Giving Voice to Problem-Solving: Hearing Students' Techniques in Video Reflections

Dr. Tammy VanDeGrift, University of Portland

Dr. Tammy VanDeGrift is a Professor and Chair of Computer Science at the University of Portland. Her research interests include computer science education, pedagogy, and best practices for retention and engagement.

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Abstract

Written exams are regularly used to assess students' skills in problem-solving in engineering and computer science courses. Written solutions document students' thought processes, but there may be other thinking and reasoning that the instructor cannot observe from a solution alone. The pedagogical technique reported in this paper is the use of video reflections of solutions to exam problems. Students created one short video explanation of their solution to a randomly assigned exam problem for each exam. The educational objectives for the video included: 1) encourage reflection and meta-cognition about the creation and testing of a solution, 2) practice oral communication of technical process.

From 2021 to 2023, students in three different computer science courses took exams and created video recordings of their solutions. The exam problems involved writing short code snippets, applying algorithms, applying networking protocols, generating state diagrams, and writing proofs. The instructor watched the video reflections to gain insight into the solution-generation and solution-testing process of their students in addition to assessing students' work. The instructor awarded the maximum grade of the written solution and the video reflection solution; therefore, students could improve their solution on the video and earn a better grade.

Students completed an optional end-of-semester survey about all assessment practices in the courses, including the exams and video reflections. The survey data was analyzed to evaluate if exam reflection videos were perceived as supportive to students' learning and accurate demonstrations of understanding. Students appreciated the opportunity to explain solutions and steps more thoroughly, think more deeply without exam time pressure, fix errors, and make solutions more efficient. About one-third of students updated at least one solution by finding errors prior to or during the recording of their explanations. While oral communication was not explicitly graded, the instructor observed that students used the vocabulary of the discipline correctly. A few students thought the extra step of creating a video was cumbersome; however, the majority appreciated the opportunity for revision and explanation of their solutions. Written exams remain a common form of assessment of problem-solving skills in many engineering and computer science. Video creation posed more work and time for both students and instructors; however, there are educational benefits of requiring students to review and explain their work: it provides authentic engineering communication practice and seeds a habit of metacognition.

Introduction and Related Work

Educators design pedagogical methods, activities to support student learning, and assessments of student learning, while often considering the theoretical framing of how students learn. While engineering and computer science learning experiences include hands-on, practical experiences with active learning exercises, laboratory work, experiments, projects, and internships, exams remain a primary tool for assessing students' conceptual understanding, problem-solving ability, and skill development [15, 17, 18, 34, 43]. Freeman *et al*. found that active learning increases

students' performance on exams across many fields in science, technology, and mathematics [15]. In fact, the meta-analysis by Freeman and others showed that students' grades increased by half a letter grade and failure rates reduced when students were taught using active learning methods [15]. While there are many strategies to engage students with active participation in classes, exams are still common for assessment. This paper focuses on adding reflection videos to written exams in computer science courses.

Exams have been a common technique for the assessment of student learning and professional preparation for many years in secondary, post-secondary, and professional education [27]. Exams may be popular assessment tools since the exam environment can be controlled, instructors can monitor students' actions, and instructors can put more trust that individual students produced the work. Exams can also take many forms. Some exams are written for fast marking, such as the use of multiple-choice questions and Parson problems [12]. Some exams include open-ended prompts, so students can craft a written argument. Some exams allow for open resources in a proctored setting [31], some are take-home [6, 7, 20, 39], some are completed in groups [5], and some computer science exams are on the computer while others are on paper [11, 16, 19]. In engineering and computer science courses, exams may include problems for students to solve, data for students to model and analyze, short code snippets to trace, and problems for which diagrams are constructed. This paper focuses on adapting written exams that include problem-solving, diagram-generation, and code-writing problems.

During the covid-19 pandemic in 2020 and 2021, most higher education courses were taught on-line. Without in-person classroom monitoring, faculty had to trust that students completed their own work throughout the course. While some institutions invested in proctoring software, some institutions left it to the faculty to move the assessment process to the online environment [1, 3, 6, 23, 45]. Paper [42] describes a cheating mitigation strategy for online exams. The faculty continued to use similar problem-solving exams while teaching online, but they required students to create a video to explain their answer to one of the exam problems. Their goal was to minimize cheating, but they found that the exam videos had educational benefits for both the students to practice communication and for the instructor to understand students' processes. In this paper, we applied the use of exam videos in on-campus courses to see if the educational benefits are similar for in-person learning environments.

Explaining one's process through videos is a form of reflection. Reflection and meta-cognition are essential skills for students to develop as learners [25]. Some faculty use exam wrappers to encourage students to reflect on their study habits, so they can use time more effectively for future exams [4, 10, 41]. Some faculty allow for exam corrections, so students have an opportunity to re-think about the problems [43]. Exam videos provide a similar opportunity to correct or update the original solution. Explaining one's process on a video is similar to how students respond in oral exams. In the design of video exams for this paper, students had time to think about a problem after taking the exam before recording the video of the explanation. In oral exams, students usually need to respond without a lot of thinking or reflection time. Some universities regularly use oral exams in computer science courses [17, 28, 35]. Video reflections are similar to oral exams in that faculty can hear students' explanations and learn more about students' processes. Video reflections are different in that students record them privately without the stress of talking directly to the instructor.

Several other educational interventions use videos. For example, Schilling and Estell created videos to provide feedback to students on their work [36]. They found that students paid attention to the feedback and corrections/suggestions since watching a video may be a better communication format for students than having them read comments embedded in a file. As another example of using video technology for learning, some faculty have created assessments where students explain a concept from the course via video [2, 8, 13]. A third example is becoming more common for engineering and computer science courses: videos can capture students' project presentations instead of using class time for live presentations [44].

The main purpose of exam videos is to combine the strengths and benefits of oral exams without providing extra stress and test anxiety for students [9, 11]. In fact, data collected from students show that making videos provided overall less stress and test anxiety for many students. They appreciated the second chance on an exam problem and having the option to take more time to think about a problem. The main advantages for the instructor were gaining better insight about students' steps in building a solution and learning more about the assumptions and misconceptions they made about the problem, model, algorithm, or code they created.

The remainder of this paper describes the educational environment, details about the exams and the video reflection, students' experiences, and instructor's observations.

Context: The University, Courses, and Students

The University where this study was conducted is a primarily undergraduate institution on the west coast of the USA. The university has a School of Engineering, which houses four ABET-accredited programs in civil engineering, computer science, electrical engineering, and mechanical engineering. About 3500 undergraduate students attend the university, of which approximately 160 are computer science majors (about 35 to 45 per cohort). The university offers small classes, with most sections enrolling 15 to 25 students.

Students took in-person, written exams and recorded video explanations in three different computer science courses taught by the same instructor: Theory of Computation (ToC), Computational Biology (CB), and Computer Networks (CN). Table 1 shows the courses, enrollments, and semesters for this study. Note that ToC is required for the BSCS degree. The CB and CN courses are elective computer science courses in the program.

Table 1: Terms, courses, and enrollments for the duration of the study

Term	**Course**	**Enrolled (# sections)**	**# Non-CS Majors**	**Women; Men; Non-Binary**
Fall 2021	ToC	52 (2 sections)	4 (2 math; 2 electrical engineering)	19; 33; 0
Spring 2022	CN	19 (1 section)	0	3; 15; 1
Spring 2022	CB	15 (1 section)	5 (4 biology; 1 math)	3; 11; 1
Fall 2022	ToC	31 (2 sections)	1 (1 electrical engineering)	4; 27; 0
Fall 2023	ToC	37 (2 sections)	0	7; 29; 1

Almost all students who took these courses were upper-division computer science majors. Table 1 lists the number of non-CS majors and shows the gender identities of students.

Exams and Video Reflections

Each course had three in-person 55-minute written exams, scheduled every three to four weeks during the 15-week semester. After the exam period, students recorded short videos explaining one of the exam problems, randomly assigned by student ID final digit. Students submitted their videos through the course management system, Moodle. Sample instructions for creating videos using Microsoft Teams (Microsoft products are free for the students) were posted to Moodle; however, students could use any software to create videos.

Exams served as the primary assessment tool for individual learning in all three courses. Table 2 shows how much the video reflection submissions were worth on each exam and how much each exam contributed to the overall grade. ToC also had a written final exam, but the final exam did not include a video reflection. The instructor learned that getting in touch with students who forgot to submit the final exam reflection video proved difficult in fall 2021, so they did not include the video reflection for the final exam in the next two offerings. The main reason the ToC video submission points differed on each exam was simply to get the exam total to equal 100. The set of video reflection questions per exam are shown in Appendix A.

All three courses included homework or labs (25 – 30% of overall grade) and more open-ended projects (15 – 25% of overall grade). ToC had an assignment where students created art to demonstrate some concept from the course (5% of overall grade). CN had an podcast about the impact of technology in a developing part of the world (12% of overall grade).

Appendix A shows the exam question topics for the exams used in this study. Appendix B shows the instructions that students were given for creating exam videos.

Table 2: Exam reflection video points and exam weights for overall grades

Course	Video submission points per exam (out of 100)	Each exam's contribution to overall grade	Exam total contribution to overall grade
ToC	10 or 12	10%	10 x 3 = 30% (*)
CN	8	12%	12 x 3 = 36% (+)
CB	8	12%	12 x 3 = 36% (+)

* also had final exam worth 20% of overall grade, but final exam did not have video reflection
+ no final exam in the course

Data and Methods

To evaluate how well the video reflections and written exams worked, students were invited to complete an optional online survey about all course activities. To incentivize responses, students who completed the survey earned extra credit points toward the homework/labs portion of the final grade (note: these extra credit impacted the overall grade by less than 1%). The survey and study were approved by the Institution's Review Board.

For this study, student responses to the following survey questions were collected and analyzed. The first four questions had possible responses of a) Not descriptive, b) Minimally descriptive, c) Somewhat descriptive, d) Mostly descriptive, e) Very descriptive.

1. Exams and studying for exams supported my learning of <Theory of Computation, Computer Networks, Computational Biology> course material.
2. Exam videos (random problem explanation by video) supported my learning of <Theory of Computation, Computer Networks, Computational Biology> course material.
3. Exams and studying for exams accurately demonstrated my understanding of <Theory of Computation, Computer Networks, Computational Biology> course material.
4. Exam videos (random problem explanation by video) demonstrated my understanding of <Theory of Computation, Computer Networks, Computational Biology> course material.
5. Did you alter at least one solution to an exam problem while recording an exam video?
    a. Yes b. No
6. How did recording an exam video change your thinking or problem-solving process, if any? (Text entry)
7. Would you like to have exam videos as a supplementary way to showcase your learning in future courses?
    a. Yes b. No

Data for questions 1-5 and 7 were quantitatively aggregated to observe trends. The free text entry for question 6 was analyzed and coded into emergent themes [40].

The total number of respondents across all courses was 119 out of 155 potential respondents, for an overall survey response rate of 76.8%. The response rates per section were: 44/52 (ToC FA21), 27/31 (ToC FA22), 25/37 (ToC FA23), 11/20 (CN SP22), 12/15 (CB SP22).

Students' Experiences

The analysis of students' experiences was guided by two research questions:

1. Did students value the opportunity to create video reflections for exam problems?
2. How did the video explanations change their problem-solving process?

Did students value the opportunity to create video reflections for exam problems?

The answer is yes. Most students appreciated having the video reflections for exam problems. Of the 119 survey respondents, 106 (89.0%) said they want video reflections in a future course (survey question 7). Of the 119 respondents, 79 reported updating or correcting a solution on the video reflection (survey question 5). This corresponds to the rate the instructor saw when grading the paper exams and the video reflections.

Students valued the opportunity to create video reflections. Most students reported that the exams and videos supported their learning and demonstrated their understanding. Table 3 shows the number of responses in each category for the survey questions 1 – 4. All 119 responses were complete (no missing answers). 84% said that the exams mostly or very much demonstrated their

knowledge. 86% said that the videos mostly or very much demonstrated their knowledge. A lower percentage of students felt exams (80%) and videos (65%) mostly or very much supported their learning. Still, this percentage shows that the exams and videos had value for the students. Interestingly, the videos had a higher percentage of students in the "mostly" or "very" category than the exams for assessment.

Table 3: Students' rankings of not descriptive, minimally descriptive, somewhat descriptive, mostly descriptive, and very descriptive to exams and videos supporting their learning and demonstrating their understanding. (N = 119)

Ranking	Exam – learning	Video – learning	Exam – assessment	Video - assessment
1 (not)	0	2	0	0
2 (minimally)	5	9	4	2
3 (somewhat)	19	31	15	14
4 (mostly)	48	38	32	25
5 (very)	47	39	68	78

If we divide the data in Table 3 by course, the distribution of responses changes a little bit. Table 4 shows the percentage of students who responded with "mostly" or "very" for the questions by course. The CN course had lower percentages than the other two courses. This may be due to the fact that much of the homework, labs, and projects in CN are more applied and the exam questions are more theoretical. In ToC and CB, the exam questions are more similar to the homework and labs. Overall, the data supports the conclusion that students appreciated exams and the videos for learning and assessment.

Table 4: Percentage of students who responded with "mostly" or "very" descriptive for exams and videos supporting learning and demonstrating understanding by course.

Course	Exam – learning (mostly or very)	Video – learning (mostly or very)	Exam – assessment (mostly or very)	Video – assessment (mostly or very)
ToC	85.4	67.7	84.4	86.5
CB	83.3	58.3	91.7	91.7
CN	27.3	45.5	72.7	81.8
Combined	79.8	64.7	84.0	86.6

How did the video explanations change their problem-solving process?

Question 6 on the survey was analyzed to answer this research question. Students' free text responses about how the video changed their thinking or problem-solving process were categorized into emergent themes [40]. The author read all the responses and found these themes: see errors in thought process, deeply explain solution, justify steps, step back and think without time pressure of the exam, made problem-solving or solution more efficient, helped student remember problem after the exam, and did not change process. Each student's answer was tallied into one of the categories. If their response spanned multiple themes, the theme located higher in Table 5 was used for the tally. Hence, the sum of the Combined column is 119.

Table 5: How students' processes changed when creating a video (N = 119 Combined)

Theme	Combined	ToC	CB	CN
See errors in thought process or solution	40	31	5	4
Thoroughly or more deeply explain thought-process for better understanding	23	20	1	2
Justify steps	4	4	0	0
Step back and think without time pressure	29	21	4	4
Made problem-solving or solution more efficient	2	2	0	0
Helps me remember content after the exam	1	1	0	0
Did not change	9	7	2	0
No answer (left text box blank)	*11*	*10*	*0*	*1*

The most popular answer is that the video reflection process gave them the opportunity to debug and update errors in their solution. This is the primary reason the instructor included the exam videos in the course – to give students a chance to practice the habit of checking/testing their solutions. The next most popular answer was that it gave students a chance to step back to reflect on their work without the time pressure of an exam. Students also realized the videos gave them the opportunity for deeper understanding by explaining their work and justifying their approach.

Here are sample responses for each theme (Student numbers indicated below are random identifiers and not tied to their university ID numbers). Text was bolded by the author to highlight the connection to the theme. A more complete list of sample responses can be found in Appendix C.

See errors:

- I think by being able to step out of the stress of the test, and verbally walk the audience through my thinking process I was more clearly able to **see the errors in my own thought process** and correct them on the spot. The exam video was very helpful! (ToC Student 41910).

Deeply explain for understanding:

- If anything, recording the videos helped encourage a **more thought out solution** to a problem and helped to understand the concepts behind the problem rather than just trying to solve it correctly in the allotted test time. Considering problems in a more stress free environment helps showcase a **deeper understanding** than an exclusive test demonstration. (ToC Student 41919)

Justify steps:

- It was good to explain the problem because then **I truly had to justify the steps I took** during the exam in a different setting. I can see how useful making a video would have been if I had been assigned a question I was not as confident on or had gotten wrong because I surely would have changed my answer and been able to see what I did wrong by having to explain it not in the context of a test (where pressure is higher). That would have made the material that I missed stick even more. (ToC Student 41956)

Step back without time pressure:

- It gave me some time to think about my solution in a **non-stressful exam environment** (CN Student 47239)

Made solution more efficient:

- It helped me see what my train of thought and thinking process was through verbally explaining it. By knowing what my mental strategy was, I was able to **better formulate a more efficient way of solving problems**. (ToC Student 42135)

Helped remember content:

- Since we spend so much time on questions and there's the pressure of having to get the right answer, the **exam sticks in my mind for quite a while even after the exam**. Being able to think about problems with no help and with added pressure and then figuring out the answer after the fact gives me an **epiphany-like moment**, which solidifies my understanding of the concept. (ToC Student 42166)

Instructor's Observations and Reflections

Every pedagogical decision has trade-offs in terms of costs and benefits. In this section, we focus on the benefits and the downsides of using video reflections after exams. If the instructor had infinite time, having students explain every solution to every problem in one-on-one conversations and allowing for iterative refinement would be a rich and authentic way to assess students' skills and knowledge. This approach is not practical for most courses and undergraduate students may find oral examinations quite stressful. The instructor thinks the exam video reflection on a single problem strikes a good balance. Students get to record in a more private setting, they have a chance to iterate/refine their work on one problem, and they still get practice explaining their work.

What are the benefits of video reflections from the instructor's perspective?

- Students' rationale: The biggest benefit was definitely hearing students' rationales for their solutions. Some students even walked through several test cases during the video explanation, which is great computing practice. It was very rewarding to hear students' voices and get more insight into how they explained the content of their solutions. It was also rewarding to see students catch their own errors while explaining their solution and see them update solutions on the video. Some students even re-did the solution prior to recording the video and would state something like, "I realized I did this wrong during the exam. With more time to think, I updated my solution and will show my thought process."
- Students' communication skills: Another advantage is that students practiced explaining their thinking out loud [13]. The instructor did not explicitly grade communication skills showcased in the videos, but students demonstrated great communication skills and used the technical vocabulary correctly. Explaining solutions is just as valuable as creating solutions in professional practice, so these videos helped students practice those skills. One student even mentioned in office hours that the exam videos helped them prepare for technical interviews, since they were more comfortable recording themselves and outlining the steps to produce a solution.
- Resources for peers: Another upside is that the exam videos can be great resources for their peers. With students' permission, the instructor can share the exam videos with other students in the class. Some students explain concepts better than the instructor. These videos can be helpful for other students' learning by providing more diverse explanations.

- Second chance for demonstrating knowledge: Of course, the main upside for students is that they get a second chance on one exam problem and the instructor awarded the better grade (exam solution or video reflection solution). Some students who felt time-crunched left their assigned problem to the end of the exam, since they knew they could provide more details later. The instructor encouraged students to use their exam time wisely and students could work on problems in any order. The instructor observed that about two-thirds of the students updated a solution to at least one video problem during the semester, which is similar to the student survey results. Most video edits improved students' solutions. In just a handful of cases, students noticed an error and corrected the solution to produce a different error. The instructor kept track of the increase in the exam grade for ToC students in Fall 2023. The average increase in exam points on just the video question was 0.79 for exam 1, 1.03 for exam 2, and 1.47 for exam 3. The exam topics increased in difficulty as the semester progressed, so it is not surprising to see the trend of increasing improvements.
- Students as people: Watching the videos was actually very enjoyable for the instructor. Sometimes, a pet would be introduced as they came on camera. Some students showed a lot more of their personality on the video than they do in class.

What are the downsides of video reflections from the instructor's perspective?

- More work for students and instructor: The main downside of adding videos to exams is the extra work for the instructor and the students. It takes about three more minutes per student to grade exams. The instructor graded all written exams problem-by-problem, assigning points to each question, so the grading could be done anonymously (instructor did not see student's name when marking). After the written exams were graded, the instructor watched the videos and noted any updates to the solution for the assigned video problem. This process could be streamlined by watching the video while grading the corresponding written problem. However, the instructor would know the student's identity if using the video while grading the paper.
- Contacting students whose videos were not uploaded: Some students forgot to submit a video or their video upload process did not fully complete. The instructor emailed the set of students with missing videos the day after each exam to ask for their videos. The size of this group varied from zero to five students per exam.
- Potential for solution sharing: Another downside is that students can acquire solutions to problems after the exam period and before the video is created. Students signed an exam agreement stating they would not engage in this behavior; however, the instructor could not patrol students' activities between submitted the exam in class and recording the video later that day. This is the main reason the instructor had each student complete just one video reflection per exam (cheating would only impact up to 15% of the overall exam grade). The instructor did not detect any cheating when watching the videos, but cheating is a possible outcome when using the video reflection assessment technique.
- Inequitable technology access: A potential downside is providing equitable student access to technology and network bandwidth to create and transfer videos. Students at the university get free access to the Microsoft suite, so all students can use Microsoft Teams to record videos without purchasing extra software. No students expressed roadblocks for creating videos, and some opted to use their cell phone cameras or Zoom. A few students

had poor Internet connectivity, so transferring video files sometimes failed or took a lot of time. Reasons for having maximum-length two-minute videos was to keep the watching/grading time reasonable and keep the file transfer time manageable.

Stress and Anxiety: The instructor learned more about exams by doing this study. Exams are stressful for some students. They feel a lot of pressure to do well and some students experience anxiety and tension. That was evident in reviewing the free-text survey responses. It is a good reminder for the instructor to find other ways to de-stress the exam environment. The instructor allows students to use one notesheet during each exam, but perhaps other modifications to the testing environment can alleviate even more stress.

Application to multiple course types: The instructor used exam video reflections in three different computer science courses to see if the technique is beneficial across different types of courses, exam content, and types of exam questions. The students' responses were most positive in Theory of Computation and Computational Biology. These two courses have exam problems where students must create a solution, such as building a finite automaton, a Turing machine, a grammar, a proof, or a code snippet. The Computer Networks course does not focus as much on writing code or creating new models; instead, the exam questions focus more on applying well-established networking protocols for situations like framing, encoding, forwarding, encrypting, and grouping data into packets. Courses in which students need to produce novel solutions or showcase solution steps may be better choices for exam video reflections. If students do not need to explain much more than what is in the written solution, exam video reflections may not provide much additional educational benefit for the students and the instructor. If there is no added value for students, they might perceive recording videos as busy-work.

Summary

This paper reports on adding exam reflection videos to traditional, written exams in three computer science courses. The exam videos provided benefits for learning and assessment for both the students and the instructor. Students reported that seeing a problem again and working through the explanation gave them a chance to debug and fix mistakes, especially when given the opportunity to think about the problem after the exam period. Communicating one's problem-solving process is essential to learning and the professional practice of software engineering. Hearing students' explanations also gave great insight to the instructor about how students create solutions, their technical vocabulary, and the misconceptions they have with the material.

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Appendix A: Exam Topics

Table A1: Exam question topics/points for the ToC video reflection questions

Exam #	Topic	Question's Points
1	Create Deterministic Finite Automata	15
	Create Nondeterministic Finite Automata	15
	Create regular expressions	15
	Prove language is regular	15
	Conversions between regular models	15
2	Prove language is non-regular	12
	Create a context-free grammar	12
	Create a Pushdown Automaton	12
	Prove language is context-free	12
3	Prove language is non-context-free	14
	Create a Turing Machine	14
	Prove language is decidable	14
	Prove language is undecidable	14

Table A2: Exam question topics/points for the CN video reflection questions

Exam #	Topic	Question's Points
1	Sliding window frame and ack delivery with dropped frames	10
	CDMA chipping codes signal aggregation	10
	Cyclic redundancy check bit calculation	10
	Manchester and 4B/5B encoding	10
	File transfer time calculations	10
2	Calculate distributed spanning tree	10
	Applying subnets to determining where to forward packets	10
	Using CIDR addressing for forwarding	10
	Constructing forwarding table using link state routing	10
	Determining fragments for smaller MTUs	10
3	Using TCP state diagram to determine client/receiver segments	10
	Determining host's resources in overlay peering system	10
	Determine forwarding order using fair queuing	10
	Congestion window size calculation in TCP	10
	Creating Huffman encoding for compression	10

Table A3: Exam question topics/points for the CB video reflection questions

Exam #	Topic	Question's Points
1	Python code to determine indices of 6-mers with at least three 'A' characters	15
	Python code to generate random DNA string with given GC-percentage and length	15
2	Python code to determine total alignment score between two strings	15
	Python code to return list of positions of substring found in a different string	15
	Apply global string alignment algorithm to two strings (using dynamic programming)	15
	Apply local string alignment algorithm to two strings (using dynamic programming)	15
3	Python code to return positions of motifs that exceed scoring threshold	15
	Python code to calculate distance between points and to find closest point from list	15
	Apply Hertz-Stormo algorithm to find motif	15
	Apply k-means clustering algorithm	15

Appendix B: Instructions for Students to Create Exam Videos

Here is the text from the in-person exam to direct students to complete the video reflection.

Post-Exam Instructions:

Take out your phone/tablet and take a picture of your solution to the assigned problem below. Note that once you take out your phone, you cannot edit the exam solutions any further.

These are problems, not the short-answer questions.

- *ID ends in 5 – 7: Problem #1*
- *ID ends in 8 – 9: Problem #2*
- *ID ends in 0 – 2: Problem #3*
- *ID ends in 3 – 4: Problem #4*

After you take the photo, you should close the exam booklet, and submit your physical exam booklet with your crib sheet. Do not share your work with any other students in either section of the course.

Before 11:59pm today:

- *Create a video of you (with your face and paper/share screen) explaining your solution for all parts of your assigned problem. Explain how you designed the solution and why it works (or does not work). The video should not need to be more than two minutes long.*
- *You can use MS Teams to record a video of you explaining how you developed and tested your solution while screen sharing the photo that you took. Instructions for creating a MS Teams video are posted to Moodle.*
- *Do not spend time re-recording the video – just talk through your solution as if you are explaining it live. No post-processing of the video is required.*
- *Upload your video to the Moodle submission link before midnight tonight.*
- *The video counts toward the overall grade on the exam, so be sure to complete this step. Missing videos will earn a score of 0 for that part.*
- *Talking through your problem-solving process is a useful skill for your professional development, including interviews and working with teammates.*

Appendix C: Sample Student Responses By Theme

See errors:

- I think by being able to step out of the stress of the test, and verbally walk the audience through my thinking process I was more clearly able to **see the errors in my own thought process** and correct them on the spot. The exam video was very helpful! (ToC Student 41910).
- By recording an exam video I was able to acknowledge my mistakes after working on the exam and it helped me problem solve my own solutions and helped solidify my learning of the course topic more by re-looking over my solutions and **correcting my mistakes** and understanding the process again and again. Also explaining my solution out loud helped a lot with understanding and saying my mistakes out loud is similar to reading the problem again and re-analyzing. (ToC Student 41972)
- Often after the exam while walking to my next destination, I'd think over problems that I had been unsure about and that would allow me to work through in my head again. Also when explaining, **I'd find bugs in my problem solutions** which was also great when recording. (ToC Student 52439)
- Recording the exam video changed my thinking process because it reminded me to make sure the Turing machine I am creating has all the proper components it needs to solve the problem. The solution I altered was changed since **it was missing a component that made that answer incomplete**, so being able to go back and add that piece in was nice. (ToC Student 61229)
- I think there was only one exam video where I defended what I put on the exam. Once I completely changed my approach after **noticing how wrong I was** originally, and another time I **noticed a few minor errors** in what I put on the test. Having a second chance for a problem with relatively unlimited time to think was just such a stress relief. I can't really answer exactly how the videos changed my thinking or problem-solving but I know that my thinking did change a couple times. (CB Student 47143)
- recording an exam video helped me realize if there was a simple error and fix it, and if there was a big issue in how I carried out an algorithm it **helped me see my mistake** and then fix it and reinforce the correct way of solving a problem. (CN Student 47491)

Deeply explain for understanding:

- If anything, recording the videos helped encourage a **more thought out solution** to a problem and helped to understand the concepts behind the problem rather than just trying to solve it correctly in the allotted test time. Considering problems in a more stress free environment helps showcase a **deeper understanding** than an exclusive test demonstration. (ToC Student 41919)
- It made sure that we had **in-depth knowledge** of the particular problem and were not just regurgitating information. (ToC Student 42139)
- It helped me to really **articulate my thought process** on how I approached the problem and why I did what I did. I think its easy to fall into the trap of "memorizing" patterns in problems and doing certain techniques or problem solving that is more about memorizing similar problems and applying it to the current problem rather than actually understanding why this solution is correct. (ToC Student 42260)

- I was able to explain **why I thought a certain way**. Being able to speak it aloud, helped me **vocalize my thought process** which I think is a valuable skill when working with others. (ToC Student 52550)
- The exam videos made me **think about why I wrote down the things that I did**. By having to explain these concepts, I would have to simplify my steps in order to clearly explain to someone that would be watching my videos without prior understanding of the content. (CB Student 47247)
- I do not think that is changed my thinking on how to solve the problems but It did help me **prove to myself that I got it right and that demonstrate that I understood it**. (CN Student 47496)

Justify steps:

- It was good to explain the problem because then **I truly had to justify the steps I took** during the exam in a different setting. I can see how useful making a video would have been if I had been assigned a question I was not as confident on or had gotten wrong because I surely would have changed my answer and been able to see what I did wrong by having to explain it not in the context of a test (where pressure is higher). That would have made the material that I missed stick even more. (ToC Student 41956)
- Recording videos didn't so much made me think of the question itself but ways to present my explanations in a clear, concise way. And so when explaining my answers, I had to take into account all steps of the solution and **think critically when considering test cases to prove my solution is valid**. (ToC Student 61200)

Step back without time pressure:

- I had **more time** and there was a **lot less pressure** to answer right away. This gave me time to answer properly and I found this to be very useful. (ToC Student 42175)
- It gave a second view on solving the problem that **wasn't on a time crunch**, because during an exam you are fighting time so any extra time thinking might cost you, so with the video it gives time to re-evaluate how to solve the problem not under the time stress. (ToC Student 52256)
- I think when the stress of the exam is over you don't overthink it. There was always at least one problem on the exam, where I'm thinking, "**I know I can do this, but I don't have the thinking process for it right now**." As I'm walking home from class, I think of all the solutions and figure out that I actually did know what to do, but I was just thinking down the wrong path. When doing the video after having time to think, you get to say your thoughts aloud as well which helps you read the thinking process easier. (ToC Student 52348)
- Being able to record an exam video kind of **relieved some pressure** for that specific problem and allowed me a "second chance" of reorganizing my problem-solving process. (ToC Student 52491)
- It made me **slow down** and read the problem step by step before forming any assumptions about the problem and tackling it head on without any tactic. (ToC Student 61303)
- It helped me re-think a question in a **non stressful environment** (CB Student 47240)
- It gave me some time to think about my solution in a **non-stressful exam environment** (CN Student 47239)

Made solution more efficient:

- It helped me see what my train of thought and thinking process was through verbally explaining it. By knowing what my mental strategy was, I was able to **better formulate a more efficient way of solving problems**. (ToC Student 42135)
- It did not do anything especially noteworthy. If anything, I made me think about how to **explain things more concisely**. (ToC Student 42154)

Helped remember content:

- Since we spend so much time on questions and there's the pressure of having to get the right answer, the **exam sticks in my mind for quite a while even after the exam**. Being able to think about problems with no help and with added pressure and then figuring out the answer after the fact gives me an **epiphany-like moment**, which solidifies my understanding of the concept. (ToC Student 42166)