to seek creative story ideas and get help for their implementation. Therefore for individual approaches, the tool should offer ways for students to get help with story ideas and code; for the collaborative approach, the tool should offer ways for students to communicate and coordinate while working on the stories and implementations. Finally, since collaboration was welcomed because of how it allowed students to receive help from others and learn from others' different coding styles, thought processes, and creative ideas, developing features to augment these benefits would enhance the collaborative authoring experience.

Recommendations. In our study, students engaging in collaborative storytelling lacked a tool for viewing the overall structure of their narratives. Several groups (G6, G7, G8, G10) addressed this by creating either a table, list, or summary of scenes in the first page of their script on Google Doc, which specified what each scene is about, whether it is a branching scene or not, and which student is in charge of it. Thus we recommend supporting this in future collaborative storytelling systems. The system design can build on authoring tools, such as CrossTale [12] and Animation Pad [25]; their systems offered global and local views so that users can see the narrative structure (e.g., an abstract representation like the one in Fig. 9) and also local views in which users can edit individual scenes.

None of these authoring environments, however, involved authoring with programming. Thus, they should be extended with features to support the needs in collaborative programming, some of which include modular architecture, real-time pair programming, and version control. The system offering global and local views can be used to modularize each student's code effectively, minimizing users' concerns over working on the same file. In our study, our approach to modularizing students' code was by requiring students to add code to functions allocated to them—the functions had each student's name, e.g., *function background_james()*. However, $S27_{6,7}$, for instance, created files for each member, e.g., *background_james.js*, to further compartmentalize each member's code. $S27_{6,7}$ said, "group programming is never fun especially if it is not modulated. If you have to work on the same part together, it doesn't work." This illustrates the pain points other students ($S23_6$, $S11_7$) have also experienced. They did not want to be impacted by other members' errors, which the instructor saw happening when multiple students worked at the same time. This caused students to avoid working at the same time ($S20_{6,7}$, $S23_6$, $S27_{6,7}$) because they checked whether their code worked by running the program and if someone else was adding their code at the same time, an error, or incomplete code, caused the program to crash. Thus, collaborative storytelling systems using text-based programming should offer a version control feature so that multiple students can work on their own "branch" (like in GitHub), edit their scenes, run the code to check their scenes, and merge with the "main branch" once their scenes are complete. Finally, real-time pair programming (e.g., allowing users to see which scene others are working on) should be supported to inform users that someone else is working simultaneously or to allow collaborative coding on the same file.

6 CONCLUSION

We explored individual and collaborative authoring processes for creating interactive narratives using text-based programming for creative coding. Our work highlights the benefits and challenges of individual and collaborative approaches and compares how the two authoring processes impact students' experiences and creativity. Both approaches were found to enable and encourage creativity. Our analysis of generated narratives was in line with this finding as students, in both approaches, made creative use of the narrative components. While students preferred the individual storytelling because they felt more ownership of the work and could focus on applying the learned coding concepts without concerning themselves with communication and coordination, the collaborative approach generally resulted in longer and more complicated narratives, which is a potential explanation for why students preferred to read collaboratively authored narratives. We also contribute a set of design implications and recommendations to improve the administration of and experience with individual and collaborative storytelling with text-based programming. All in all, our work contributes an understanding of ways to administer individual and collaborative authoring of interactive narrative in creative coding.

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