The XXXIV[th] Annual International Occupational Ergonomics and Safety Conference
Virtual Conference
September 15-16, 2022

# Teaching and learning accident theory using a complex learning experience

**Ciro F. Bustillo Lecompte[1], Daniel Huynh[1], Sydney Riley[1] and Kathryn Woodcock[1]**

[1]Toronto Metropolitan University, 350 Victoria Street, Toronto Ontario Canada M5B 2K3

Corresponding author's Email: ciro.lecompte@ryerson.ca

**Author Note:** All authors are affiliated with the School of Occupational and Public Health at Toronto Metropolitan University, formerly known as Ryerson University. Dr. Lecompte (corresponding author) is adjunct faculty, Ms. Riley and Mr. Huynh are Occupational Health and Safety alumni and have served multiple terms as Teaching Assistants while working professionally in industry, and Dr. Woodcock is a professor and originator of the signature learning experience reported in this paper.

**Abstract:** Professionals in occupational health and safety (OHS) and applied ergonomics frequently analyze accidents to explain adverse occurrences or determine measures to prevent recurrences. In an undergraduate OHS program, the Accident Theory course introduces knowledge and skills relevant to this practice.

The term "complex learning experience" refers to an activity within a course that requires learners to engage in a discovery process and develop multiple interrelated skills through an activity that spans across multiple class meets and in which there are several deliverables and assessments of various kinds, including self-assessment and peer-assessment.

The activity resembles the "real world" not just in the performance of a realistic task, like a laboratory procedure, but in the qualities of ambiguity, uncertainty, creativity, interpersonal inter-reliance, and the possibility of multiple satisfactory endpoints. This paper describes and discusses such a complex, multi-week learning experience using the simulated investigation protocol, in which investigators acquire information about a hypothetical accident by interrogating a role-player equipped with a rich but hidden set of relevant and irrelevant information provided on request. While the exercise superficially centres on the practice of investigation, the entire exercise includes preparation, analysis, and presentation that elevate the level of learning from remembering declarative knowledge about accident theories to understanding its relevance.

Furthermore, the complexity of the exercise necessitates that learners apply, analyze, and evaluate relevant concepts and reward those achievements through a gamified "tournament" format. The paper reports on the cumulative experience of using the exercise for over 20 years from the perspective of instructors, teaching assistants, and students in relation to the teaching and learning goals for the exercise. The paper also discusses the robustness of the exercise under fluctuating external forces, including scaling for burgeoning class sizes, the sudden switch to remote learning and subsequent planned remote learning during COVID-19 and for distance learning, and the role of teaching assistants.

*Keywords:* Learning experiences; Accident analysis; Simulated investigation; Practice

## 1. Background

Professionals in occupational health and safety (OHS) and applied ergonomics frequently analyze accidents to explain adverse occurrences or determine measures to prevent recurrences. In an undergraduate OHS program, the Accident Theory and Analysis course introduces relevant knowledge and skills.

While theory can be taught and learned, it is analysis that makes theory useful to professionals. The course regards accident analysis and causal explanation as a "practice," not a uniform procedure. As a practice, the practitioner has agency to collect information, often interactively with others, to co-construct its meaning, and determine actions to take in each unique, complex situation. Conventional lectures, readings, and tests can present foundations of shared knowledge, values, and beliefs of the field, which inform practice. However, practice also incorporates each practitioner's individual conditions, creativity, and problem-solving into their approach to each case. Deferring self-awareness to internships and early career experiences risks the possibility that some new practitioners will misunderstand the taught knowledge as a uniform procedure and fail to adapt to unique situations, their individual characteristics, or both.

Much "investigation" training focuses on prescriptive procedural knowledge about interview techniques and collecting and preserving physical evidence, which shapes an expectation that investigation is an uncomplicated matter of executing procedures. However, causal explanation itself affects future safety. We do not fix what has happened; we fix what we believe has happened. Dekker (2017) provided many examples of deficiencies of intuitive causal thinking. Rasmussen (1993) described premature closure when a causal explanation matches a known phenomenon or a condition for which a

ISBN: 9781938496608

DOI: https://doi.org/10.47461/isoes.2022_bustillo

remedy exists. Even training may not overcome intuitive reasoning. Training in the "Five Rules" of causal statements did not achieve significant improvement in causal contributors uncovered through investigation (Drury et al., 2002). The infrequency of accidents and the lack of objective feedback limits the benefit of natural experience. Simulated investigations (Woodcock et al., 2005) provide experiences that combine facilitated observation, objective feedback, and introspective reflection to benefit self-awareness.

This paper reports on the use of simulated investigations as part of a "complex learning experience" within the course that incorporates multiple interrelated skills through an activity, spanning multiple class meets, producing several deliverables and assessments of various kinds, and undertaking both self-assessment and peer-assessment, to establish a foundation for the practice of accident analysis and causal explanation.

## 2. Simulated investigation of hypothetical accidents

In the simulated investigation method (Woodcock et al., 2005), the hypothetical accident story author determines the combination of facts, events and conditions involved in the accident, enabling objective assessment of the quality of investigations of that story. In this complex learning experience, the hypothetical accidents are authored by groups of students as part of the exercise. Across all stages of the exercise, students play two roles: as "author" and storyteller (jointly with a team) of a hypothetical accident story, and as "investigator" (individually, except in pilot testing). In addition to performing, students also undertake reflective analysis from both perspectives.

This section will describe authorship, investigation, and analysis elements of the exercise, and the intentions behind the decisions made in the design of the exercise. Learning objectives and exercise elements are tabulated in Table 1. An instructor's guide is available from the authors.

### 2.1 Authoring hypothetical accidents

In this exercise, authoring the hypothetical accidents provides an opportunity for students to apply course content about accident models, systems theory, types of human error, and the contribution of design. They may supplement this with personal experiences or observations from workplaces or family experiences. Consistent with curriculum and course focus, assignment rules require that the accident be one that would be investigated by a generalist OHS practitioner, i.e., the type of job position many of them will attain, and not a transportation accident specialist, fire marshal, nuclear regulator, coroner, police detective, or other specialist. Assignment rules also require that technologies and systems be limited to technologies and systems familiar to a typical university student at their level of training. The purpose of simulated investigation is to practice and gain insight into causal reasoning, not to test encyclopedic knowledge of exotic technologies familiar to one member of the accident author group. Groups must validate their stories in a meeting with the Teaching Assistant (TA) to ensure stories are plausible, after experiences with investigators stymied by stories incorporating impossible scenarios.

In the simulated investigation method, the investigator receives a brief prompt, typically representing an email, form, or phone message to investigate something. All other facts are fully prepared in advance but revealed only in response to the investigator's specific questions. Therefore, story authors must prepare not only causally relevant information, but also irrelevant information that may be sought by investigators due to bias, administrative habit or curiosity, and facts an investigator might seek to rule out a possible explanation for a particular event, that is, differential information. A lack of response would inform the investigator that their biases had drawn them off the causal chain: feedback that is not present in the real world. Teams can test pilot their story against another team to allow both teams to find areas for story improvement and to experience the format of the interactive investigation.

### 2.2 Simulated investigation "tournament"

The simulated investigations take place in several rounds. In a synchronous class, it has been typical to allocate one week for the pilot testing of stories at the beginning, and one week for story reveals and discussion at the end. As class sizes have burgeoned from 15-25 to 75-95, it is necessary to allocate three weeks for the individual investigations (the actual "tournament"). Simulated investigations are limited to ten minutes, for uniformity and feasibility in the amount of classroom time available in person. While this amount of time is unrealistically brief compared with "real" investigation, it is also unrealistically convenient for all witnesses to be simultaneously present and all evidence to be available immediately on request. In practice, we find that some investigators would like another few minutes, but others are happy for the time to end. With limited time, there is more learning opportunity from two 10-minute investigations than from one 20-minute experience. Following the ten minutes, the investigator spends up to ten minutes writing a recap of what they believe to be the causal chain and returns it to the story team for assessment.

Table 1. Mapping of learning goal to exercise element

| Learning goal | Exercise element |
|---|---|
| Apply the principle that multiple normal and abnormal events and conditions contribute to adverse occurrences. | Author a hypothetical accident story: Brainstorm eligible stories, select optimal story, and enhance details. |
| Apply taught accident theories. | Populate the hypothetical story with contributing factors. |
| Apply consciousness of temporal and structural relationships of causality. | Classify and tabulate story details according to causality. |
| Develop awareness of causal contributions of the task, the equipment, the environment, and the social system, in addition to personal characteristics and actions. | Classify and tabulate story details by type of factor. |
| Identify temporospatial and logical relationships among facts in differentiating causal from non-causal information. | Diagram accident for report. |
| Consider and apply knowledge of types of evidence: testimonial, physical, and documentary. | Prepare evidence of different types to be revealed to investigators asking appropriate questions. |
| Practice writing skills. | Prepare narrative form of story.<br>Report on the exercise as a science report. |
| Acquire or develop skills using word processing. | Follow designated formatting requirements including running headers, re-start pagination after front matter, object linking and embedding of tables, figures, and flowcharts, and optimizing image quality and table layout. |
| Observe the influence of the individual investigator's approach to information collection on the data available for analysis. | Perform group's story for another group during pilot test round<br>Simulated investigation tournament: Perform group's story for individual investigators. |
| Develop consciousness of the parameters of investigation quality (comprehensiveness, efficiency, lack of bias). | Develop rubrics or metrics and rating investigations of their story on the prescribed dimensions. |
| Practice quantitative and qualitative analysis. | After completion of the tournament, analyze and report on the relationship between investigation approach and results in the form of a science report. |
| Experiment with approaches to organizing student's own inquiries to efficiently collect comprehensive, unbiased information. | Investigate multiple accidents authored by other groups during the tournament. |
| Reflect on the relationship between strategic intentions, experience, and investigation effectiveness. | Record reflections/observations in log during tournament.<br>After completion of the tournament, receive feedback from story authors. |
| Learn about the importance of favours and relationships among professionals. | Observe a relationship between providing and receiving opportunities for additional out of class investigations . |
| Develop group work skills. | Project planning to define and use a mutually agreeable approach to producing the required elements. Group contract and groupwork memo. |
| Meet other members of the large class. | Work with new people in the same group.<br>Meet new people in the process of investigations of each other's group story. |

The exercise requires advance preparation by the instructor and TA to ensure that storytelling teams can stay occupied with an investigator throughout the investigation period rather than waiting for the next investigator, investigators remain "unspoiled" until they complete the investigation and return their report to the story team, and all students have a fair opportunity to access the three to five investigations they need to perform (number depending on class size).

## 2.3 Reflective analysis

To promote self-awareness and reflection, the exercise requires that students do several analyses, both as groups and as individuals. The story team must assess each investigator for comprehensiveness, bias, and efficiency on a 1 – 5 scale after reviewing their causal chain report. After completing all performances, among the investigators who may be tied for the highest score, they must select the "best" investigator of their story and explain their reasoning. The best investigator for each story is recognized in the "reveal" finale session. Groups also compile all of the scores they assessed and present the exercise in the form of a lab report, describing the story, the method of data collection, the results, and the interpretation of the results, prompting group discussion of the investigation scores. Through assessing 30 or more different investigators, teams should

observe that despite uniform information having been authored for the story, investigators uncovered widely varying versions of the story. It is this observation, more than one's own performance of three to five individual investigations, that reinforces the key lesson of the exercise: the investigator is a strong influence on what is learned and believed about causation of any event. Repeated performance of the story shows students that people they know, like, and respect as smart, well-intentioned peers can fall prey to biases or inefficiently jump to conclusions. Good intentions are inadequate: disciplined, logical, and systematic approaches must be used. This insight can also inform further personal reflection on where their own investigation efforts could be improved.

The TA receives investigation scores from teams and confidentially communicates compiled scores to students after all investigations are completed: investigators do not have knowledge of results between their consecutive investigations. When immediate results were provided, we did not see that feedback shaping subsequent investigations of what are often quite different stories. Rather, immediate feedback often produced pride or dismay, not deep reflection. More importantly, when scores were returned directly from the group to the investigator, we sometimes observed patterns of retaliation for low scores. We instead emphasize contemporaneous introspective analysis by the individual investigator of how they felt each investigation went and a comparison of those notes with the scores when received later. In the contemporaneous notes, students may remark on strategies they used, how confident they are in their findings, plans for future approaches, and anything else relevant.

When investigators receive feedback on their scores from the stories they investigated, and after they see the reveals of the full stories, they can compare actual results with their contemporaneous impressions, and craft their individual report tabulating their scores and reporting on what they learned from the experience, and their impression of what they think was intended to be learned.

During the finale of the tournament, each team presents a reveal of their causal chain and comments on trends they observed about pitfalls and successful strategies. Students who investigated each story can learn what information they did not uncover and compare their approach to the reported pitfalls.

As with all group work assignments we use, we require the students to begin the project with a group contract and conclude with an individual group work memo in which they report, but do not rate, the contribution of each member of their group. The emphasis is on paying attention to the ways different people may contribute when collaborating. Naturally, disputes sometimes occur, but students are expected to address these during the exercise and not use *post hoc* peer ratings to punish each other.

## 3. Observations

The previous section described the exercise design. This section reports on cumulative observations from the perspective of instructor, teaching assistant, and student, supplemented by student comments from the exercise. CBL and KW have delivered the course 25 times to 954 students since KW developed the course over 20 years ago. KW accounts for about 90% of the teaching. CBL, DH and SR have supported the course as Teaching Assistant multiple times each. Class sizes varied from 9 to 96 and reflected an increasing trend over time, with larger class sizes in synchronous in-person classes than distance education, other than the classes delivered in emergency remote mode due to COVID-19. Most (70%) students have experienced in-person delivery, with 30% remote or distance. The authors discussed their perspectives and derived several themes from the experience, including gamification, community development, and higher-order thinking skills, and reflective practice. Remote learning and burgeoning class sizes have been notable external factors.

### 3.1 Gamification

Beyond deliberately referring to the exercise as a "tournament" and groups as "teams", the exercise feels like a competitive game, particularly with a time limit for investigation. Recognition of individual investigators and particularly good stories as "best" is amplified with award certificates, and the reveal session has a celebratory atmosphere, with many teams engaging in creative presentation in the reveal of their full story. "Best investigator" recognition has been seen on alumni résumés. The exercise has been described as the closest thing to a pure investigation opportunity, without organizational biases and interpersonal pressures, and a safe place to explore one's own causal thinking and get feedback from the "real story" itself, through the peers who authored the story. Students are naturally curious and story-reveals in the final session gain high attention after several weeks of suspense. One student said:

> *"For me personally, this simulated investigation exercise was by far the most exciting and useful assignment that I have carried out since the onset of my studies."*

### 3.2 Community development

The complexity of the exercise promotes a sense of "uniting against a common enemy", whether the enemy is the other teams or the course syllabus. In a large cohort that is currently over 75 students per year, the exercise provides a structure for students to meet most peers in the course, either as teammates or as individuals who investigate their story or a team whose story they investigate. A student wrote:

> *"... helped me learn a lot about the importance of teamwork and developed my skills as an investigator that I will be able to take with me for the rest of my career as a professional. I found that communicating and working as a team was very important to the overall success of the group as it helped create the story of the accident smoothly and established effective causal factors that flowed together with the story itself. ... I noticed that when creating the story, it was beneficial for us to brainstorm different factors and scenarios as a group, and then come together to create a realistic accident. This helped me greatly as creativity is something that I struggle with, especially when creating stories and working on other assignments, such as creating an accommodation plan for an injured worker."*

### 3.3 Higher-order thinking

There is ample declarative knowledge in OHS, and students with adequate memory can progress smoothly through much of the program relying on acquisition and production of that declarative knowledge. Some students are more accustomed to unnaturally well-defined problems and are nervous about this exercise, but instructors and TA reassure them, provide factual clarification where their question has not already been answered in the available guidance, and encourage them to work with their group to decipher the task, as the learning experience is often in the deciphering and not in the delivery of the task. Neither the investigations nor the reflection has "right answers", and the assessment focuses on the process of learning and progress with the practice of analysis and causal reasoning. Voting for the "People's Choice" accident story prompts students to think about the purpose of the exercise and the story that best fulfilled those aims. Typically, the top choices on student ballots are the same stories selected by Professor / TA consensus, showing good insight by the students. A student wrote:

> *"There are many students who lack the work experience to be able to sit in class, get lectured about this subject and have the material really sink into them. By having to make up an accident situation and all that goes into it (the causal factors, connecting the actions and consequences of those actions) I was able to fully grasp the complexities of what actually needs to happen for there to be an 'accident'."*

### 3.4 Reflective practice

For most students this is likely their first experience with accident investigations from both an academic and professional standpoint. This complex learning exercise allows for students to rapidly experience investigation of multiple accidents and reflect on the results of their practice. The requirements for each accident scenario to incorporate multicausality, human factors and design, and not focus on "violations" or "complacency" ensures students are rewarded for thorough investigation techniques. Creating the stories means students are conscious of what other investigators are not discovering, and how biases affect fact-finding as well as conclusions. Through this exercise, students can reflect on the experience within the bounds of the class and keep those insights in mind as they enter the workplace. A student wrote:

> *"In terms of being a witness to ongoing investigations, it allowed me to see what other investigators were doing correctly and what I believed to be inefficient. In terms of being an investigator in this exercise, it allowed me to perform in the position to seek causal factors for accidents and allowed me to improve my ability to investigate efficiently. Overall, I believe playing both roles actively refines our investigation process to become more comprehensive, efficient, unbiased, useful, and reliable. ... I learned utilizing [human factors systems model] and working backwards helped immensely in finding causal factors; I learned this while observing other investigators."*

### 3.5 Remote learning as disruption or opportunity

The in-person class "tournament" allows the instructor and TA to ensure fair access to investigations, eavesdrop to reinforce general principles, and mediate difficulties. The sudden campus closure due to COVID-19 occurred between pilot and first simulated investigations in 2020. Prior to COVID-19, it seemed undesirable to offer this experience in remote format. However, the pandemic rapidly equipped virtually everyone with video meeting skills, essential to remote performance. Logistics were quickly developed to provide comparable TA consultation, booking, record-keeping, time limits, score submission, and reflective reporting, and a remote format of the course has since been made available as an option. In-person preparation entails planning classroom setup and log sheets and forms; remote classes require investigation-booking spreadsheets to schedule virtual investigation appointments and online forms to submit results. Asynchronous classes may be

able to complete the individual investigations in two weeks or even one week in a very small class, since investigations do not need to fit into the three-hour timetabled classroom booking. Remote learning lacks some of the guardrails against loafing and procrastination. This can adversely affect story quality and require more TA support in story validation for unprepared groups. Remote mode also permits inequitable booking of some groups over others, and for some students sign up to investigate more than their share of stories, thus the investigation schedule requires instructor / TA monitoring.

### 3.6 Burgeoning class size

The course was created when cohorts were typically 16-20 students, and the exercise has been maintained as class size has increased up to 96, albeit with some complications. Group sizes above five or six students become prone to loafing, undermining not just individual learning but group effectiveness. Even in smaller groups, students in a large cohort may have become accustomed to loafing and require emphatic external motivation to avoid failure of group dynamics. Keeping groups of manageable size requires additional groups in larger rosters. Physical capacity of the classroom limits the number of groups presenting stories at the same time and increases the number of tournament rounds, reducing lecture weeks. Additional groups also greatly increase TA time required for story validation, coaching, monitoring, and feedback/marking. During tournament rounds, more investigators working in the same class period increases transition times between investigators, either reducing investigation opportunities per person, or requiring "out-of-class" investigations to top up. Widespread proficiency with virtual meeting apps acquired during the pandemic makes that medium likely to replace rendezvous in the cafeteria for out-of-class investigations. Nine groups have been subjectively optimal for in-class delivery, providing the most investigation experiences per person with the fewest out-of-class investigations; adjustments proliferate above 12 groups, or about 60 students.

## 4. Discussion

Accident theory is challenging, abstract and can be difficult to learn in a way that is useful in practice. Students have found this complex learning experience memorable and beneficial, often comparing it favorably to conventional lecture-based learning. Dedicating the latter half of the course to the learning experience allows students to use the exercise to apply course content during the creation of hypothetical accidents, to the investigation of other groups' hypothetical accidents, and to introspection.

In the investigator role, students have an opportunity to test and develop investigative skills in the classroom environment, experiment with approaches, and make mistakes with little to no risk, while gaining feedback to compare their findings to the full and objective sequence of events. These features build skills and confidence in a way that real work experience cannot, due to professional risk, lack of objective feedback, and often systemic biases. Instructors and TAs facilitate fair access to experiences, compiled performance feedback, and prompts to stimulate reflection.

As hypothetical accident authors, students consider and apply what they have learned about potential causal factors and multifactorial causality within a systems perspective to produce a scenario in which a causal chain is embedded amidst irrelevant information. During the group story-telling sessions, students observe multiple individual investigators as they seek and extract causal information from this realistically noisy background. This observation helps them to make objective assessments of a variety of investigation strategies as they prepare for their own investigation practice. Instructors and TAs ensure the validity of stories for the exercise and provide structure for students to observe and assess investigator performance.

Remote learning has proven to be feasible for motivated students but can require more administrative monitoring of the interactive logistics. Burgeoning class sizes provided more investigation opportunities, but more than 12 groups of 60 students began to detract from the experience, suggesting dividing larger cohorts into sections.

## 5. References

Dekker, S. (2017). The Field Guide to Understanding 'Human Error'. CRC press.

Drury, C. G., Woodcock, K., Richards, I., Sarac, A., Shyhalla, K. (2002). A new model of how people investigate incidents. Proceedings of the Human Factors and Ergonomics Society 46(13), 1210–1214.

Rasmussen, J. (1993). Diagnostic reasoning in action. IEEE Transactions on Systems, Man, and Cybernetics 23(4), 981-992

Woodcock, K., Drury, C.G., Smiley, A.S., and Ma, J. (2005). Using simulated investigations for accident investigation studies. *Applied Ergonomics 36*, 1-12.