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UNDERSTANDING AND ENHANCEMENT OF STRUCTURAL ENGINEERING PRINCIPLES INCORPORATED IN FIRE DEPARTMENT DATABASES AND EDUCATION

An Interactive Qualifying Project Report

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by

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Abstract

This project involved investigating the information accessible to Fire Investigators pertaining to principles of building construction. A national survey, interviews, and a literature review revealed a potential for supplementation. Our project team concluded that an interactive tutorial to help Fire Investigators identify building collapse dangers would be beneficial. Our expectation is that a visual mode of presentation will convey the information most effectively, allowing Fire Investigators to apply this information to real life situations and improve their occupational safety.

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Introduction

Once deemed the final dwelling of soon-to-be-retired Firefighters (interview with Bob Staunton), the field of fire investigation has evolved nationally into a profession that is well educated, well trained, and very effective at determining the origin and cause of most investigated fires. With the help of technological developments in forensics and digital photography, the field of fire investigation has advanced most profoundly in just the past ten years.

Notwithstanding the extensive advances in training and methods of investigation, our project team has found that the education of Fire Investigators lacks emphasis on the concepts of building construction. This lack of emphasis seems unbefitting for fire professionals that enter buildings after they have sustained the totality of fire and water damage. Our project team recognized this circumstance as an opportunity for improvement. Recognizing that most fire professionals do obtain a certain amount of training related to building collapse, our project team sought to investigate whether an educational supplement could prove to be beneficial for Fire Investigators.

It was hypothesized that an investigation into the education and practice of Fire Investigators would prove that there was an opportunity for supplementation of the knowledge base related to the concepts of building construction. Our project team believes that enhancing knowledge of these concepts could help Fire Investigators better recognize structural collapse dangers. The very ambitious goal of this project was to create a piece of technology that could ultimately improve the occupational safety of Fire Investigators.

Our project team's work became a two-fold pursuit. First, the mission was to research the extent of education of Fire Investigators, focusing specifically on concepts taught relating to building construction and structural hazards. The goal of this investigation was not to expose a lack of structural education, but rather to find concepts that our project team could expand upon with a more thorough and visually-based explanation. The scope of this research involved interviewing Fire Investigators, reviewing course work of fire training schools, and surveying students and teachers at these training schools. The ambition of this research was to achieve an awareness of the state of structural knowledge of practicing Fire Investigators, and also of those entering the field. After collecting and organizing the research, our project team focused on identifying concepts of building construction which need greater emphasis.

The second objective of our project team was to create an interactive computer-based tutorial that would contribute to filling the void of structural knowledge and building safety the project team previously identified. This interactive tutorial could present and explain the most relative concepts of structural collapse to the fire investigation community, with emphasis on visual presentation, and avoidance of numerical theory. The interactive tutorial could focus on situations related to structural integrity that Fire Investigators have already faced on the job, and integrate concepts of building materials and construction techniques. Our project team believes this tutorial could help Fire Investigators make better judgments related to the structural integrity of given building.

The biggest challenge that was faced in the design and development of this tutorial was to create a product that would be received positively within the Fire Service.

Our project team decided that the best way to insure acceptance of the tutorial was to fully understand our client. The most productive mode of understanding the Fire Service was the interviewing process. Although the main intent of the interviews was to gain an overall understanding of the fire investigation profession, our project team also received a better understanding of the best mode of presenting the information of the interactive tutorial, based on questions we asked the Fire Investigators about their learning styles. It was decided that the tutorial could best service our client if the concepts were presented with extensive visual aids, and interactive examples.

It was the strong belief of our project team that an interactive tutorial was the very first step in trying to bridge the perceived gap of knowledge related to building construction that existed in the Fire Investigation field. The project team found that the knowledge base of Fire Investigators related to the concepts of building construction existed primarily as an observed science. This knowledge base was the result of years of experience and observation, and therefore lacked the underlying theory that explained why things happen from a scientific standpoint. The group sought to supplement this already existing observational knowledge with theoretical knowledge presented in a visual format. The success of this project relied primarily on our project team's understanding of the educational database of the fire investigation field, and establishing that supplementation it this database would prove to be beneficial.

1. Background

This chapter discusses the background to the topic of the project, which is the understanding and enhancement of the educational database of the Fire Service. This background includes the dangers that Fire Service personnel face in their professions, as well as the inherent drawbacks of fire professionals relying on experience-based education alone, as it pertains to building collapse.

1.1 Firefighting and the Dangers of Structural Collapse

The Fire Service has three basic criteria as it pertains to firefighting strategy: protection of life, containment of the fire, and protection of property. In this context, the protection of life includes that of the Firefighter as well as the civilian. The life safety of Firefighters is threatened not only by the smoke and fire itself, but also by structural hazards. Fire destroys the structural elements and/or connections in a building, and the fire event places loads on some structural elements that may contribute to structural failure. Once a structural collapse starts, the results are unpredictable since different buildings will react in different ways.

Unless a building is designed and built to be fire resistive (Type 1, which is defined by the *Massachusetts State Building Code*), there is no provision in the design of the structure to help prevent failure due to fire. Even if a building is defined as Type 1 construction, failure due to fire exposure can still occur (i.e., under extended fire exposure, structural members in a Type 1 building can fail). Fire resistance is a property of materials which prevents or retards the passage of excessive heat, hot gases or flames under conditions of use. Whereas Type 1 buildings are considered to be

"noncombustible" (2 to 3-hour minimum rating for structural members), Type 5 buildings are considered combustible (0 to 1-hour rating) (Massachusetts … 780 CMR). The vast majority of buildings are non-fire resistive (Type 5), and thus may easily collapse as a result of assault by fire on the structural system (Brannigan 11).

Wood burns and thus loses structural strength and integrity. The vast majority of structural fires are fought by Firefighters standing on or under wooden structures (Brannigan 12). It is a fact that occupants have usually been safely evacuated from a burning building before the collapse danger becomes great. Very few persons, other than Firefighters, are killed by burning building collapse. Only Firefighters are close to a burning building when it has been weakened by flames to the point of collapse danger. The fire endurance characteristics of lightweight construction systems have been discussed and debated within the Fire Service for years. The actual time to collapse, and the presence or absence of warning signs prior to collapse, are of great interest to the Fire Service (Dunn 1-5).

The way that buildings are constructed has changed significantly since the beginning of the 20th century. Efficient and cost-effective methods of construction are increasingly prevalent these days and are more prone to collapse in the event of a fire. It is not economically feasible to construct a building in the same way as during the early 1900's, for building materials are becoming increasingly expensive (*Reading a* …1). Lightweight construction materials and methods are praised by the building industry as the answer to affordable housing in this country. State building codes set minimum requirements (e.g., required load-carrying capacity, fire resistance, etc) in order to maintain a minimum level of safety, yet the dangers of lightweight construction are still

real and ever present to the Fire Service. Even if a building is defined as "fire-resistive" by the building codes, this does not guarantee it will survive a fire or the fire fighting effort (Brannigan 12).

In a scientific study conducted by the Federal Emergency Management Agency (FEMA) entitled *Trends in Firefighter Fatalities Due to Structural Collapse, 1979-2002*, it was found that Firefighter deaths in residential buildings have more than tripled in the last decade compared to the previous decades (1994-2002: 33 deaths; 1983-1992: 9 deaths) (Brassal; Evans 24). Moreover, in a FEMA study entitled *Wood Truss Roof Collapse Claims Two Firefighters Memphis, Tennessee*, researchers express that awareness and concern about the hazards of lightweight construction need to be increased throughout the Fire Service (Routly 21).

1.2 Lack of Information About Structural Collapse in the Fire Service

Many fatalities in the Fire Service have resulted because personnel have not been adequately informed or have not understood potential failures in structures. There are too many instances of fatalities that have occurred because Fire Officers did not recognize construction elements and the conditions under which they are likely to fail (Brannigan 15-17). Throughout this nation, structural collapse is one of the leading causes of Firefighter deaths, yet, except for a select few books on the subject, there is a complete lack of useful, accurate information about the danger for Firefighters (Dunn 3). Live firefighting training may inadvertently be delivering the wrong message. This training often emphasizes repetitive measures and "putting the wet stuff on the red stuff"

(Brannigan 2-3). Structural collapse is a major hazard to Firefighters, and it is too dangerous for live training.

After a burning building collapses and kills or seriously injures a Fire Service member, the Chiefs and Company Officers are usually unable to reason objectively why the building collapsed or even *how* the building collapsed. Emotions such as sorrow and anger distort the investigation. Even when impartial investigators arrive at the scene, little accurate information is derived concerning structural collapse (Dunn 3-5). Since there are always legal considerations involved when a person is killed or injured in a fire, the officials in charge of the investigation are often concerned only with placing blame (Dunn 5). Valuable information about collapse danger and safety lessons which could be given to Firefighters, Company Officers, and Chiefs are often overlooked and lost during the investigations.

1.3 Dangers of Fire Investigation

Exposure to the possibility of structural collapse pervades many specializations within the Fire Service. The safety of Fire Investigators is often taken for granted, since many investigators assume by the time they arrive at a fire scene, the potential safety hazards are either eliminated or diminished to the point that they are no longer a concern. Many fire departments across the country have yet to understand that conducting fire scene investigations is inherently dangerous (Donahue 1-3).

For years, the mindset of Fire Investigators has been to respond to a fire scene to conduct an examination as quickly as possible, oftentimes as the fire department is still performing suppression or overhaul operations. There are several important reasons for

this expedience, which include: scene security, evidence preservation, and the importance of interviewing witnesses to obtain key information before they leave the scene. This mindset is continuously reinforced countless times through fire investigation training and education programs (Donahue 4). Responding to fire scenes as quickly as possible is certainly an essential investigative tenet, particularly where arson is suspected (in which case an expedient criminal investigation is required). However, it also happens to be the time when Fire Investigators are the most vulnerable to injury under hazardous conditions of the building.

1.4 Drawbacks of Relying On Experience Alone

Some Fire Officers have learned to make useful, but limited judgments regarding the loss of structural stability in a fire. Unfortunately, many of the commonly taught indicators, such as sagging floors, strange noises, etc. may be too little too late. In addition, experience with one type of building element, such as solid sawn wood joists, is not valid for wood trusses, or wooden I-beams. Furthermore, architects and the building industry continue to design and build structures that vary in type, design, materials, and building methods. Thus, simply memorizing different categories of building construction (e.g., Type IV construction) is not sufficient -by itself- for predicting structural collapse.

Firefighters must not wait for "experience," for in the Fire Service the price of experience is blood and grief. Proper training and a working knowledge are far less costly than experience. In FEMA's study entitled *Trends in Firefighter Fatalities Due to Structural Collapse, 1979-2002*, researchers found absolutely no correlation between years experience in the Fire Service and deaths due to structural collapse (Brassel; Evans

15). Relying on experience alone is not sufficient. Fire professionals must be aware of the governing principles involved in structural collapse and building safety that apply in all situations.

1.5 Value of Increased Knowledge

Fire professionals who can recognize and evaluate the strengths and hazards of buildings will increase their own efficiency and safety. Fire professionals should learn to look at visibly-exposed connection systems (e.g., floor joists seen from beneath the floor level) which transfer the loads from one element to another along a given path. A fire professional's ability to read a building, evaluate its strong and weak points, and then determine his/her degree and place of involvement would put that person at an advantage when it comes to safety. Firefighters try to achieve a fit between the perceived situation and their memory store of mental schema (Pauls; Groner 5). Accordingly, good situational awareness results from the availability of schema that suite well to situational features (Pauls; Groner 5).

1.6 More Useful Information Is Needed

Fire Officers need more intelligible knowledge (i.e., knowledge which they can understand and relate with) to help them develop a rough fireground baseline. This knowledge can be used to help them evaluate how much time they have before a structural collapse can occur when fire is exposing (and weakening) structural members. Additionally, Fire Investigators need more intelligible knowledge to assess the safety of damaged buildings as they enter to perform their investigations. In order to provide the

Fire Service with more accessible knowledge about building construction, new educational tools should be tested to supplement the current database of the Fire Service. These educational tools must encompass all those structural principles which pertain to the subjects previously mentioned, whilst maintaining simplicity and convenience. In order to develop these new educational tools, the current state of education within the Fire Service must be thoroughly analyzed.

In the Fire Service, as in other fields, this is the "age of information." Progressive Fire Officers and Fire Investigators are realizing that information is the key to successful firefighting. Structural hazards of a building are some of the most important items of information that a fire professional can know to conduct their work efficiently and safely.

2. Project Methodology

This section will describe exactly why our project team chose the methodical path that is described in full detail later in this report.

Creating a Hypothesis

When the majority of the background research was completed, our project team began forming a hypothesis. Certain gaps were seen in the texts, course, and other educational materials that were known to be widely used in the training of fire professionals. As a result, those who work in hazardous conditions may lack accessible knowledge of structural principles that could at some point play a part in their safety. Armed with this strong opinion, our project team set out to create a valid hypothesis that could eventually fill those gaps and hopefully in the broad spectrum, possibly even save lives of fire professionals. This hypothesis took the form of an interactive tutorial. It was believed that by using real life examples without the necessity for great technical knowledge of computers or mathematics, a helpful and interesting educational supplement could be produced. For the complete analysis of the texts covered by this project, please refer to Chapter 3. Initial Research - Review of Texts and Other Available Resources.

Familiarity with Current Education

With the new hypothesis our project team then needed to conduct research in multiple facets to support and show proof that our hypothesis was correct and that there is a need for supplementary educational tools concerning structural principles. Since texts are only one form of education for fire professionals and it was known that many attend

seminars, various 90-hour courses, and receive other widely distributed educational pamphlets, it would be impossible to assume what all fire professionals know or do not know certain principles based only on review of certain texts. It was decided that only through interviewing those currently in the Fire Service, by surveying the students who intend to enter this profession along with the curriculum coordinators from fire academies in a wide demographic, could we more firmly establish their current knowledge base.

One of the main focuses when creating interview questions, seeing as how our goal was to determine what types of educational background they were lacking, was to not offend the intelligence of the interviewees. These interviewees were well established in the field, many for more than 20 years, who held officers positions and like everyone else, do not like to feel unintelligent. By being subtle in our questioning, and by wording the survey correctly it was possible to achieve a comfortable atmosphere and receive valuable input not only on what that particular person knows but insight on what and how to write questions on the survey intended for students attending fire colleges in the area. With this critical analysis of the first draft of the local survey, our project team then revised and released the survey to a group of professors at the Massachusetts Fire Academy via their Director of Fire Science. To read more about the interviews and the local survey, please refer to Chapter 4. Interviews - Research of the Work Environment and Chapter 5. Local Surveys - Understanding the Current Knowledge Base, respectively.

Once it was established what the current knowledge base was in the Worcester area, and surveys were returned form the M.F.A., our project team needed to look at a broader spectrum. Because the education of fire professionals is mandated only by the

town, not the state or the government, materials and focuses could change by moving across the country. Now that invaluable research was done through the interviews and local surveys, our project team felt comfortable creating another survey to be distributed throughout the country to get a broader sense of the education in the entire United States. If the same supporting evidence as to the need for educational supplements was found nationally as it was locally, there would be no question that the original hypothesis that there is a lack of education in the area of building construction and the associated hazards along with the need for supplementary materials was correct.

Proving the Hypothesis

As our project team received responses from the national survey, the original goal only seemed more and more necessary. Now, even though the development of the interactive tutorial had been an ongoing process from early on, it had new life and purpose and was ready for completion and then testing. To create such an interactive program, it took hours of self-education on the parts of the team members to learn the PowerPoint program, and all the features it contains. Custom animation, moving pictures, and light-hearted examples, mixed in with factual data were the foundational concepts used to capture the attention of intended users.

With a beta version of the tutorial complete, it was ready to be distributed to a test audience along with a post-tutorial quiz and follow-up questionnaire. Feedback was welcomed and a few minor glitches were found and dealt with in this way. Overall, this portion of the project was crucial; because it showed whether or not the concepts and examples given were applicable in the field of fire investigation. For a complete description of the tutorial testing phase, refer to Chapter 9. Tutorial Testing.

3. Initial Research - Review of Texts and Other Available Resources

This chapter examines the current educational database of the Fire Service. Fire Service institutions, textbooks, and software that pertain to the education of fire professionals in principles of building construction and structural hazards are thoroughly analyzed in this chapter. Additionally, current efforts to increase awareness of structural collapse dangers throughout the Fire Service are also studied.

3.1 Current State of Education and Standards for the Fire Service

Since its inception in the early 1970's, the National Fire Protection Association (N.F.P.A.) Professional Qualification series has identified the competencies necessary to perform the various positions within the Fire Service. In accordance with *NFPA 1021* (2003) and *NFPA 1033* (2003), both Fire Officers and Fire Investigators must possess a basic knowledge of building construction and be capable of identifying safety hazards in a building. According to the N.F.P.A., their standards should be used for training design, evaluation, certification, measuring and critiquing on-the-job performance, and setting organizational policies, procedures, and goals.

Aspiring Fire Officers and Fire Investigators many times study Fire Science after high school. Locally in Massachusetts, many attend Anna Maria College to earn an undergraduate degree in Fire Science. The Fire Science program at Anna Maria College reflects current N.F.P.A. standards in an effort to address the challenging and dynamic aspects of public sector Fire Service leadership and administration. There is only a single course within this program which discusses building construction.

A course entitled *Building Construction for Fire Protection* explores the components of building construction that relate to fire and life safety. The focus of the course is Firefighter safety, and it addresses elements of construction in preplanning, fire operations and operating emergencies. The textbook for this course is entitled Building Construction for the Fire Service by Francis L. Brannigan. The material discussed in Brannigan's book was assembled from his experiences and by his reading and questioning of practicing engineers.

Upon completion of a degree in Fire Science, many ambitious fire professionals attend the Massachusetts Firefighting Academy (M.F.A.) (though a Fire Science degree is not an admission requirement). The M.F.A. was brought into existence by Massachusetts General Law, Chapter 842 of the Acts and Resolves of 1971, in response to a growing awareness of Americans to "the fire problem," as discussed in such reports as America Burning (http://www.mass.gov/dfs/mfa/index.shtm). The Academy offers over 300 topical continuing education courses. The M.F.A. is a center for post-employment training, hence holding a position within the Fire Service is a requirement for admission. Since the Massachusetts Fire Training Council is the sole certifying agency for certification of all levels of Fire Service personnel in the Commonwealth of Massachusetts, it has the authority to approve courses and curriculum taught by the M.F.A. This council bases Fire Service certification on N.F.P.A. standards.

There is only a single course offered at the M.F.A. that discusses building construction. M.F.A.'s *Structural Hazards* course is designed to give Fire Service personnel some insight into structural hazards that may be encountered. The presentation of the course helps to make Firefighters more aware of building defects common in old as

well as new construction. The textbooks for this course include Building Construction for the Fire Service (Brannigan) and Collapse of Burning Buildings by Vincent Dunn. Similar to Brannigan, Vincent Dunn has no technical training in Structural Engineering or structural fire safety; his book is based on his personal experiences as a decorated Fire Officer.

The above books by Brannigan and Dunn have many similarities. Both approach the subject of structural principles in a very empirical and simplistic manner. Each book heavily emphasizes proper vocabulary and terminology as it pertains to building construction. Moreover, both books contain telling on-site photographs that help the authors convey their messages to the reader. Both these books share a common drawback in their presentation of the causality for structural collapse. Upon reading either one of these books, a reader may feel overwhelmed with specific fragments of knowledge and may experience difficulty understanding the major unified concepts of building construction. The contents of these books are thoroughly described and analyzed in the following sections of this report.

3.2 Current Research for Increased Awareness of Structural Collapse

As the Professional Qualification series of the N.F.P.A. has grown, it is becoming increasingly difficult for fire professionals to find the necessary time to accomplish these levels of competency. Despite the potential danger to fire professionals of sudden building collapse, there is only minimal information about the subject in the Fire Service. Currently, efforts by the National Institute of Standards and Technology (N.I.S.T.) have been made to increase an awareness of structural collapse in the Fire Service.

In 2003, the N.I.S.T. developed a DVD to help fire departments improve training to better prepare Firefighters for building collapse, in which test buildings were burned for experimental data collection. Moreover, the N.I.S.T. is currently trying to develop and evaluate an early capability for Firefighters to detect structural collapse in a burning structure (Duron 1). N.I.S.T.'s study entitled *Early Warning Capabilities for Firefighters: Testing of Collapse Prediction Technologies* is based on monitoring structural vibrations induced by fire, and using these measurements to define indicators that can provide warning of impending collapse (Duron 18-19). These attempts to correlate measured responses with changes in structural behavior during a fire have shown that trends in response magnitude, response statistics, and in changing system parameters can all be used to track changing structural conditions leading to collapse. It was also noted in this study that this capability may prove to be useful for Fire Investigators, as well as Fire Officers (Duron 19).

3.3 Textbook by Francis L. Brannigan

The text Building Construction for the Fire Service by Francis L. Brannigan relates various aspects of building construction to the life safety concerns of fire professionals. This book is incorporated into the curriculum of many Fire Service programs, such as those offered at the Massachusetts Firefighting Academy, Anna Maria College, and John Jay College of Criminal Justice. In this book, Brannigan reviews construction methods and techniques that may place a fire professional in danger. Brannigan also includes tactical considerations for fire operations. Indeed, Brannigan has devoted over thirty years of his career to the safety of fire professionals in building fires.

Francis Brannigan started his career as a Navy Firefighting Officer during World War II. Since 1966, he has concentrated on Firefighter safety in the deadly environment of a building fire. The first edition of his book was an instant success in 1971. Since then, Brannigan's book has sold more than 130,000 copies in three editions; the most recent was published in 1992. When Brannigan first started composing his book, he found no appropriate body of knowledge to which to refer. Hence, Brannigan started compiling information himself by taking many thousands of pictures of building construction, which serve as the evidence for his claims about building construction.

Before our project team reviewed the contents of this widely-used textbook (*see Chapter 6 for national survey results*), we first developed an evaluation scheme (*see Table 1 below for summary*). First, our project team believes that the book should contain highly accurate information about the principles of building construction and structural hazards. Moreover, this information should be portrayed in a fashion that is entirely accessible to training fire professionals. More precisely, the material covered must not rely on mathematics to convey the concepts, for fire professionals usually do not learn extensive mathematics during their academic careers (*see Appendices for course listings*).

Since many principles of building construction are mathematically intensive, our project team seeks to observe how Brannigan portrays these concepts in his book. The second criterion that our project team will use to evaluate this book is its level of appeal to the reader. Our project team seeks to observe how well Brannigan is able to maintain the interest of the reader throughout the duration of the book. In order to make an

accurate assessment of the book, project team members must read the book carefully, and strictly adhere to these evaluation criteria.

Brannigan's book does indeed contain a vast amount of construction pictures which directly relate to each of his discussions. Moreover, the sections of his book are carefully organized into fourteen separate chapters. Initially, the book reviews general principles of construction and then examines wood and ordinary construction in great detail. Other chapters include discussions concerning garden apartments, principles of fire resistance, steel construction, concrete construction, fire growth, smoke and fire containment, high-rise construction, trusses, automatic sprinklers, and rack storage. Since the book is so carefully organized, there is minimal overlapping of material covered.

Brannigan's book offers careful and in-depth descriptions of various elements of building construction. In the second chapter of the book, in which the general principles of construction are discussed, Brannigan is able to draw interesting analogies to portray rather complicated concepts. For example, Brannigan demonstrates the principles of axial strength by shaping a sheet of paper into various forms. These intelligible analogies further prove Brannigan's absolute dedication to the educational needs of fire professionals, who typically are not familiar with engineering principles.

Although Building Construction for the Fire Service is considered by many to be the best book of its kind, it still suffers from three or more specific drawbacks. These drawbacks include: excessive concern for detail, failure to unify most of the principles discussed, and ineffectual use of mathematics. Since Brannigan often goes into meticulous detail during his discussions, the book turns out to be very lengthy. As a

result, the content of the book feels drawn out and may become monotonous for the reader. This is an important drawback to address because fire professionals generally have many obligations to attend to in their careers and may not be willing to read the book in its entirety. If the book is actually read in its entirety, the reader may feel overwhelmed with information.

Brannigan presents various articles of information in his book without always properly discussing how certain facts are inherently related. As a result, the reader may experience difficulty retaining all of the information and then apply that information in complex situations such as a fire investigation. For example, Brannigan states that "a twelve foot beam can carry half the load of a similar six-foot beam," yet he does not describe the material properties that govern this occurrence (e.g., bending moment resistance).

For the most part, Brannigan avoids discussion of mathematics in his book. Yet, when he does refer to mathematics, he does so in a very ineffectual manner. For example, Brannigan calculates the load resistance of two different columns without discussing the mathematical principles that could apply to any column encountered. Since Brannigan has not been formally trained as an engineer, the book does contain certain instances in which inaccurate information is expressed. For example, Brannigan states that a *kip* is a term meaning 1000 pounds per square inch (psi), when in reality, a *kip* represents 1000 pounds. It is known that the book contains a multitude of construction pictures, yet these pictures lack visual indicators to focus the reader's attention on certain aspects of the photograph as it applies to the concepts being discussed.

Building Construction for the Fire Service has served as an invaluable source of insight into the educational literature used by fire professionals as it pertains to building construction. Our project team intends to expand upon the book's many strong points, as well as develop innovative ways to improve upon its drawbacks.

Table 1: Textbook Evaluation Criteria

Evaluation Criterion	Description
Criterion I (Informational Content)	- Highly accurate information about building construction / structural hazards. - Information should be accessible to fire professionals, and thus should not rely on mathematical explanations.
Criterion II (User Appeal)	- Maintains the interest of the reader. - Use of multimedia sources.

3.4 Textbook by Vincent Dunn

Collapse of Burning Buildings by Vincent Dunn is a book that relates various aspects of building construction to the life safety concerns of fire professionals. This book is incorporated into the curriculum of many Fire Service programs, such the *Structural Hazards* course at the Massachusetts Firefighting Academy (M.F.A.). In this book, Dunn discusses his experiences with structural collapse during building fires in great detail. Dunn also recommends a variety of safety precautions that Firefighters should exercise prior to a potential structural collapse.

Vincent Dunn has served the New York Fire Department for over 40 years; he has worked as a Firefighter, a Company Officer, and a Chief Officer. Dunn also is an adjunct professor at Manhattan College, John Jay College of Criminal Justice, and the National

Fire Academy, where he teaches such courses as *Fire Protection Design of Buildings* and *Building Construction and Life Safety Systems*. Indeed, Dunn has devoted a significant portion of his career to educating fire professionals about the dangers of progressive building collapse during fires exposures.

Before our project team reviewed the contents of Dunn's textbook, we first referenced the evaluation scheme that was used to assess the effectiveness (i.e., completing the task of expressing complex principles of building construction to the reader) of Brannigan's textbook. This evaluation scheme involves an assessment of the informational content, as well as the style of presentation of the book to be reviewed. Please see Table 1 for a summary of this evaluation scheme.

Collapse of Burning Buildings focuses almost entirely on how a building fails, thereby excluding many principles of how a building is constructed. Moreover, Dunn discusses building collapse with more sensory detail that any other textbook encountered by our project team during this project. Dunn begins the book by discussing general collapse information, but soon delves into information concerning collapse of stairways, flat roofs, sloping peak roofs, fire escapes, etc. Each chapter of this textbook is devoted to a particular type of building collapse. Furthermore, each chapter begins with a narrative in which Dunn recounts specific events from his firefighting career. For example, at the beginning of his fifteenth chapter entitled *Wood-Frame Building Collapse*, Dunn recounts a time in which he witnessed a wooden wall collapse onto a fellow Firefighter.

At the end of each one of Dunn's chapters, he offers "lessons to be learned." These lessons represent words of advice from Dunn based on his extensive experience

dealing with building collapse as a Firefighter. These recommendations are based mostly on sensory perceptions (e.g., hearing, smelling, etc.) that a Firefighter can use to help predict building collapse. Overall, Dunn's textbook clearly presents principles of structural hazards in a very different style then Francis L. Brannigan does in his book entitled Building Construction for the Fire Service. Whereas, Brannigan starts with basic principles of building construction and then uses those facts to introduce dangers of building collapse, Dunn delves directly into discussion of building collapse from the very beginning of his book.

Dunn's method of presentation clearly assumes that the reader is quite familiar with basic principles of building construction. Hence, Dunn's book would be a great educational tool for training fire professionals who are familiar with the information presented in Brannigan's book. The way in which Dunn presents information about building collapse clearly shows that he strived to create an educational tool in which fire professionals could relate to on a very personal basis. Furthermore, Dunn's book does not feel as drawn out as Brannigan's book. Dunn's book is very interesting throughout because he frequently grabs the reader's full attention by recounting some of his intense experiences as a Firefighter.

Similar to Brannigan's book, this textbook suffers from specific drawbacks. First, Dunn's book overemphasizes the classification of building construction into the five types (e.g., Type IV construction). Understanding the differences between building construction types is important, but assumptions made about a particular type will not apply in all situations. For instance, a building may have components that represent multiple types of building construction. Dunn does discuss principles of building

construction that could be applied in any situation (e.g., effects of different loads on members), but our project team believes a greater emphasis upon these would have been more effective. Similar to Brannigan's book, Dunn's textbook contains a vast amount of excellent pictures directly related to the discussion, but they do not include indicators to direct the reader's attention to specific aspects of the photographs.

Collapse of Burning Buildings has served as an invaluable source of insight into the educational literature used by fire professionals as it pertains to building collapse. Our project team intends to expand upon the book's many strong points, as well as develop innovative ways to improve upon its drawbacks.

3.5 Textbook by Edward Allen

The *Building Construction and Life Safety Systems I / II* courses at John Jay College of Criminal Justice (a college for fire and law enforcement professionals) utilize the following textbooks: Building Construction for the Fire Service (Brannigan), the International Building Code, and Fundamentals of Building Construction: Materials and Methods (Allen). Before our project team reviewed the contents of Allen's textbook, we first referenced the evaluation criteria that was used to assess the effectiveness (i.e., completing the task of expressing complex principles of building construction to the reader) of Brannigan's textbook. This evaluation scheme involves an assessment of the informational content, as well as the style of presentation of the book to be reviewed. Please see Table 1 for a summary of this evaluation scheme.

Edward Allen's textbook provides a complete, up-to-date description of building construction practices. This textbook does not discuss structural hazards and deviates

from any theoretical concepts of building construction. Instead, Allen's textbook is primarily intended for contractors, tradesmen, and building technology students, who are mainly concerned with the actual construction of a building and not about the hazards that may appear during and after a fire.

Allen's textbook covers a wide variety of building construction practices, which range from foundation construction to interior ornamentation. Similar to Brannigan's book, this textbook provides excellent pictures of construction that are directly relevant to the discussions. Moreover, similar to Brannigan's book, Allen's textbook lacks indicators in the pictures to direct the readers' focus to specific elements of the illustration.

Allen's textbook completely avoids mathematics and theoretical principles during the discussions. As with Brannigan's book, this textbook is very long and may overwhelm the reader with various articles of information. It is apparent that Allen's textbook was not intended to be read cover to cover, but rather for a tradesmen to seek certain articles of detailed information related to his/her work. Moreover, this textbook provides comprehensive table of contents and index sections for the reader to use.

Unlike Brannigan's book, this textbook does not direct any attention to the educational needs of members of the Fire Service. Hence, fire professionals would have a much easier time relating to Brannigan's book than Allen's textbook.

3.6 Virtual Reality Fire Investigation Software

The primary objective of this project is to supplement the current educational database of the Fire Service as it pertains to principles of building construction and

structural hazards. More specifically, our project team believes that there exists a great opportunity to enhance the education of Fire Investigators. By the nature of their profession, Fire Investigators are granted adequate time to assess the structural integrity of a building before entering. Hence, our project team strives to supplement the knowledge of training Fire Investigators in order to increase their occupational safety. In order to accomplish this, our project team had to first learn about the Fire Investigation profession.

Our project team reviewed many textbooks that are used by training Fire Investigators. This literature review helped our project team discover what types of building construction knowledge Fire Investigators are expected to be familiar with. Conducting interviews with current Fire Investigators will help our project team understand the day-to-day operations of a typical Fire Investigator, but they will not provide us with any field experience. It is impossible for our project team to perform a real-life fire investigation because of insurance concerns. Although, an alternative option to a real-life fire investigation was discovered by our project team.

A few years ago, a national initiative to improve the skills of Fire Investigators was launched by the National Fire Protection Association (N.F.P.A.) and the Federal Emergency Management Agency (F.E.M.A.). One resultant of this effort was the development of the interactive CD-ROM set, entitled *InterFIRE VR*. The *InterFIRE VR* program allows users to search an actual fire scene while consulting with various types of law enforcement and fire officials. This program was designed to teach a comprehensive and systematic investigative approach that can be applied to any fire scene (www.interfire.com). Moreover, the Society of Fire Protection Engineers (S.F.P.E.)

affirms that this program is the first-ever CD-ROM to use photo-realistic virtual reality technology for fire investigation training purposes (Massive Effort… 1).

InterFIRE VR's content was developed over a period of more than two years by fire investigation experts from various federal agencies. A house was set on fire and suppressed by a local fire department for use in this program. Additionally, many actors were used to play various roles during the course of the virtual fire investigation. The resulting software provides both a strong overview and specific detail on many aspects of fire investigation procedures. The scenario investigation in this program is considered to be the "flight simulator" for Fire Investigators (Massive Effort… 1).

It is a goal of both the N.F.P.A. and F.E.M.A for the *InterFIRE VR* program to supplement the nation's 31,000 fire departments. Hence, these agencies aim to deliver this program into the hands of every Fire Investigator in the United States (1-2). Our project team ordered two copies of *InterFIRE VR* from F.E.M.A. and studied its contents.

The study of the *InterFIRE VR* CD-ROM served two purposes for our project team. First, our project team viewed the CD-ROM as a part of our literature review. Our project team wanted to see if this program offered any information about building construction and/or structural hazards to Fire Investigators. Second, our project team sought to understand the complexities that Fire Investigators face in their profession. In order for our project team to supplement the education of Fire Investigators, we must first understand the typical problems that Fire Investigators face. This strategy also applies to Fire Investigators in training, for they are usually involved in field exercises at real fire scenes (*see Section 4.2*).

Upon reviewing the contents of *interFIRE VR*, our project team realized that this software does not cover any principles of building construction, nor does it identify structural hazards. This fact was surprising to our project team, since the developers of the program clearly had a great opportunity to do so. More precisely, the developers went to great lengths (e.g., development of new virtual reality software) to grant the user the ability to virtually navigate through a damaged building, yet they did not spend any time to identify possible structural hazards for the user. Hence, it is clear that the emphasis of this software is solely on basic fire investigation procedures, such as the collection of evidence and interviewing witnesses.

Our project team found that the *InterFIRE VR* program is an extremely valuable source of information for our project. Using this program, each team member performed a virtual reality fire investigation and received feedback concerning job performance in the form of a text report (*see Appendices section for text report*). By using this program, our project team was able to place ourselves "in the shoes" of a Fire Investigator and learn about the complexities of the profession. By reviewing the contents of *InterFIRE VR*, our project team has gained valuable knowledge about basic fire investigation procedures. Furthermore, the study of this software reaffirms that there is indeed a great opportunity for our project to create an educational supplement which covers the principles of building construction and structural hazards- something that *InterFIRE VR* clearly does not do.

3.7 N.F.A. Handoff Course

Many volunteer and career Fire Service personnel do not have the time to attend on-campus programs at the National Fire Academy (N.F.A.). To reach these students, the

N.F.A. offers a variety of handoff courses (i.e., courses that students can take at home). These handoff courses are produced by the N.F.A. and developed by the National Audiovisual Center (N.A.C.), which is a division of the National Technical Information Service (N.T.I.S.). The N.A.C. is a centralized resource for federally-developed training and educational materials. N.F.A. handoff courses are field tested across the nation for at least two years –validated, refined, modified, improved, and reviewed– to assure that course content and design are effective and accurate.

One handoff course that specifically relates to this project is entitled *Principles of Building Construction: Combustible*. The overall goal of this course is to provide knowledge about the classification system of buildings, the importance of fire resistance for structural support elements, and the risks associated with performing fire-suppression activities inside and around buildings involved in fire. This program consists of three CD-ROMs, which includes a student manual, an instructor's guide, six PowerPoint lectures, and examination questions (with answers). This course addresses the professional development of a broad range of fire department positions. Moreover, this course addresses professional competencies related to building construction as noted by the National Fire Protection Association (N.F.P.A.).

Before our project team reviewed the contents of this educational software, we first referenced the evaluation scheme that was used to assess the effectiveness (i.e., how well the textbook was able to convey information about principles of building construction to the reader) of Brannigan's textbook. This evaluation scheme involves an assessment of the informational content, as well as the style of presentation of the educational tool. Please see Table 1 for a summary of this evaluation scheme. In

addition to these criteria, our project team also observed what specific features of PowerPoint are utilized to convey the information in an effective manner, in order to assess the possibility of using this software for the development of an educational supplement.

This building construction course is sectioned into six PowerPoint presentations, which represent six separate modules. Module 1 provides an introduction and overview of the five types of building construction (Type I–V, as defined by the *Maryland Building Performance Standards*). At the end of this lecture, the user is provided with an activity to complete. In this activity, the user is presented with various photographs of building construction and is asked to classify each as one of the five construction types.

Module 2 describes the types of loading that may act on a building, which include: dead, live, concentrated, distributed, impact, axial, eccentric, and torsion. It should be noted that the demonstration of the difference between a concentrated load and a distributed load is very unclear (*see Figure 1*). This section of the course also describes the basic principles of tension, compression, and shear. Furthermore, the basic mechanical properties of wood, steel, and concrete are discussed, as well as the different types of trusses that are used for roof support. Toward the end of Module 2, the user is presented with a diagram of a building and various articles of loading which reside. The user is then asked to identify each article of loading as one of the types of loading previously discussed.

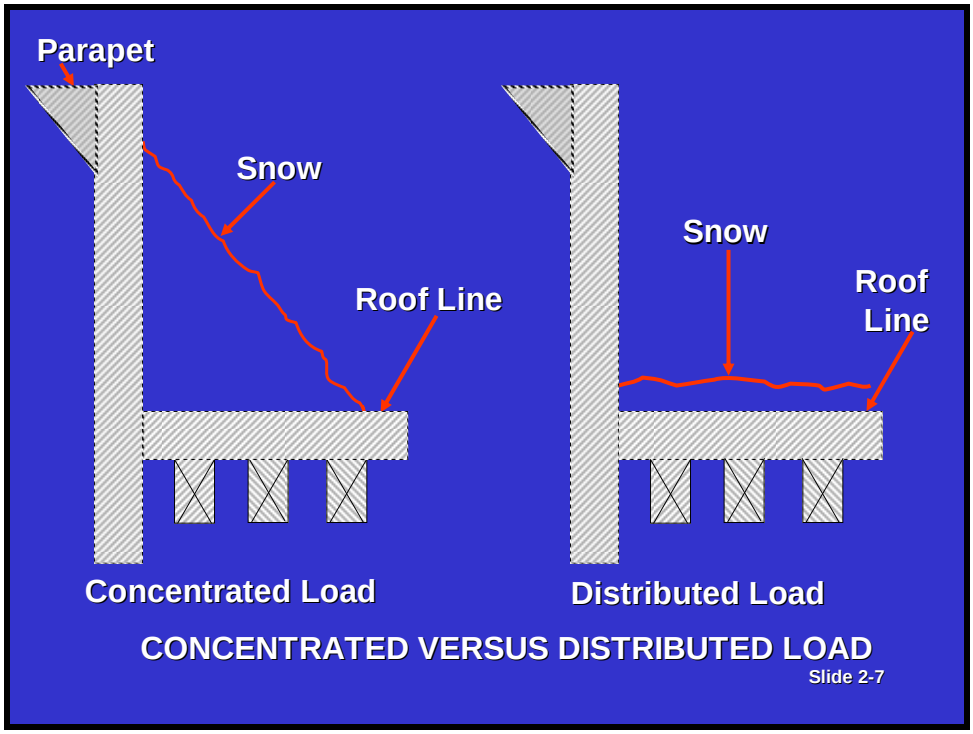

Figure 1: Slide 2-7 from Module 2 (N.F.A. handoff course)

Module 3 discusses the construction principles for wood-frame buildings, which includes log, post-and-beam, balloon, platform, and plank-and-beam framing. Certain factors are discussed that pertain to the strength of wood (e.g., decay), as well as mechanical connection methods to link wood members. Module 4 discusses the principles of ordinary construction, which includes topics such as masonry bearing walls, fire-cut floor joists, roof construction, and areas that may be vulnerable to fire spread.

Module 5 discusses the principles of heavy-timber construction and how fire can spread through such structures. Module 6 is the culminating activity in which the user is presented with various firefighting scenarios and is asked to identify and describe the characteristics of the particular building classification, its construction features, and critical considerations for the Incident Commander.

In addition to the lecture slides, this course includes a brief video which is run using a basic media player entitled *Ladder 27: a Survival Story*. This video shows footage of Firefighters from the Phoenix Fire Department attempting to ventilate the roof of a house that is involved in fire. The roof of this structure collapses, yet the Firefighters that fell through the roof miraculously survive. The remainder of the video discusses the inherent dangers of steel gusset plates used for roof truss connections.

In addition to reviewing the contents of this course, our project team also analyzed the final exam (*see Appendices section for this exam*). This final exam is indicative of what specific concepts the user is expected to have learned by the course's conclusion. It was found that this final exam poses questions that mostly deal with basic incident procedures (e.g., incident action plan) and specific terminology (e.g., identifying what a *scupper* is). Instead of focusing on such important concepts as how loads are transferred through structural elements and the implications for Firefighter safety, the majority of the questions involve the identification of various types of building construction.

The *Principles of Building Construction: Combustible* course offered at the N.F.A. has both strengths and weaknesses. Overall, the information is clearly presented and accurate. The course has very interesting activities that integrate pictures of construction with computer-generated flames realistically exhausting from certain locations. Additionally, the materials are logically separated into six sections.

The most noticeable drawback of this course is the strict separation between the text and the corresponding pictures. More specifically, the pictures used to supplement the text completely lack indicators and explanations for the user. Moreover, complicated

plan details are often presented with little to no explanation. Another major drawback of this course is the PowerPoint presentation is extremely dull and repetitive. More precisely, a user watching the PowerPoint presentation may feel like he or she is reading a textbook because most of the slides only contain text. Additionally, users will have difficulty finding a specific topic to study since the sections of this course do not link to a table of contents. Studying the contents of this course will assist our project team as we strive to supplement the educational database of the Fire Service as it pertains to principles of building construction and structural hazards. Our project team intends to expand upon the many strengths of this course, as well as seek innovative ways to improve upon the course's drawbacks.

3.8 Firefighter's Handbook (Delmar)

Upon receiving results from the national survey (*see Chapter 6 – National Survey*), our project team was able to identify different textbooks that fire academies across the country are using to teach principles of building construction. In addition to the texts by Brannigan and Dunn, the national survey identified Firefighter's Handbook: Essentials of Firefighting and Emergency Response as another textbook that is being used to teach principles of building construction at many fire academies.

This handbook is currently in its second edition and meets the 2002 NFPA Standard 1001, which identifies the minimum job performance requirements of career and volunteer Firefighters whose duties are primarily structural in nature. The authors of this textbook specialize in a variety of professions within the Fire Service, which include: firefighting, emergency medical service, fire science/training instruction, and fire

inspection/investigation. Moreover, the information in this textbook is primarily used in Firefighter I/II certification courses (*see Appendices for course listings*). This textbook is a comprehensive guide to the basic principles and fundamental concepts involved in firefighting, emergency medical services, and hazardous materials operations.

This textbook consists of thirty chapters; one chapter of the textbook is devoted to discussion of building construction. The second edition (printed in 2002) contains a chapter on building construction that has been completely revised to address new building structures and additional considerations in structural collapse. Additionally, a special section of the chapter has been dedicated to Francis L. Brannigan. Chapter 13 of this textbook is entitled "Building Construction" and was written by David Dodson, who has 24 years of experience as a Firefighter and 7 years experience as a Training/Safety Officer.

Before our project team reviewed the contents of this textbook, we first referenced the evaluation scheme that was used to assess the effectiveness of Brannigan's textbook. This evaluation scheme involves an assessment of the informational content, as well as the book's style of presentation. Please see Table 1 for a summary of this evaluation scheme.

David Dodson modeled Chapter 13 of the Firefighter's Handbook: Essentials of Firefighting and Emergency Response after the book entitled Building Construction for the Fire Service by Francis L. Brannigan. Dodson emphasizes that Brannigan's book has greatly influenced his outlook on the principles of building construction and recommends the book to others by saying that it "is a must read for any firefighter and critical reading for anyone wanting to promote into fireground decision-making positions" (Dodson 263).

Similar to Brannigan's book, Chapter 13 of this textbook offers excellent photographs of building construction that directly relate to the topic being discussed. Though unlike Brannigan's book, the photographs are in color, making them more telling for the reader.

Chapter 13 of this textbook by Dodson has many strong points. This chapter includes certain charts that summarize different articles of information conveniently for the reader. For example, Dodson includes a chart that characterizes the performance of construction materials as "good," "marginal," or "poor" based on forces of compression, tension, shear, or fire exposure. This chapter also involves discussion of historically-significant building collapses to which the reader may easily relate. Taking after the literary style of Vincent Dunn, Dodson includes sections that are entitled "street smart tips," which offers a Firefighter's experience-based judgments about topics in building construction. At the end of the chapter, key terms and their definitions are listed for the reader in a very convenient fashion. Most importantly, Dodson is able to incorporate safety concerns that may be unknown to the reader, such as the dangers of modern prefabricated stairways, the hazards of a building during the construction phase, the retention of heat in concrete, and the dangers of parapet walls that include attached billboards.

Dodson's chapter on building construction has similar drawbacks as Brannigan's book. Dodson devotes a large portion of this chapter to the classification of building construction according to the five types. For example, he extensively discusses the common features of Type II construction (e.g., building materials used). Although, he does mention that "the five broad building types can actually lead to dangerous

assumptions." Moreover, he also states that "newer construction and alternative building methods may not fit cleanly into one of the [construction types]" (Dodson 267).

Dodson also emphasizes terminology, as opposed to unifying concepts (e.g., transmission of loads) throughout his chapter. For example, he identifies an extensive number of roof types (e.g., gable, hip, etc.), yet he does not discuss their relevance to Firefighter safety (e.g., structural collapse potential). These drawbacks culminate in the review questions at the end of the chapter. Many of the review questions ask the reader to list and/or define terminology of building construction. The reader is not asked to critically evaluate the safety of certain load paths or make comments about the behavior of structural elements when specific loads are applied.

Dodson stresses that his chapter "is merely an introduction" and "firefighters must bridge the information in [the] chapter with a long-term commitment to [the] study and research of building construction" (Dodson 261). Dodson also states that "Firefighters must rely on building material knowledge, building construction principles, and an understanding of fire effects on buildings in order to predict or anticipate collapse" (Dodson 262). Overall, Chapter 13: "Building Construction" contained within the Firefighter's Handbook: Essentials of Firefighting and Emergency Response resembles Brannigan's Building Construction for the Fire Service in many ways. Dodson is able to expand upon Brannigan's book by offering color photographs and introducing information about newer types of construction (e.g., prefabricated stairways). This book adds to the literary database that our project team has compiled thus far concerning the training of fire professionals in the principles of building construction.

4. Interviews - Research of the Work Environment

One of the most important and informative contribution towards our understanding of the fire investigation profession came through the interview process. The goals that our group sought to accomplish through the interview process were consistent with the other components of our research. Our project team sought to identify the extent of knowledge in the concepts of building construction, establish an area that could benefit from an instructional supplement, and discover the most appropriate means to communicate our concepts that would be understood and accepted by the fire investigation community. Our project team hypothesized that the data received from the interview process would substantiate the theories we had already established through our preceding research. We anticipated that the Fire Investigators we interviewed would have taken classes pertaining to building construction, but these classes did not go into great detail on the subject. Our project team thought that any considerable familiarity with building construction, if it existed, would most likely been the result of years of experience, and not formal education. Furthermore, our project team believed that we would investigate our hypothesis that fire professionals could benefit from an educational supplement that presented these concepts in a visual manner, that were related to real life situations.

Unlike any other modes of our project team's research, a person-to-person conversation could give us a clearer and perhaps more accurate insight into how our work could prove beneficial to fire professionals. While much of our research of texts and course materials had established our perception that Fire Investigator's knowledge of building construction could benefit from a supplement, the personal verification provided

by an interview would be a vital part to our argument. Most significantly, our project team thought that interviews could give us the best and most honest answers that we could not find in textbooks.

The interviewees that we chose for this project were recommended to us by our project advisors, and also by contacts established by the group throughout the interview process. Our strategy for contacting the perspective interviewees entailed us calling them and identifying ourselves as WPI students who were trying to learn more about the field of fire investigation for the purpose of completing a project. In all cases, the Fire Professionals who we spoke to were very accommodating and open to helping us.

One of the major challenges faced during the interview process was to accomplish our goal of understanding the knowledge base of fire professionals without seeming imposing. First and foremost, our project team has an enormous amount of respect for the Fire Service, and we are quite humbled by the opportunity to study their profession. Our project team was also informed about the favorable relationship that our school had established with this community over the years. So the challenge that our project team faced was getting an accurate depiction of the state of Fire Investigator education, without jeopardizing the relationship and trust previously established. The way our project team strived to overcome this challenge was to recognize that there was already a broad educational foundation that we were not trying to improve, but rather supplement. Whenever during the interview process, our intentions were questioned, this was the answer we were prepared to give. Though ideally, we were trying to keep our intentions generally vague as to totally avoid any Fire Investigator feeling like his knowledge or skills were under investigation.

4.1 Captain Metterville from the W.F.D.

Our first scheduled interview was with Captain Metterville. Captain Metterville is a Fire Investigator at the Worcester Fire Department. Before our project team went into the interview, we put extensive thinking into the preparation of questions. The project team wanted to ask questions that would be informative for the group, but would not be too intrusive. This being our project team's first interview, we had very little idea of how receptive Captain Metterville would be to our inquiries. Therefore, we started the interview with very straightforward questions, such as asking him to give a basic job description. From this question, many other unscripted questions developed just from conversation. This first part of the interview proved very informative in that it gave our project team a good overview of Captain Metterville's duties. More importantly, this initial segment of the interview established a good comfort level that lasted throughout the proceedings. Our project team learned that Captain Metterville's main responsibilities include determination of origin and cause of a fire in buildings. He works cooperatively with many other professionals like law enforcement, forensic investigators, fire commanders, electricians, and building inspectors, who all contribute in some way to the investigation.

The next phase of the interview was really gauged to answer our questions about a typical Fire Investigator's knowledge of structural concepts, and how these concepts are used on a daily basis. The project team initiated this part of the interview by inquiring about Captain Metterville's education. Captain Metterville has earned a degree in Fire Science and has received additional training from the Massachusetts Firefighting Academy. He had also completed classes at the Massachusetts Firefighting Academy.

From previous research, our project team knows that the M.F.A. offers a course that deals with concepts of structural hazards. So our immediate conclusion was that Captain Metterville had some familiarity with concepts in building construction.

Our project team was curious to know if Fire Investigators with only class-related experience were qualified to work in the field right away. Captain Metterville emphasized that a person cannot become a Fire Investigator in the Worcester Fire Department immediately following college training. Hence, an aspiring Fire Investigator must start out as a regular Firefighter and slowly work his/her way up the ranks within the Worcester Fire Department, passing required tests along the way, before officially becoming a Fire Investigator. As a result, Fire Investigators at the Worcester Fire Department all have extensive experience working on fire scenes.

Our next question was geared towards finding out if knowledge of these concepts was helpful in his typical job activities. Our project team asked him to verbally walk us through his routine as he gets to a fire he is investigating. Captain Metterville explained that it was important for Fire Investigators to arrive at the scene of the fire as quickly as possible (even as the fire is still occurring) in order to track witnesses or suspects before they leave the scene. He also emphasized that it is important to begin the investigation inside the building as quickly as possible, before any important evidence or pieces of the scene are misplaced. Once inside the building, Fire Investigators usually start their investigations in areas of the least damage and then make their way to the areas of most damage. He explained that the area of most damage in a building is usually the location of origin of the fire. If the Fire Investigators believe that the fire could have started as a result of an electrical occurrence, then professional electricians are brought to the scene.

Captain Metterville also mentioned that his strategy for entry into the building remains consistent among various types of buildings.

Although he gave a very descriptive account of what he does when he arrives at a scene, Captain Metterville never mentioned checking the building for any loss of structural integrity, or signs of possible collapse. From this question, our project team concluded that Fire Investigators are more focused on observing things related to determining cause and origin than observing the structural integrity of the building, especially when they first arrive on the scene.

At the end of the interview, we became more straightforward and asked Captain Metterville if he had ever encountered a building that was deemed too unsafe to investigate, and who makes the decision that it is structurally unsafe. Captain Metterville mentioned that if a building is deemed unsafe by either his own judgment or by the judgment of a building inspector, he will not enter the building to conduct his investigation. Moreover, if a Building Inspector expresses that the building is safe, yet Captain Metterville does not feel the same way, he will not enter the building. He also mentioned that it was once necessary to use a crane to disassemble sections of a building to conduct an investigation on a structure that was near collapse.

When asked about how he obtained his knowledge relating to concepts of building construction, Captain Metterville answered that the majority of his knowledge about building construction was derived from experience in his profession.

4.2 Lieutenant Rousseau and Lieutenant McGrath from the W.F.D.

Our interview with Lieutenants Rousseau and McGrath was our second in the Worcester area, so we anticipated that many of the answers to our questions would be the same as those provided by Captain Metterville. However, we did introduce some new questions to learn more about on the job training and use of new technology in the profession. These new questions were based on data we received from our previous interview, and our project team thought warranted further investigation. Also, our project team observed that this particular fire investigation unit responded to more cases of residential fires, so our questions would reflect this fact.

One of the most important new questions that our project team thought of was about the evolution of fire investigation technology. As our project team began to consider the development of our own piece of technology, we started to think about how new technology has been received in the past by fire professionals. We thought that this would be a worthwhile subject to ask about as it would give our group a perception of how to design our technology to be received successfully. Moreover, if we found that Fire Investigators were not very receptive to technology in the past, we could develop a method of presentation that would gain better acceptance.

Our goals going into this interview were mostly the same as the interview with Captain Metterville. Our project team sought to gain a better understanding of the fire investigation profession including the responsibilities of the investigator, the routine of an investigation, and the educational background of the involved investigators. Also, our project team wanted to understand the educational background that the investigators had in the concepts of building construction, and how the knowledge of these concepts are

applicable to the daily activities of a Fire Investigator. Although our project team anticipated much of the information received in this particular interview to be a repeat of what we learned in the interview with Captain Metterville, it was still an important step in our investigation to receive that confirmation.

For opening up a forum-type atmosphere in the interview, our project team asked the lieutenants to give an overall job description. We learned that both Lieutenant Rousseau and Lieutenant McGrath are experienced Fire Investigators for the Worcester Fire Department. They provided our project team with a few copies of guides they use to conduct their work including NFPA 921: Guide for Fire and Explosion Investigators 2001 edition. They also mentioned that they had a copy of the *interFIRE VR* training CD-ROM which was used periodically.

Next, our project team asked for a verbal walk through of their routine when they get to the scene of an investigation. This question was important to us in this particular interview, because it would give our project team insight into whether the routine for residential investigation was any different from the investigation conducted in a metropolitan area. Lieutenants Rousseau and McGrath responded by explaining how during their investigations, they generally work from the areas of least damage to the areas of most damage, which allows them to "size up" the structure. They said that this process was performed mainly to determine the integrity of the structure. One of the common observations of a structure that has been recently extinguished is ponding. Ponding, they explained was the gathering of water in large puddles on the floor that caused deflection of the floor boards. The deflection of the floorboards causes more water to gather, thus creating a possible collapse condition in the floor. The lieutenants

went on to say that in cases of ponding, they will often drill holes in the floor to drain the water, but often they are conducting their investigation while walking through very deep puddles of water. Other observations made during the "size up" to identify possible structural hazards include bowing of the walls, and sagging of the floors. The investigators stated that if a building is ever deemed unsafe to enter, they rely solely on witness testimony to conduct the investigation.

This portion of the interview proved to our project team, unequivocally, that investigators do have some knowledge of possible structural hazards, and given this knowledge, they are very adept in making sound judgments pertaining to the integrity of a structure. This information confirmed our project team's expectation that if given the opportunity to obtain a more in depth understanding of concepts of building construction, they would most likely take advantage of this information, as it could be applied directly to already existing practices.

When we further inquired about other hazards posed by their profession, the Lieutenants talked about how most of their investigations were done in high crime areas at night. To combat this hazard, the investigators noted how they performed investigations at least in pairs. Next, our project team asked the investigators about their education. Lieutenant McGrath mentioned that few practicing fire investigators have formal Fire Science degrees. However, he noted that recruits just entering the field often have a formal degree in Fire Science. Lieutenant McGrath went on to say that he was a Firefighter for 24 years before becoming a Fire Investigator. Both lieutenants talked about how they like to help newer recruits obtain on-the-job experience by pairing them up with more experienced Fire Investigators whenever possible. This group of questions

helped to affirm our project team's former idea that much of a Fire Investigator's skills of structural assessment are based very much on experience.

Upon asking about the technologies used in their profession, both lieutenants agreed that the Worcester Fire Department lacks the technological tools that other similar agencies have in their possession for fire investigation, like the FBI. They said this fact could be attributed to the lack of funding from the state. The acquisition of this information was one of the primary goals of this interview as stated previously. Although this Fire Investigation unit did not have access to any of the new technologies in their field, it did not mean they were resistant to using them. Overall, the project team's inquiry into the Fire Investigators' use of new technologies yielded no evidence that refuted our assumption that they would be open to utilizing these new technologies.

Other interesting information that our project team received from the interview was related to evidence preservation. Both lieutenants talked about how it is very important that Fire Investigators and Firefighters maintain communication at a fire scene. Specifically, they talked about how many Firefighters don't realize how important it is for investigation purposes to try to leave debris where they find it. This often proves quite challenging as loose debris can cause a spark to reignite the fire.

The most productive aspect of this interview was the discovery that the investigators do practice observation of buildings to ensure structural safety. These observational skills are a result of years of experience. Consequently, these skills are limited to structural hazards that they have previously encountered on the job. In the event that the investigators encounter a new type of hazard, they may not be able to detect it. Also, new recruits in the field would be generally unaware of any hazards, due

to their lack of experience. As a result, our project team confirmed that there exists an opportunity to supplement whatever knowledge already exists in relation to concepts of building construction and Firefighter safety.

4.3 Captain Bob Staunton from the B.F.D.

One of the objectives our project team tried to achieve throughout the interviewing process was an understanding of how Fire Investigators utilize technology to make their fire investigations more efficient and safe. Specifically our project team set out to understand how Fire Investigators learn to use this new technology, and generally how willing they were to changing the field to make way for improvements. However, after conducting interviews in the Worcester area, our project team found that investigation techniques and technologies had not changed since the time the interviewees had entered the field. So it was important to note that these individuals have not been exposed to any new technology since their careers began. At this point our project team felt it was important to find an investigation unit that was on the cutting edge of the field and whose practice would not be restricted by a small budget. As a result, our project team contacted and set up an interview with the arson investigation unit located at the Boston Fire Department Headquarters on Mass Ave.

Captain Bob Staunton is a Fire Investigator who works for the Boston Fire Department in the arson investigation unit. This particular arson investigation unit investigates any large fires where damage claims would be expensive, any fire where a person was hurt or killed, or any fire where arson was suspected. Their investigations are not limited to any particular type of fire, and include car fires, residential fires, and fires

in any buildings of business. This unit usually works in teams of up to five people, splitting the tasks of taking pictures, questioning suspects and investigating structural damage. The team of arson investigators has arrest powers, and carries firearms.

Captain Staunton talked about how important it is for an investigator to be at the scene of a fire as quickly as possible for several reasons. First, it is an opportunity to photograph witnesses and interview them before they leave the scene. Also, he noted that people are much more likely to tell the truth about an incident right away, as the shock of the incident is still fresh, and there is not enough time to think about a lie that may improve their situation legally. Once the fire has been extinguished, the investigators follow the orders of the incident commander, who decides if the structure is safe for them to enter. From there, the investigators start by doing a walk around the whole building to get a general idea of how the fire progressed. After this point, it seems that all analysis of structural integrity is done, and the investigator moves into the building to focus solely on the investigation of cause and origin. In the case when the Incident Commander deems a structure unsafe to enter, the entire investigation is conducted from witness interviews.

Captain Staunton was certified by the National Fire Academy in Maryland. His training consisted of a relatively equal balance between classroom and hands-on learning experience. He noted that previous generations of Fire Investigators were generally given the position right before their retirement so there was often little motivation to conduct thorough investigations. In addition, these investigators had little or no training that was specific to fire investigation. This is a stark contrast to today's Fire Investigators, who stay in the field for a good portion of their career, and thus have a lot of motivation to do the best investigation possible. This new wave of Fire Investigators

also enter the field with a solid education in the methods of fire investigation and are consistently sharpening their skills by attending classes and seminars pertinent to fire investigation throughout their careers. Lastly, the investigation process has recently become much more meticulous as a result of insurance lawsuits being so much more prevalent.

An interesting point that came up was that the number of incidents that actually turn out to be caused by arson is roughly 10%. This can be attributed to the fact that it is just not financially a good idea to commit arson, because property values are too high compared to twenty years ago. The highest rate of arson occurred between 1970 and 1990, a time when the property values were so low, that the insurance money collected from a fire exceeded the actual property value, making it very profitable to commit arson. One building alone could be burned and rebuilt several times, resulting in a large insurance claim by the culprit.

Throughout the interviewing process, our project team found that the practices of the arson investigation unit have not changed in any major way as a result of new technology. However, we did learn that every member of the arson investigation unit has access to a computer, and they are used on a daily basis. Thus it is safe to assume a reasonable level of comfort with computer programs. Additionally, the one example of new technology used in the department was the digital camera which replaced conventional 35mm film. When the digital camera was introduced, a Firefighter from another department taught the unit how to use the camera and the software. This is a very useful piece of information as it shows a willingness and ability to learn how to use a new piece of technology.

The overall benefit of this interview towards the advancement of our project goals was positive in three separate facets. First, the interview gave further insight into exactly how principles of building construction affect the daily job activity of arson investigators. Although preliminary assessment of structural integrity is made by the Incident Commander, a Fire Investigator has plenty of opportunity to make their own judgment while doing the complete walk around the building. The walk-around is primarily practiced to assess fire damage from areas of the least damage, to areas with the most damage. This practice has proven to be routine in every investigation, and in the opinion of the project team, the opportunity exists to modify it to including a systematic check of building construction hazards to ensure structural safety. Thus, a more extensive knowledge of structural concepts could greatly benefit Fire Investigators in this activity.

Second, our project team learned that the fire investigation field is one where new recruits are increasingly more educated in techniques of proper investigation, even before they have any field experience. This fact is significant as it shows that the next generation of Fire Investigators is generally very motivated to learn. It is our project team's assumption that this ambition to learn will means that if a legitimate improvement to the field of fire investigation was offered, it would be widely accepted.

Lastly, the forum-type atmosphere that our project team experienced during this interview gave us the opportunity to talk to several Firefighters in a very friendly environment. The situation resulted in a very comfortable setting for the free exchange of ideas, and was important in establishing a line of communication between our project team and the fire community that could be relied upon in the future, if necessary.

5. Local Surveys - Understanding the Current Knowledge Base

The first survey our project team conducted was what we now refer to as the local survey. The local survey was written and distributed for the purpose of obtaining a sense of the region's educational background specifically related to the principles of building construction and structural hazards, and to obtain a sense of how consenting the audience would be to an educational supplement that more thoroughly emphasized these principles. Our project team decided that the best audience of the survey would be students and faculty of a firefighter training academy.

The goal of the local survey was to achieve an understanding of the educational background and expectations of new recruits and current Firefighters still receiving training. Similar to the interviews, surveys ideally gave our project team an impression of these educational aspects from the point of view of the students themselves, instead of from literary research. An advantage the survey held over the interview process was that it gave our project team a perception of a broader audience. The survey was distributed to a comparably large audience that gave our project team a better idea of the general opportunity for educational supplementation in the area. Although the local survey was not introduced to an audience large enough statistically to prove representative of a greater population, it did give us an opportunity to learn more about the fire professional community on a larger scale. An obvious disadvantage was that it could not be as detailed as an interview, as the effectiveness of the survey depended largely on its briefness, and ease of completion. Therefore the questions that our project team could ask were limited to only the most important and straightforward questions.

5.1 Survey Goals

The goals our project team tried to achieve through the local survey were clear-cut. First, we wanted to identify the experiences of our audience, both educationally and professionally. Questions pertaining to this goal were written assuming a very wide range of fire professionals would be taking this survey. These questions classify the responder in terms of certification, years of experience in the field, and rank. This portion of the local survey was important as it would reveal any divergence in knowledge of principles of building construction and structural hazards that resulted from educational or professional experience.

The second goal of the survey was to identify the extent of knowledge of principles of building construction and structural hazards and whether this knowledge was a product of institutional education, or on the job training. Questions relating to this goal asked specifically about the emphasis of these concepts in courses taken, and also if knowledge of these concepts helps them in their daily work. The response to these questions not only gave the project team an idea of the emphasis of these principles in the educational process, but also gave us an idea of how useful the respondents thought such knowledge could benefit them professionally. Our project team thought that the willingness of the responders to learn these principles would be especially important to the pursuit of our overall project goals.

Our final goal was to understand the willingness of our responders to use an educational tutorial to supplement their knowledge of building construction. Questions pertaining to this goal included asking the amount of time the respondent would be

willing to spend using an educational supplement outside of the classroom, and if such a supplement could ultimately help them in their career.

5.2 Creating a Professional Survey

Our project team decided to use a traditional survey format (i.e., text-based) since it was intended to be distributed to a large number of people and telephone or in-person interviews would not be feasible. Also, because the demographic of the survey group indicates that the audience would consist mostly of middle-aged, working-class men who may or may not be technologically inclined, it was decided that they would be the most comfortable with a hard copy format.

To create the survey questions the group needed to consider many things. Again, Chapter 10 of the IQP Handbook helped by providing the team with guidelines for forming precise questions that will ensure return of the information for which it was intended. Some examples of these guidelines are listed below:

> - Is the question simple enough, specific enough, and sufficiently well-defined that all of the respondents will interpret it in the same way?
> - Does the question contain any words or phrases which could bias respondents to answer one way over another?
> - Is it clear to respondents exactly what types of answers are appropriate?
> - Are any assumptions implied by a question warranted?
>
> **(Doyle, IQP Handbook) 1**

Though these rules may seem obvious and simplistic it becomes extremely important that the respondents understood how the survey and the creator wishes them to answer. On the other hand, but in the same line of thinking, if the question is not asked in the correct way, the answers that are returned may be quite difficult if not nearly

impossible to interpret and in effect, make it hard to form logical conclusions from the data. For example, by asking the question "Does the knowledge of building construction help you in your every-day job?" the group initially believed that when the results were returned, an implication of structural engineering might play a role in the fire professional's work environment.

What was realized later in the survey development process was that since most fire professionals are not full-time employees, and many have daytime jobs, in the minds of those taking the survey, their "every-day job" could be anything. By simply changing that phrase to "fire-related career", the question is now clear to those being surveyed. Also, when the survey results were returned, our project team would be able to derive beneficial background knowledge from the question instead of having to throw out numerous extraneous points. This type of understanding and further insight was collected during the interviews held with key individuals in the City of Worcester and Boston Fire Departments that were described in the previous sections. The various drafs of the local survey can be found in *Appendices section*.

Questions numbered 1, 2, and 3 comprised the first series of questions which was designed to determine as much about the background of the respondent, as it is related to the fire department, as possible. Answering simple, factual questions concerning such things as past education, length of employment in the Fire Service, and current position not only provide important information to be used later in grouping the respondents for statistical analysis but "warm up" the audience to answer the tougher questions that follow.

The next set of questions was designed to determine the respondent's educational background as it relates to building construction specifically. The results of this segment showed our project team if any knowledge of building construction was retained and used by those in the Fire Service, and how it is applied to their job. These were questions numbered 5 and 6.

Questions numbered 4, 7, and 8 are unique from the other sets of questions in the sense that they were intended to determine the mindset of the audience more than simple fact. Because it is quite difficult to earn promotion in the Fire Service, and a great deal of work and time need to be spent to achieve a higher rank, it isn't uncommon for fire professionals to decide not to seek promotion. If a person does not seek promotion, they may very well not care to further enlighten themselves by using an additional educational supplementation, whether or not it provides other benefits. By asking if a person expects to be promoted at some point, if they would or would not take advantage of a tutorial were it at their disposal, along with the less intrinsic question of how long a person might be willing to spend on a tutorial, our project team hoped to identify if the individual could even be counted as someone willing to take the tutorial before they are included in the rest of the data analysis.

Finally, our project team left the last question open-ended for any comments that the respondents wished to provide. This invitation was intended to leave the audience with the feeling that their answers are meaningful and useful, and it also has the possibility of alerting our project team to something they could have overlooked. Although our research into survey writing techniques did not recommend use of an open-ended question, our project team thought that this strategically-placed question at the end

of the survey could provide some valuable insight into the willingness of the students to learn from an educational supplement.

5.3 Ensuring an Accurate Response

The first priority in obtaining data from any survey is guaranteeing survey accuracy. There are several actions our project team undertook while writing and distributing this survey to ensure -within our best efforts- that it would be an accurate representation of the populace.

When drafting the original survey our project team referred to the texts cited in the bibliography, as well as Chapter 10 in the IQP Handbook for the Introduction to Survey Methodology and Design (Doyle, IQP Handbook). It was understood that creating a survey using professional standards would increase the reliability, honesty, and therefore overall accuracy of the results.

Through research, our project team learned that the first aspect to conducting an accurate survey was making sure the communication of questions was completely clear (Fink 1995). It was important that the survey recipient knew exactly what they were being asked so that they could be confident the answer they chose was accurate. If questions are confusing in nature, people taking the survey may accidentally answer inaccurately, or may decide not to take the survey at all (Fink, 1995). Aspects that contribute to a clear survey include simple vocabulary, and questions that are completely objective in nature (Fink). Objective questions are particularly important because there is no room left for interpretation. Our project team's aim was to create questions where the

choices for the recipient were obvious and distinct. If a recipient was forced to do any interpreting between answers, there is a good chance that results will be skewed.

Another important feature to writing a survey is avoiding order bias (Alreck and Settle, 1995). Order bias is a situation where the person taking a survey is inclined to answer a question a certain way based on the order the questions are asked. There are three aspects to order bias including initiation, routine, and fatigue (Alreck). Initiation bias is the tendency of a survey to start with very challenging questions. This kind of survey tends to cause a recipient to think the survey will be too hard, and not take the survey. Our project team avoided initiation bias by starting with questions that would be straightforward and easy to answer. Routine bias is the tendency of a survey recipient to answer all questions the same. For example, if a survey is set up with every question having a rating scale from one to ten, there is a predisposition for people to fill in the same answer for each question. This occurrence could cause drastic inaccuracies in answers. To avoid this predisposition our project team designed the survey to have a variation of question types, and to avoid using a scale system. The final type of bias is fatigue bias. It is obvious that someone taking a survey is probably not overly entertained, so our project team tried to make the survey as short and effective as possible. Questions were factual and straightforward, and were designed so that the responder would have to do very little thinking. Also, the only question that required thinking and an expression of original thought was the open-ended question, which was purposely put at the end of the survey. Consequently, if a responder had trouble responding to this question, which was the hardest on the survey, their possible frustration with this question would not affect the additional parts of the survey.

During the distribution of this survey, there were specific measures that our project team undertook to further our chances for conducting an accurate survey. Primarily, we assured verbally, and in writing at the top of the survey, that the survey was completely confidential. Our project team believed that if the survey recipients knew they would not be linked to their personal answers, the honesty of responses would improve, and could also increase the number of people willing to take the survey. And the final measure to facilitate a truthful response was to simply ask for it. Our research indicated that being personable with survey recipients and politely asking them to answer the survey as honestly as possible dramatically increased the chances that they would do so (Fowler 1995).

5.4 Distribution of the Local Survey

From researching the career path of Fire Investigators and other fire professionals, our project team found that a considerable number had attended the Massachusetts Firefighting Academy (M.F.A.). The M.F.A. is an educational institution that offers certification courses for fire professionals. Our research of this institution revealed that all students are already practicing fire professionals who are trying to obtain additional certification in order to advance within their professional field. Our project team believed that an opportunity to survey this audience would be especially beneficial to our project as it would give us data from an audience that had a wide range of experience. Thus, if knowledge of principles of building construction and structural hazards were acquired later in a fire professional's career, our survey would expose this fact.

In trying to make arrangements to distribute our survey at the M.F.A., our project team was put into contact with Bill Miller, an instructor at the academy. Bill Miller informed us that many of the students at the academy attended classes at infrequent intervals, because the students' work at the academy was often balanced with their Fire Service work, and therefore it would be difficult for him to arrange a time to give these students the survey. Therefore, he thought that our best option was for him to give the survey to all of the faculty members at M.F.A. Faculty members of the M.F.A. are also previously and currently practicing Fire Service members, so the results of a survey of this new audience were still beneficial to our project.

Prediction of Results

Given the responders of our survey were established fire professionals, our project team expected that most respondents would reveal that the overall audience was quite experienced professionally and educationally. We expected most responders to be certified fire professionals, and most to have some type of fire degree. We also expected that most respondents will have spent at least ten years in the field. Thus, our project team expected that a certain amount of knowledge of building construction would exist, and that these responders would have the experience to know that this knowledge greatly benefits them professionally, especially as it pertains to their occupational safety.

5.5 Analysis of Results

The results of the local survey were what our project team had expected (*see Appendences section for numerical analyses of the local survey*). Generally, the respondents were quite experienced both educationally and professionally.

Educationally, twenty-six out of thirty-eight of the responders were extensively certified by academies such as the M.F.A., and twenty-nine out of thirty-eight were graduates of any accredited fire academy. Professionally, the years of experience of the responders greatly exceeded the project team's expectations, with twenty-one out of thirty-eight responders answering that they had more than sixteen years. These answers showed that the respondents to our survey had been exposed to a great amount of educational material and that if subject matter pertaining to concepts of building construction existed within the educational systems for Fire Service personnel, it is very likely that these responders have been exposed to it.

A resounding majority, twenty-nine out of thirty-eight responded that they had taken at least one course that dealt exclusively with building construction as part of the curriculum. More importantly, the same overwhelming majority responded to say that they had found that knowledge of these concepts had helped them in their career. In relation to the tutorial, thirty-six out of thirty-eight responded by saying they would use a supplementary educational tutorial on their own time to further their knowledge in the concepts of building construction and structural hazards. Twenty-four out of thirty-eight respondents said that they would be willing to spend more than thirty minutes of their free time to use such a tutorial.

The responses to the local survey were greatly beneficial in legitimizing the intentions of our project. Beyond a reasonable doubt, it was proven to our project team that fire professionals are generally open to a tutorial to supplement their knowledge of building construction and structural hazards. More significantly, it was proven that a more extensive knowledge of these concepts would be useful in their jobs. In fact, many

responders mentioned specific ways that such knowledge could benefit them professionally, which the project team had not previously considered. Such examples included knowledge of how fire travels through a building, fire inspections, and decisions relating to evacuations and operational times. This survey also showed that a knowledge base of concepts related to building construction already exists among many practicing fire professionals. This is an important piece of data because it let the project team know that the tutorial did not have to be designed for a totally uneducated audience, and in all likelihood, many of the concepts presented in the tutorial would be a supplement to knowledge that already existed. Our project team interpreted this fact as proof that the material covered in the tutorial would be within the realm of understanding of the fire professionals, and they would benefit from the supplementary educational experience.

5.6 Conclusions

Overall, this local survey had broad implications for the project. The local survey provided a very insightful exposure, in the form of actual data, into whether or not there was a need to provide additional education to fire professionals and therefore solidify if the purpose of the project was just or not. If it had been found that all surveyed had complete knowledge of structural principles and never used any of them in their job, our project team's hypothesis would prove to be invalid. Alternatively, if many of the responders showed an interest in promotion, and have not learned much about building construction, but can still give examples of how it would help them at their job, it is a step towards establishing the validity of the project team's hypothesis that there exists an opportunity to supplement that knowledge base.

6. National Survey

Because the format of the local survey was fresh in the minds of our project team, the knowledge base for creating a professional survey was already present. With all the initial research completed, it was a smooth transition to creating the nationally-distributed survey. The results of the national survey would prove to be extremely important in the solidification of the original hypothesis because it exposes (as expected) that many fire colleges across the nation, not only in the Worcester area, have inadequacies in the study of structural principles as they may pertain to the life safety of fire professionals. This section will discuss in detail how and why this survey was created. Also, the results, conclusions, and findings are described here.

6.1 Intentions

This survey, similar to the local survey, was intended to determine the current state of education pertaining to building construction of Fire Investigators. But instead of limiting the demographic area and sending the survey to a one or many fire academies in virtually every state, the results can be used to represent the entire United States, and conclusions can be drawn that pertain to all fire colleges and, in turn, every fire professional.

Again, similar to the local survey, our project team formulated specific questions designed to uncover certain aspects about the curriculum of each school. Question 1 asks: “Does your training school offer any courses which involve discussion of building construction and/or structural hazards?” This straight-forward question was very important in setting aside the schools that didn’t offer the study of building construction

in their curriculum at all, despite the growing concern for structural collapse in their industry. Question 2 asks: "What textbook(s) are used in these courses?" This question was included to determine whether or not our project team's evaluation of what texts were widely used was indeed correct. Question 3 asks: "Is computer software used in any of the courses offered at your school?" By asking this question, our project team could determine if it was a feasible solution to use an interactive computer program (i.e. would they be able to use it) as an educational supplement. Finally, Question 4 asks: "Are students expected to learn from any of these articles of computer software on their own?" This question, like the question in the local survey asking if a person was expecting promotion, tells more about the thought process that a training program might have. If the students are expected to learn on their own in other areas, it would not be unwarranted to assume that the students would also spend time on such a tutorial as the one that the project team plans to develop for this project.

6.2 Methodology

By using the power of the Internet, our project team was able to locate a list of every fire academy in the United States ("Fire & Rescue Training by State"). From this list, the larger state schools were preferred and chosen first because they would most likely have the most up–to-date and current educational programs. But because some states do not have a large, state funded fire academy, in order to ensure the widest coverage possible, if there was only one fire academy in that particular state, it was chosen as well.

With the list of every fire academy, our project team addressed all envelopes by hand and included a self addressed envelope for the recipient to use for returning the survey. Also included in the package was a cover letter stating what was the purpose of the survey is, which was signed by each member of our project team to show professionalism and to ensure that this survey would be taken seriously.

To save time and money, instead of contacting someone at each school and asking them to distribute the survey amongst the students, our project team decided to send only one survey to each chosen fire academy, with attention to the Chief of the Training Division. By making our request simpler, this would hopefully increase the chance that the person would respond, and if they did, speed response time. Also, our project team would not have to make as many copies of the survey and mailing fees would be reduced dramatically. Since only one survey at most would be returned from each school, this would also make data analysis stage of the process simpler as well.

6.3 Results and Analysis of Data Received

From the fifty surveys that were sent out, nineteen responses were received. By using an equation obtained from Applied Statistics for Engineers and Scientists (p.257, Petruccelli, Nandram, Chen), it was possible to determine a confidence interval in which our project team can be positive that the results for this survey can be applied to all Fire Investigators. Using a sample size of fifty, representing the number of surveys sent, out of one hundred total fire academies in the nation, the group can be 85% sure (plus or minus ten percent) that if every survey from every fire academy was sent and received,

that the national survey results will reflect accurately the results that could be collected from every fire school. This calculation can be found in the *Appendices section*.

Figure 2: Response to Question #1- Does you training school offer any courses which involve discussion of building construction and/or structural hazards? illustrates the responses to Question #1. It shows that of the nineteen responses, eleven indicated their academy or institution had a course solely devoted to building construction or structural hazards[1], seven only had a course partially devoted to construction and hazards, while one had no courses devoted to the topic. Percentage wise this reflects that 37% of the fire academies may either offer partial study or possibly no studies in building construction or the hazards that can arise from the inherent mechanics. The figure is shown below.

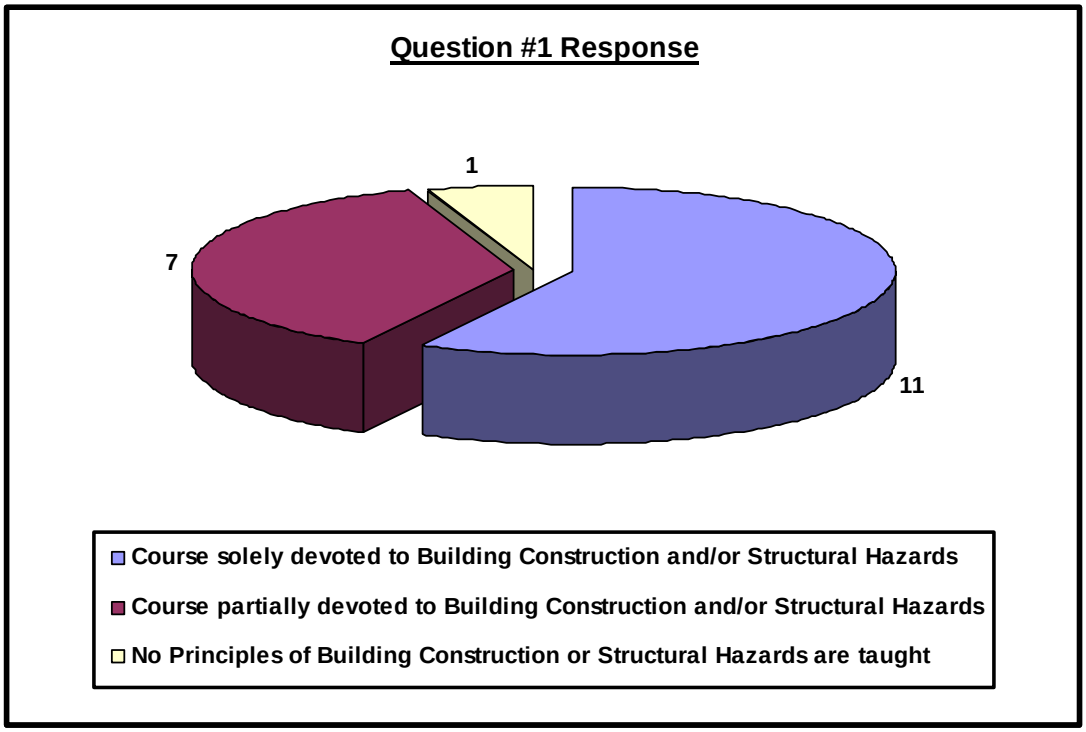

Figure 2: Response to Question #1- Does you training school offer any courses which involve discussion of building construction and/or structural hazards?

[1] Some respondents answered twice, stating that they had classes both partially and solely devoted to the aforementioned topics. These were counted once in the category of solely devoted.

Figure 3: Response to Question #2- What types of textbooks are used in these courses? Note: Some Institutions used more than one type of text. presents the response data to Question #2. The graph shows the different types of texts and other learning materials used by the polled schools. Of the twenty five recorded answers (some schools used more than one text), the Brannigan text was used the most with six mentions, followed by the IFSTA Fourth Edition of Essentials and NFA-Principles of Construction: Combustible, Non-Combustible with four and three citations, respectively. Dunn's text, the NFA institute guides and manuals for the "building construction series, the Delmar Firefighting book, and text materials developed by specific course instructors were each mentioned twice while the N.F.A. courses, IFSTA-Building Construction Related to the Fire Service, materials developed by the state, and no response each were recorded once. Reviews of some of these texts can be found in *Chapter 3. Initial Research - Review of Texts and Other* Available Resources. The figure is shown below.

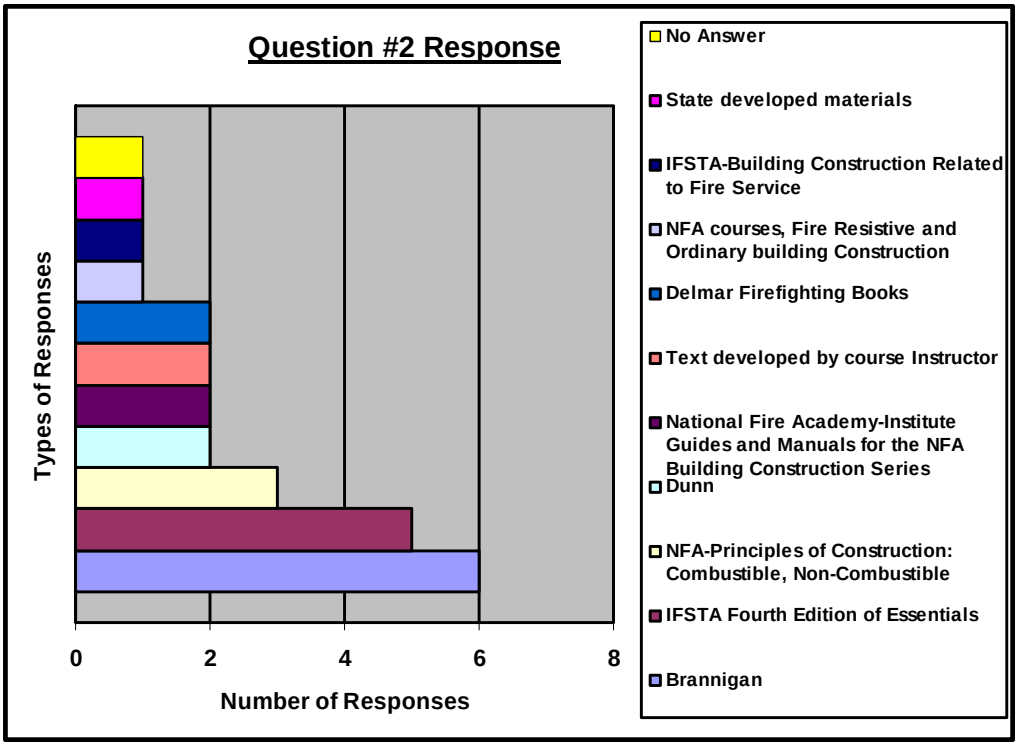

Figure 3: Response to Question #2- What types of textbooks are used in these courses? Note: Some Institutions used more than one type of text.

The chart in *Figure 4:* Response to Question #3- Is computer software used in any courses taught at your school? Note Some Institutions used more than one type of software. indicates that most of the polled schools do use some sort of educational tutorial in their learning programs with eight responses. "Not Applicable" was chosen the second most times with seven responses. Four schools indicated that they used interactive computer simulations, while blended learning courses, Instructor "I" Distance Learning, Web CT, and general "online courses" were each recorded once. Note that some institutions used more than one type of software. The figure is shown below.

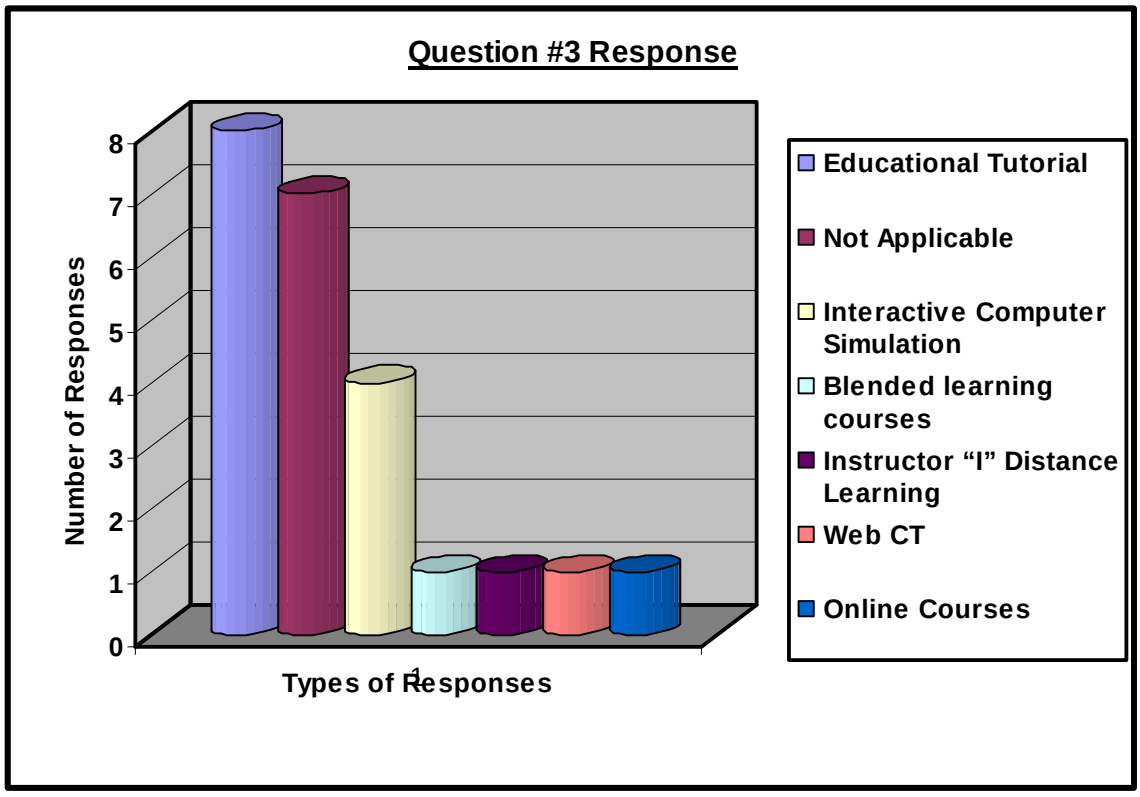

Figure 4: Response to Question #3- Is computer software used in any courses taught at your school? Note Some Institutions used more than one type of software.

Figure 5: Response to Question #4- Are students expected to learn from any of these articles of computer software on their own? is a graph of the response data to

Question #4. Of the nineteen schools that responded, six expect their students to learn from one of the learning tools on the list collected in Question 3, while seven do not. This question did not apply to six of the respondents. This figure is shown on the following page.

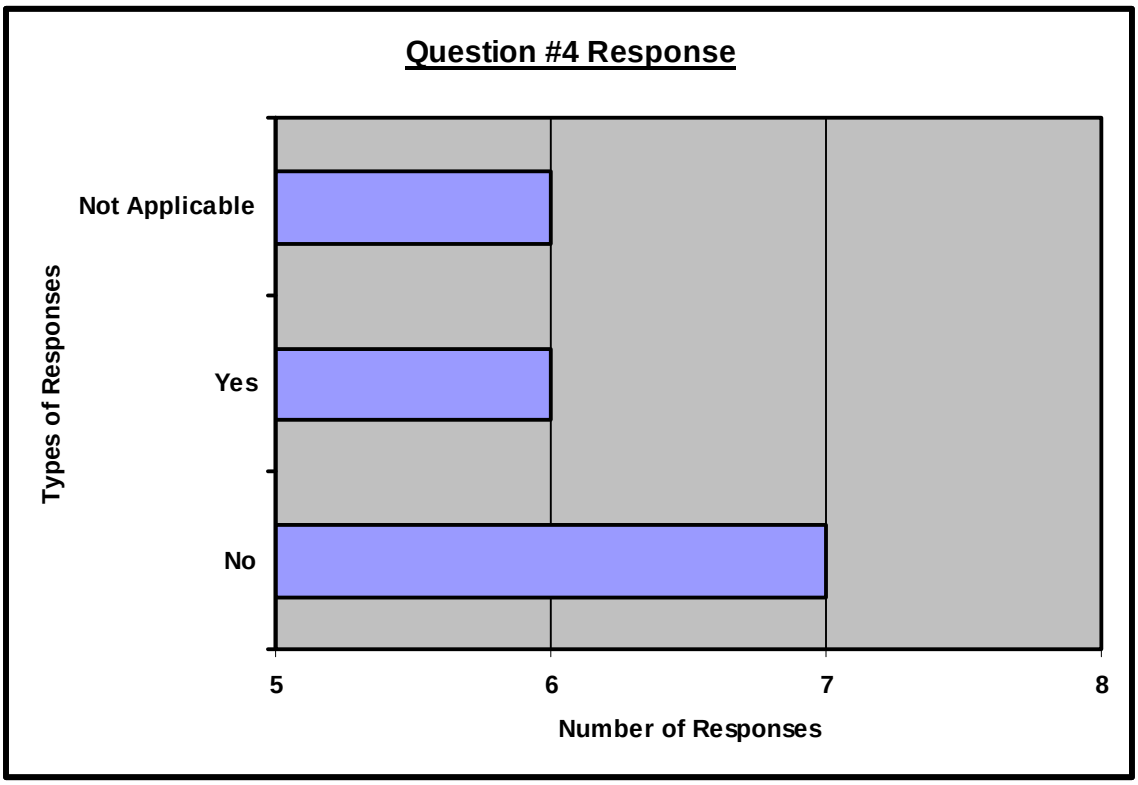

Figure 5: Response to Question #4- Are students expected to learn from any of these articles of computer software on their own?

Figure 6: Response to Question #5- What is the best way to obtain copies of course materials? shows that of the nineteen respondents, four said the best way to obtain course materials from their academy or institution was to contact them. Four also said that their course materials could not be released publicly, while two respondents chose not to answer the question. The majority of the respondents, nine, said that their materials were commercially available.

Figure 7: Response to Question #6- Would your Institution be interested in the results of this survey? indicates that eleven of the nineteen respondents would be interested in the results of this survey while the remaining eight said they would not. Figures 6 and 7 are shown on the following page.

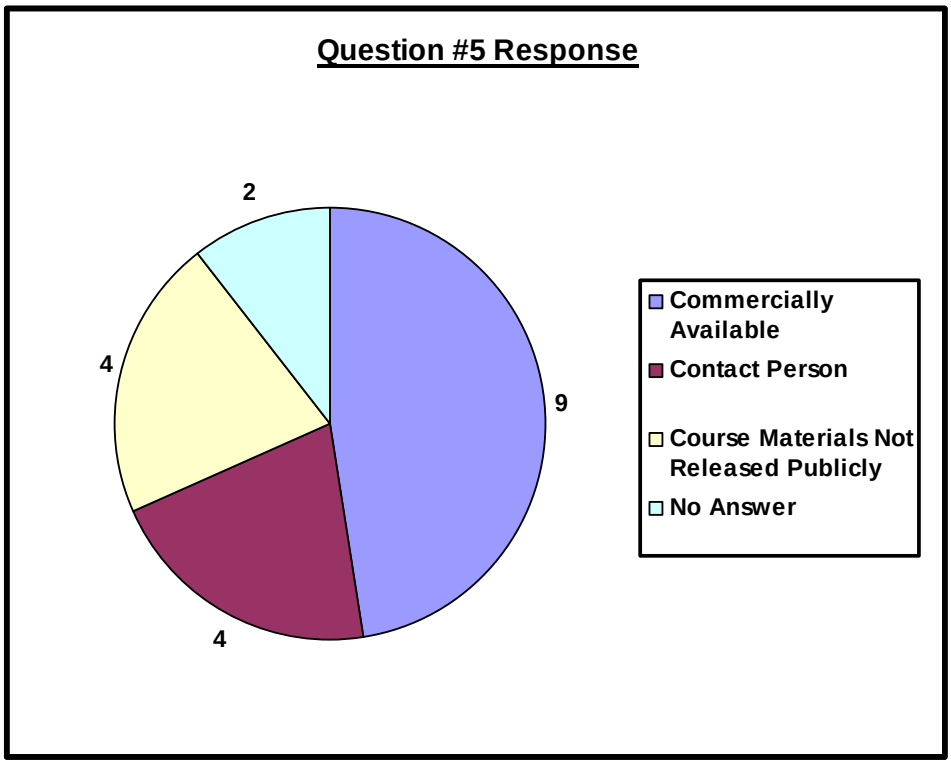

Figure 6: Response to Question #5- What is the best way to obtain copies of course materials?

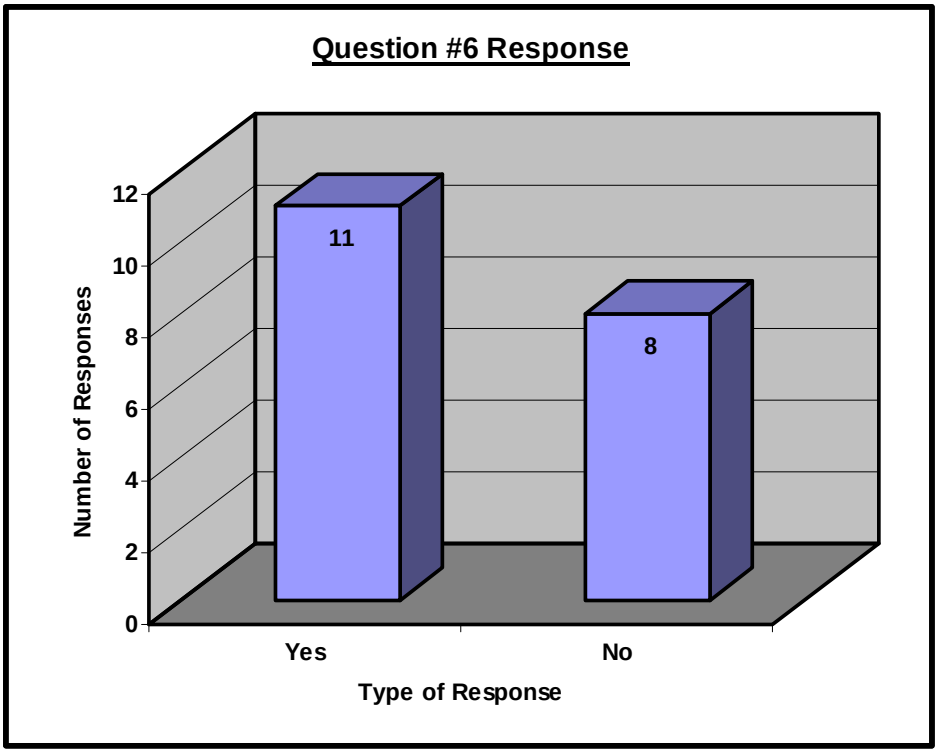

Figure 7: Response to Question #6- Would your Institution be interested in the results of this survey?

6.4 Survey Follow-Up

In an effort to try and increase the amount of responses, and hence the confidence interval of our national survey's accuracy, our project team attempted to contact those schools who did not respond to the first attempt. This process was limited greatly by time constraints but did however result in the collection of one more survey.

The survey follow-up did have a positive impact on the amount of course materials collected by our project team. From the surveys collected, those who chose to include personal contact information were called and asked if they would send course catalogs and any other available course materials, or to simply refer our project team to a website where something of the like could be found.

This process, though not entirely beneficial to the statistical validity of the survey results, is good general practice for professional surveys and only added to amount of educational materials for our project to review. This, in turn, added to the pool of knowledge of how building construction is taught in the fire schools around the country.

6.5 Conclusions and Findings

The most pertinent data collected from this survey as it pertains to the project can be taken from Questions 1-4. Question 1 illustrates how more than a third of all fire professionals who have attended the polled schools have taken courses only partially concerning building construction and its hazards, or have had no exposure to the subject at all while in school. As demonstrated in *Section 1.1 Firefighting and the Dangers of Structural Collapse*, Firefighter deaths in residential buildings have more than tripled in the last decade compared to the previous decades, and many researchers from the Federal Emergency Management Agency (F.E.M.A.) believe that awareness and concern about the hazards of lightweight construction need to be increased throughout the Fire Service. It is our project team's belief that by making sure that all fire professionals are taught thoroughly about building construction and structural hazards, these terrible statistics can be dramatically reduced.

Question 2 validates that our project team has indeed reviewed many of the most widely used texts and other educational materials, and our project team can state confidently that we possess a significant understanding of what fire professionals may learn about building construction from the fire academies across the country.

Computer-based learning technology is on the rise in today's society and would is the project team's top candidate for the form of educational supplementation to aid in learning about building construction. From Question 3, it can be seen that nearly 70% of all fire professionals that attend one of the polled academies are learning from some sort of computer-integrated study. On the same note, Question 4 shows that nearly one-third of these same students are expected to use these computer-integrated learning tools on their own time. Another one-third of the respondents said that this question does not apply to their school, and the only conclusion that can be drawn from this is that these are the same institutions who did not use computers in their learning at all in the first place.

Our project team believes that this data proves not only the need for more education in the field of building construction and its inherent hazards, but the willingness and ability of the fire academies to integrate a supplementary, computer-based learning tool that would emphasize how building construction can relate to the life safety of fire professionals. The data also shows that our project team has educated itself properly in the area of the current state of the knowledge of fire professionals as it relates to building construction and structural hazards.

7. Conclusions Drawn From Research

This chapter will reiterate what our project team has learned from the extensive research into the current knowledge base and educational curricula of Fire Investigators. It will also outline what the team has gained from the use of personal interviews, including how both the literature review and the interviews both affected the formation of the local and national surveys, and what specific conclusions can be drawn from the results of these surveys. Finally, in the following sections, our project team proposes a solution to the hypotheses that were validated with said research.

7.1 Initial Research Reveals an Opportunity for Educational Supplementation

One example of how the review of the commonly used textbooks shows a need for educational supplementation is apparent in the Fire Science program at Anna Maria College. This program reflects current N.F.P.A. standards in an effort to address the challenging and dynamic aspects of public sector Fire Service leadership and administration. There is only a single course within this program which discusses building construction. The textbooks for this course include Building Construction for the Fire Service (Brannigan) and Collapse of Burning Buildings by Vincent Dunn. Similar to Brannigan, Vincent Dunn has no technical training in structural engineering or structural fire safety; his book is based on his personal experiences as a decorated Fire Officer. Upon reading either one of these books, a reader may feel overwhelmed with specific fragments of knowledge and may experience difficulty understanding the major unified concepts of building construction.

Our project team is not alone in the belief that there is a need for increased awareness and technology concerning structural collapse for the Fire Service. The National Institute of Standards and Technology (N.I.S.T.) is currently working on a new technology that can measure the vibrations caused by fire in a building and with further advancement can possible predict when a collapse is about to occur. Researchers at N.I.S.T. have also developed a DVD on building collapse which shows burn tests of certain residential homes in an attempt to familiarize fire professionals with, and prepare them for such an occurrence. Even though a highly respected, national organization such as N.I.S.T. is concerned with the amount of information concerning structural hazards and collapse of burning buildings, there is still a lack of accessible data pertaining to these topics.

The textbook written by Edward Allen, which is used in the *Building Construction and Life Safety Systems I / II* courses at John Jay College of Criminal Justice, provides a complete, up-to-date description of building construction practices. This textbook does not, however, discuss structural hazards and deviates from any theoretical concepts of building construction. Instead, Allen's textbook is primarily intended for contractors, tradesmen, and building technology students, who are mainly concerned with the actual construction of a building and not with the hazards that may appear during and after a fire.

Similarly to the Allen book, the IFSTA 4TH Edition of Essentials is not intended for Fire Investigators and does not emphasize theoretical concepts of building construction. According to the results of the national survey, (*see Figure 3: Response to Question #2- What types of textbooks are used in these courses?* Note: Some Institutions

used more than one type of text.) IFSTA 4TH Edition of Essentials was the second most used book to "teach" building construction to fire professionals. Brannigan's book was the number one response.

Another educational material that our project team has reviewed is the N.F.A. handoff course entitled *Principles of Building Construction: Combustible*. Though this course was quite theoretically-based and covered a large variety of topics pertaining to building construction and hazards, there were certain inconsistencies in the lessons that would be very confusing to the new student of building construction. *Figure 1: Slide 2-7 from Module 2 (N.F.A. handoff course)* demonstrates one of these confusing examples. What may be an even larger issue is the fact that these materials are presented in PowerPoint, but mainly consist of text-based descriptions. This creates the feeling of reading a book on the screen and is a dry and unappealing method of education. When the entirety of the course material is reviewed, it seems as though it is very informative and accurate in conceptual ideas. But what is really important is what the students will take away from the course, and this will be directly related to what they will be tested on. After review of the final exam for the course, it was found that the questions deal mostly with basic incident procedures and specific terminology, instead of focusing on such important concepts such as how loads are transferred through structural elements and the conceptual implications for the safety of fire professionals.

When the results for the national survey were collected, another book, Firefighter's Handbook: Essentials of Firefighting and Emergency Response was reviewed since our project team did not know of it beforehand. It turns out that this book has one chapter devoted to building construction. This chapter, Chapter 13, was written

by David Dodson, a man who very much respects Brannigan and publicly praises his book. Overall, Chapter 13: "Building Construction" contained within the Firefighter's Handbook: Essentials of Firefighting and Emergency Response resembles Brannigan's Building Construction for the Fire Service in many ways. Dodson is able to expand upon Brannigan's book by offering color photographs and introducing information about newer types of construction, but his text is also characterized by the same drawbacks as Brannigan's text with emphasis on terminology and the five construction types. Refer to *Chapter 3. Initial Research - Review of Texts and Other* Available Resources for the complete discussion of the aforementioned materials.

7.2 Interviews Helped Validate the Hypotheses

Great advancements were made towards the validation of our project team's main hypothesis, which was that the knowledge base of Fire Investigators could benefit from supplementation, through the interview process. The interviews conducted with the group of practicing Fire Investigators revealed that the education and on-the-job experience obtained by these investigators resulted in a solid knowledge base in respect to the recognition of structural hazards. However, it the opinion of our project team that this knowledge base is far from complete, and that an educational supplement could further develop awareness of concepts of building construction and structural hazards, which could in turn improve the occupational safety of Fire Investigators.

One aspect of the interview process that revealed this opportunity for supplementation was the discussion of the education of Fire Investigators in general. From the interview process, our project team learned that typically, very few practicing

veteran Fire Investigators have a formal degree in Fire Science. In contrast, it was noted that this trend is changing, as a majority of new recruits entering the field of fire investigation are indeed obtaining degrees in Fire Science. Moreover, most practicing Fire Investigators, even if they do not have formal degrees, consistently took classes at fire academies to further develop their investigation skills. This information proved to our project team that the fire investigation profession as a whole had a good deal of exposure to the education provided by fire academies, and thus had received at least some exposure to concepts of building construction. However, our research into these courses revealed that the course material often lacks a good a good foundation in principles relating to building construction.

In addition to our project team's investigation into the education of Fire Investigators, the interview process provided invaluable insight into the actual job activities of Fire Investigators, and how the knowledge of the structural concepts help them in their daily activities. Upon asking about normal investigation procedures, our project team learned that a Fire Investigator usually starts with a full walk around of the structure to gather any evidence before entering the structure. This practice was said to be primarily for the investigation of the fire, but it was also mentioned that this practice could potentially reveal any structural hazards, should they be obvious from an exterior perspective. However, it was made clear that the primary purpose of the walk around was not to check for structural hazards. This aspect of the interview revealed to our project team that knowledge of building construction is not considered to be essential to a Fire Investigator's job activities, and is not a point of emphasis in practice. Nevertheless,

we sensed that these skills were consistently used by the Fire Investigators on a more subconscious level.

The interviews of several practicing and experienced Fire Investigators led our project team to conclude that years of education and experience for these investigators had provided a large knowledge base in relation to the concepts of building construction, but the opportunity still existed for this knowledge base to be enhanced.

7.3 Surveys Helped Validate the Hypotheses

The surveys were divided between those that were distributed locally at the M.F.A. to participating instructors, and the national survey which was distributed to fire academies across the country. The local survey was helpful in giving our project team insight into how the education of local area Fire Investigators included principles of building construction and structural hazards. The respondents to the local survey were instructors at the M.F.A.; they are also practicing Fire Service members and generally possess a great deal of occupational and educational experience. Very interestingly, much of their educational experience came from participating as an instructor, not just as a student of Fire Science. Subsequently, this audience was a very good source to inquire about local education.

The results of our local survey revealed that a majority of respondents had taken courses that dealt exclusively with building construction, and that they were able to name numerous examples of these courses. This fact led our project team to conclude that there exists a variety of courses available to Fire Investigators that have helped with the development of their structural knowledge base. The same majority went on to say that

these courses have helped them in their Fire Service career. Moreover, several respondents were able to site specific examples of how knowledge of structural principles had helped them professionally. *See Chapter 4. Interviews - Research of the* Work Environment for a complete discussion of the interviews that were conducted by the project team.

Overall, from the local survey our project team came to the realization that these were very well educated Fire Service members, and accordingly, they have extensive training in concepts related to building construction and structural hazards. However, the book that was most frequently cited as being used in these courses was Brannigan's Building Construction for the Fire Service. Our project team's research of this text revealed that several aspects of this text lack fundamental explanation of important building construction concepts. Thus, we concluded that the response of this survey has revealed that there is a potential for supplementation to local Fire Investigator education, which could specifically address these fundamental concepts in a more effective manner. Additionally, the fact that the responders pointed out that their structural knowledge helps them professionally supports our project team's belief that added knowledge in these concepts could be directly applicable to the life safety concerns of Fire Investigators.

The national survey responses validated many theories that were established early on in the development of this project. From the national survey data, 37% of the respondents said that their institutions offered courses only partially devoted to, or no courses at all devoted to building construction. This represents an enormous portion of the Fire Service that has little to no knowledge of structural principles and the associated hazards that these professionals may face.

Also from the data received, it was determined that in fact, a vast majority of fire academies around the nation use either Building Construction for the Fire Service by Francis Brannigan, IFSTA 4th Edition of Essentials, N.F.A. courses or texts, Collapse of Burning Buildings by Vincent Dunn, or the Delmar Firefighting Books as their primary sources for education in the area of building construction; all of which were reviewed by our project team, via the evaluation criteria developed in *Chapter 3. Initial Research - Review of Texts and Other* Available Resources, to each have their own individual drawbacks as it concerns the transfer of knowledge in this very critical discipline. See *Chapter 3.* Initial Research - Review of Texts and Other Available Resources or *Section 7.1* for further discussion of these specific drawbacks.

Results from the national survey demonstrated that nearly 70% of all fire professionals that attend one of the polled academies are learning from some sort of computer-integrated tool. The results also showed that nearly one-third of these students are expected to use these computer-integrated learning tools on their own time. Our project team believes that this data proves that there is an inherent willingness and ability of the fire academies to integrate a supplementary, computer-based learning tool that would emphasize how building construction can relate to the life safety concerns of Fire Investigators. Please refer to Chapters 5 and 6 for complete discussions concerning the local and national surveys respectively.

7.4 An Interactive Tutorial as the Solution

Through the analytical review of the texts used by Fire Investigators and the courses that are available to them, our project team has demonstrated that there exists a

tremendous opportunity for us to develop a supplement concerning the principles of building construction and how they relate to Fire Investigators. Moreover, from interviews and results from both surveys, our project team can state with confidence that the dynamic individuals in the Fire Service are ever motivated with an unquenchable desire and will to learn. Interviews contributed by helping our project team understand the personalities of the people we wish to provide with an educational supplement. It was portrayed to the project team that the more visual aids that can be used the better, and excluding as many numbers, calculations, and formulas as possible would be beneficial. Interviews established firmly the idea that hands-on, visual, or real-life example-based learning is very important in the training of Fire Investigators. Results from the surveys have shown that the use of computers is widely practiced. This proves not only the will, but the ability of Fire Investigators to advance their education through technology.

Given all of the information collected in this report thus far, our project team has developed the idea of a computer-based, interactive tutorial with real-life examples to explain the concepts of building construction as they would relate to the every day practices of Fire Investigators, if not all fire professionals. This educational supplement would introduce key concepts of structural principles such as load transfer, along with hazards that may arise due to the fragile condition buildings and their components will be in subsequent to a fire. Our project team believes that this supplement will enhance the existing knowledge gained from texts and other sources with conceptual based topics that will be important in the day-to-day life of Fire Investigators as it pertains to principles of building construction and structural hazards.

8. Development of the Interactive Tutorial

This chapter documents our project team's development of the interactive tutorial entitled *Principles of Building Construction and Structural Hazards*. This development ranges from the original conceptual ideas to the final layout of the interactive tutorial.

8.1 Opportunity and Main Vision

Our project team seeks to supplement of the educational database of Fire Investigators concerning the principles of building construction and structural hazards. Research into the training of Fire Investigators has made it apparent to our project team that the development of an educational supplement that discusses building construction and structural hazards would be very beneficial to Fire Investigators, as well as fire professionals in general.

It was decided that in order to produce an educational supplement that could greatly benefit Fire Investigators, our project team would need to expand upon the many positive aspects of the current literature. Additionally, our project team would need to find realistic solutions to the shortcomings of these educational materials. By studying the *InterFIRE VR* software (*see Section 3.6*), our project team realized the many complexities that Fire Investigators face in their line of work. After reviewing the contents of textbooks by Brannigan, Dunn, and others (*see Chapter 3*), our project team has reached the consensus that a reader of these textbooks would probably have a difficult time retaining the information and applying it in complicated situations (e.g., during a fire investigation). Hence, our project team has realized that there is an

opportunity for us to create a tutorial that captures the user's attention and instills lasting imagery in the user's mind. Additionally, our project team intends to portray information that is both accurate and applicable to the concerns of Fire Investigators.

8.2 Conceptual Ideas

Before our project team delved into the creation of a tutorial, we first had to develop conceptual ideas for the layout and content. Our project team agreed that the content of the tutorial must satisfy certain criteria in order to be effective. The criteria used to evaluate textbooks and software during our literature review (*see Table 1*) was referenced and adapted for use during the tutorial's development (*see Table 2*). First, the tutorial must include information that is highly accurate. Second, the tutorial should be as visual as possible, for fire professionals are known to be visual learners (*see Section 4.2*). Furthermore, a tutorial that is visually-based will more likely leave a lasting impression on the user than a text-based counterpart.

Table 2: Tutorial Development Criteria

Tutorial Criterion	Description
Criterion I (Informational Content)	- Highly accurate information about the principles of building construction and structural hazards. - Information should be accessible to fire professionals, and thus should not rely on mathematical explanations.
Criterion II (User Appeal)	- Maintain the interest of the user with visual references. - Use multimedia sources effectively to portray complex topics of building construction and structural hazards.

Our project team also agreed that the tutorial should involve no mathematics whatsoever. Our project team has extensively researched the curriculum of Fire Investigators at such institutions as the Massachusetts Firefighting Academy and the National Fire Academy (*see Appendices for course listings*). From this research, our project team has found that fire professionals are typically not highly trained in mathematics, so other methods of explanation need to be used in the tutorial.

Another topic of discussion within our project team was about which principles of building construction should be discussed in the tutorial. The main goal of the tutorial is for it to serve as an educational tool to help Fire Investigators achieve better occupational safety in their work. Hence, any structural principles which would not be encountered by a Fire Investigator in practice should not be addressed. Our project team began this process by outlining the topics covered in courses that we have taken at Worcester Polytechnic Institute that pertain to principles of building construction (e.g., CE2000, CE3010, etc.) (*see Appendices for topic outline*). Once this outline was complete, our project team began to identify topics that may be advantageous to include in the tutorial. Additionally, our project team was able to discard certain principles of building construction that are irrelevant to the concerns of Fire Investigators such as: foundations, earthquake loads, the design process, building codes, etc.

The next step in the conceptual design phase of the tutorial was to organize the information to be covered. In order to do this, project team members worked on developing possible methods of presentation and began to form a layout of the tutorial. Most of the early ideas were in the form of PowerPoint slides that contained static photographs of building construction and the corresponding discussion typed next to the

pictures. These conceptual slides helped our project team assess what methods of presentation could be the most effective and which others needed to be revised or discarded.

8.3 Assessment of Conceptual Ideas

In order to properly assess the effectiveness of these conceptual slides, our project team decided to review the slides with the corresponding text-based discussions hidden from view. More precisely, our project team first covered the text-based discussions with our hands and then proceeded to analyze the effectiveness of the photographs in portraying information. It was then discovered by our project team that the photographs in the conceptual slides were not effective in portraying a great deal of information. Hence, our project team soon came to the consensus that presenting photographs of building construction alone would not be an effective mode of visual presentation for the tutorial.

Our project team had previously identified the reliance on static photographs as a drawback of the textbooks by Brannigan, Dunn, and others (*see Chapter 3*). In order to help make the conceptual designs more interesting, our project team decided to find new ways of presenting the information, as opposed to just showing pictures and explanations. Hence, our project team needed to find better ways to leave a lasting impression upon the users of the tutorial.

8.4 New Methods of Presentation

In order to make the tutorial more interesting for the user, our project team brainstormed methods of presentation that would be unique. Since no person in our project team has had any experience in computer programming, a custom-built tutorial program would not be an option for us. Hence, our project team needed to utilize available software packages. Most of our team members are proficient in PowerPoint, so we decided that effective use of this accessible software could be a very possible option.

Online courses in PowerPoint, which are freely available at Microsoft's website (http://office.microsoft.com), helped our project team realize the potential of using this program to design a tutorial. Overall, these online courses proved to be very beneficial to our project team, for we were able to discover specific features of PowerPoint that would prove to be very useful when developing the tutorial (e.g., motion paths, timing schemes, etc.). Furthermore, our project team discovered that many of these features could be used in combination to create interactive animation. For example, the "motion path" feature could be used in conjunction with the "emphasis" feature to show the deflection of a beam. The inclusion of interactive animation would make our tutorial more interesting and unique to the user.

This method of presentation would highly contrast that of the N.F.A. handoff course studied by our project team (*see Section 3.7*). The largest complaint that our project team has of this handoff course is its ineffectiveness in maintaining the interest of the user. More precisely, the PowerPoint presentations are static, resembling the pages of a textbook. Hence, our project team strived to create an educational tutorial that maintains the interest of the user throughout it duration. Interactive animation could be

used as a means of maintaining the user's interest because this method of presentation requires extensive participation by the user. Moreover, since it was decided that mathematical explanation was not a plausible option, interactive animation schemes could serve to portray concepts that are highly-mathematical in more a visual sense.

8.5 Developing the Layout

The intended scope of the tutorial was discussed following our team's research into the advanced features of PowerPoint. After reviewing prior course work and narrowing the topics down to a primary set of concepts to be covered in the tutorial, our project team realized that proper sectioning of the tutorial would prove to be very important. Our project team came to the consensus that the contents of the tutorial can clearly be divided into two main sections. The first section would cover the fundamental principles of building construction and the second section would cover topics that are directly related to scenarios that Fire Investigators could possibly encounter. Our project team believes that this approach is most efficient for specific reasons.

From our experiences as students, our project team believes that knowledge of the basic principles of building construction is an essential prerequisite to the understanding of structural hazards. The Civil and Environmental Engineering Department at Worcester Polytechnics Institute organizes their courses for students with a similar philosophy. For example, students are recommended to take classes in basic engineering mechanics before proceeding to such classes as structural steel design. The same approach applies to the execution of the tutorial, for our project team cannot expect the

user –for example– to fully grasp the behavior of a wooden lintel under loading before that user is exposed to any concepts about simply-supported beams.

Another reason our project team strongly believes that dividing the tutorial into two distinct sections will be advantageous is because it will enable us to create logical subsections. For example, by clearly defining the first half of the tutorial as covering the fundamental principles of building construction, our project team may create subsections (e.g., types of loads, deflection, etc.) that follow in a logical order. Hence, new principles of building construction can be introduced that draw upon various principles covered before that point in the tutorial. Therefore, this "build-up" of knowledge will effectively culminate in the second half of the tutorial, where structural hazards may be covered.

8.6 Creating the Tutorial

After the basic scope and layout of the tutorial was confirmed, our project team began to develop specific sections of the tutorial one at a time. Sections of the tutorial were presented to the project advisors every week in order to receive a preliminary assessment of the quality, in terms of both the accuracy of the information and the style of presentation. From these weekly screenings, our project team was able to identify certain problems with the tutorial and correct them quickly.

Once all of the sections of the tutorial were complete and fully functional (i.e., free of technical errors), our project team focused on consolidating the information into a single unified tutorial. Our project team organized all of the sections produced for the tutorial into a single PowerPoint file. Furthermore, a table of contents was developed that would allow users to link to a specific section of the tutorial. Additionally, a "home"

icon was inserted into every page of the tutorial so that the user may return to the table of contents at any given time. Our project team feels that the table and contents and "home" icon are worthy additions to the tutorial because it contains over seventy pages and would be difficult for the user to navigate otherwise. Once these navigational features were added, our project team began to fully review the contents of the tutorial for any technical defects or inaccurate information.

Once the first version of the tutorial was completed, our project team developed a user guide. This user guide provides all the information that the user would need to start the program and navigate through its contents. Additionally, our project team began to discuss how this tutorial could be tested for quality.

8.7 Developing a Post-Tutorial Quiz:

Once our project team finished developing the first version of the interactive tutorial, we decided that developing a post-tutorial quiz would be advantageous. Our project team believes that such a quiz will serve two important purposes. First, it will provide users of the interactive tutorial with an opportunity to be quizzed on what they have learned. Second, it will help our project team conduct future phases of tutorial testing, whereas we may administer the quiz to testers following their use of the interactive tutorial. This statistical feedback would help our project team evaluate the efficiency of the tutorial as it pertains to portraying complex topics to the user.

Our project team decided that the post-tutorial quiz should consist of an interactive PowerPoint version similar to the main tutorial, as well as a text-based counterpart. The interactive PowerPoint version of the quiz would allow the user to test

his or her knowledge after completing the tutorial. This would occur on the users own free time, so that he or she may realize certain parts of the tutorial that he or she may need to review. The text-based quiz could be used by our project team to conduct future phases of testing, in which testers would be asked to formally complete the quiz. The results derived from this testing would help our project team assess the effectiveness of the tutorial as an educational software.

After deciding on the formats for the post-tutorial quiz, our project team began to brainstorm specific questions to ask in the quiz. Our project team believes that the user should be able to apply basic principles of building construction to all situations encountered within buildings. Hence, our project team tried to devise questions that do not resemble those found in the N.F.A. handoff course's final exam (*see Section 3.7*), in which students were simply asked to recall certain terminology and building construction types. Our project team began to record quiz questions that would require the user not only to recall certain principles and terminology, but also to apply this information to specific situations. Our project team devised multiple-choice questions that ask the user, for example, to trace the load path of a given loading throughout a structure down to the foundation.

Once our project team completed sixteen multiple-choice questions for the post-tutorial quiz, we began to devise an effective layout. Our project team decided that the use of "actions buttons" in PowerPoint (i.e., icons for the user to click on) would complement the multiple-choice questions in a very effective manner. Therefore, the user would be presented with the question and then asked to click on the icon corresponding to their choice for the answer. The goal of the interactive quiz is to allow

the user to learn from any mistakes he or she makes during the quiz. Hence, our project team decided to link all of the correct answer icons to extended discussion pages and all of the incorrect answer icons to pages that recommend that the user review a given section of the tutorial. The way in which our project team has organized the interactive post-tutorial quiz (and its text-based counterpart) will provide users with additional educational material about principles of building construction and structural hazards.

9. Tutorial Testing

This chapter documents the tutorial testing that our project team has conducted in order to properly evaluate this software. This evaluation pertains to the informational content of the tutorial, as well as its appeal to the user.

9.1 Testing Overview

The tutorial testing process involved the participation of practicing Fire Investigators at the Worcester Fire Department. This testing provided our project team with a preliminary assessment of the effectiveness of the tutorial before more focused testing is conducted (e.g., instructor/student testing). Moreover, the opinions of the participating Fire Service personnel helped our project team identify aspects of the tutorial that need to be improved.

9.2 Testing Procedure

Our project team agreed upon a scientific testing procedure for the tutorial testing. This procedure ensured that the testing was standardized and unbiased. The procedure for the tutorial testing is summarized below:

1. The tutorial is introduced to the user as an interactive educational supplement concerning the principles of building construction and structural hazards, which is intended for students training for the Fire Service.

2. The user is provided with the tutorial user manual, which contains specific information concerning the interface and commands of the tutorial.

3. The user is told to proceed through the tutorial at a pace in which they are most comfortable. For convenience, the user is told that the approximate duration of the tutorial is one hour.

4. The user is given a voice recorder and told to record any comments that come to mind as he or she proceeds through the tutorial.

5. The tester then leaves the room for the duration of the testing, unless the user requests assistance.

6. When the user has finished the tutorial, he or she will be given a post-tutorial questionnaire to respond to. This questionnaire will provide quality feedback.

Remarks:

It is important that the user proceeds through the tutorial independently (i.e., with limited to no assistance from the tester). It is intended that eventually this tutorial will be distributed to many people who will only be provided with the tutorial software and the user manual. Hence, this testing should be conducted to fit those circumstances by only providing the user with the user manual for guidance.

9.3 Documentation of Testing

General:

Lieutenant Rousseau and Lieutenant McGrath, who are both practicing Fire Investigators at the Worcester Fire Department, participated in the tutorial testing (01/18/05 & 01/21/05).

Defects Identified:

- Lieutenant Rousseau mentioned that the page relating moment arm to opening a fire hydrant was slightly flawed. The page shows a wrench tightening the hydrant, as opposed to opening the hydrant. He said that students might be confused by this.

- In the post-tutorial quiz, the correct answer section of Question 6 should be edited (i.e., the word “distributed” should replace “concentrated”).

- In the post-tutorial quiz, the correct answer section of Question 12 should be modified slightly. Both Lieutenants commented that the yellow font for some of the text was difficult to read with sun glare.

- In the post-tutorial quiz, clicking on the correct answer to Question 15 links you to the explanation for Question 14.

Observations:

- Both Lieutenants seemed to be very well entertained throughout the duration of the tutorial and the quiz. Their level of interest remained high for the duration of the testing.

- As Lieutenant Rousseau and Lieutenant McGrath proceeded through the tutorial, they mentioned various job experiences which pertained to the topics being presented in the tutorial. For example, Lieutenant Rousseau recalled investigating a building that had notched beams.

- As both Lieutenants studied the contents of the tutorial they persistently tried to relate complex concepts to real-life analogies. For example, Lieutenant Rousseau tried to understand the principles of camber by recalling the curvature of a supply truck’s axle

before and after it is loaded. This occurrence reaffirms the main strategy of the tutorial, for it focuses on portraying complex concepts in terms of familiar events and ideas.

9.4 Results of Post Tutorial Questionnaire/ Feedback

After both Lieutenant Rousseau and Lieutenant McGrath completed the tutorial, they were asked to respond to the post-tutorial questionnaire for quality feedback. The questions and corresponding responses are summarized on the following page.

Post Tutorial Questionnaire Responses

1. *Agree or Disagree*: "I felt entirely comfortable using this tutorial":

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

Both Lieutenants chose "Agree."

* *If applicable,* list interface/command problems:

Lieutenant Rousseau had problems using the tutorial on his computer, which has PowerPoint 2000.

2. Have you ever used a tutorial which closely resembles this tutorial?

☐ Yes ☐ No

Both Lieutenants chose "No."

3. *Agree or Disagree*: "This tutorial held my interest throughout its duration":

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

Both Lieutenants chose "Agree."

4. *Agree or Disagree*: "I would recommend this free tutorial to Fire Service students":

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

Lieutenant Rousseau chose "Strongly Agree"; Lieutenant McGrath chose "Agree."

5. *Agree or Disagree*: "I can relate many concepts discussed in this tutorial to my career":

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

Lieutenant Rousseau chose "Strongly Agree"; Lieutenant McGrath chose "Agree."

6. *Agree or Disagree*: "This tutorial would be a beneficial *supplement* to Fire Service curriculum":

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

Lieutenant Rousseau chose "Strongly Agree"; Lieutenant McGrath chose "Agree."

7. Comments

Lieutenant Rousseau commented: "The material covered is seen in most building construction types. [The tutorial] should be very helpful to students who do not have construction knowledge."

Please see the Appendices section for the actual questionnaire forms.

9.5 Conclusions/ Findings

After filling out the post-tutorial questionnaire, Lieutenant Rousseau spoke to the tester personally about his feelings about the tutorial. He stated that this tutorial would not directly benefit practicing Fire Investigators, but would be an extremely valuable educational tool for students training to become a Fire Investigator. This would be especially true for entering students of the Fire Service that do not have much experience working in building construction or learning about building construction in directed courses.

Lieutenant Rousseau stressed that his favorite aspect of the tutorial was that it is not overly-complex and it delved directly into the subject matter. He also said that the tutorial actually served as a convenient review for his own benefit. Lastly, Lieutenant Rousseau mentioned that the only tutorial that he had used lately was *InterFIRE VR* (*see Section3.6 for a description*). He stated that he does not like *InterFIRE VR* because it is frustrating to operate.

9.6 Progress Derived

This tutorial testing went very smoothly and our project team has gained valuable feedback from two practicing Fire Investigators. It has been brought to the project team's attention that computer compatibility of the tutorial is an important issue that must be researched. Users that have PowerPoint editions prior to the 2002 edition will have compatibility issues. To correct this problem, our project team intends to research possible solutions to this compatibility issue.

Our project team was notified about specific defects in the tutorial which were soon corrected. For example, there were instances of yellow font which were difficult for the user to discern with light glare. Our project team has also gained a level of confidence that the tutorial is headed in the proper direction, for both Lieutenants responded very favorable to the post-tutorial questionnaire and during personal discussions.

10. Conclusions/ Reflection/ Recommendations

As our project team has gathered all of this data, we have formulated opinions as to what caused certain deficiencies in the project. Upon completing the project, our team recognized that certain aspects of the research could have been enhanced. These opinions are discussed here.

10.1 Local Surveys

After distributing the local survey, and analyzing the results, our project team realized that there are several parts of the survey that could have been improved. Most of these points of improvement are a result of the fact that we were not expecting our responding audience to be staff of the M.F.A. Our local survey was originally drafted with the intention to distribute to students of the academy. However, due to time constraints of the project, and the very infrequent schedules of classes, it was more practical to distribute the survey among staff. Although the data gained from this audience proved very helpful, there were specific aspects that could have yielded even better data.

For example, Question #5 asks, *Have you taken any courses that deal exclusively with or have used building construction as part of the curriculum?* A large majority of responders answered yes to this problem, but there is some discrepancy from our project team's point of view of what a positive response actually entails. Because the responders are instructors at the academy, it is possible that they could have interpreted the question as meaning they had participated in such classes as students, taught these courses at teachers, or both. For the purpose of our survey, our data could have been more helpful if

we had separated the question into two components. The first would have asked if such courses were being taught at the academy. The second should have asked if the responder had taken the classes as a student. These two questions would have given our project team very specific insight into exactly what courses related to building construction were being taught at the present time, and compare that to the extent to which these same courses have been taught in the past.

Another question that our project team could have asked had we known during the writing process that the local survey would eventually be distributed to instructors and not to students would have been whether or not their curriculum had changed to reflect an emphasis on the concepts of building construction. From other research, our project team has learned that the number of Fire Investigators receiving accredited training is on the rise. As a follow-up question to this information, it would have been interesting to know if this seemingly greater emphasis on the importance of formal fire investigation training had brought about any notable changes in the way the courses are being taught. For example, if it was realized how important a fire education was professionally, the field of study could have been reorganized to go into more detail, seeing how practical these classes could be in the professional field.

10.2 National Survey

Though the basic outline and ideas behind the national survey were established with the local survey and much of the background research did not have to be repeated, the national survey needed to be completed much more quickly than the local survey due to project time constraints, allowing less time for it to be finely tuned. Because the

development and distribution of the national survey was done under a much shorter time span, there were several parts of the survey that could have been improved given more time to complete the task. First, the confidence interval of the survey could have been improved had our project team had more time to personally follow up on the response of every survey. Of the surveys that were not returned, our project team did make an attempt to make contact with these schools by telephone. In most cases, these calls were directed to secretaries, and not to the actual heads of the respective Fire Science departments. Most of the time the secretaries that answered the phone were willing to take a message for the head of the department to see if they had received the survey, and to fill it out and return it. In this situation, our project team felt that it had done its part to follow up on the survey, but we did not expect successful completion of the survey in this situation. The project team realized that the head of any department was very busy and could not be convinced of how filling out such a survey would be a valid use of their time. The best way our project team could have improved the response to this survey would have been to improve the distribution. By calling ahead to each institution and asking the name of the department head of the training division, and talking to them on the phone to explain the validity of the survey could have greatly improved the survey response. The surveys would have been assured to go to the correct source, and the given responder would be expecting this survey in the mail. Obviously, this process would be very time consuming, and any attempt for our project team to complete the task in this function would be nearly impossible in the given time frame.

Other problems with the national survey have to do primarily with wording deficiencies that can be attributed to time constraints that resulted in only a few drafts,

and very little time to edit. Question one asks, *Does your training school offer any courses which involve discussion of building construction and/or structural hazards? Please check the choices that apply.* The problem with this question could seem slight to the person who is writing it, but to the responder, the language and specific word in such a question is essential. The deficiency is in the part that asks if the course "involves discussion." In the writing of this survey, the intention was to express that building construction was the focus of the course. But the specificity implied by the word choice "discussion" could be interpreted as exactly that, discussion. It is entirely possible that some classes at the institution focus exclusively on building construction, but these classes are taught totally devoid of class "discussion." This potential confusion due to poor word choice could result in an inaccurate response. This problem could have been solved by re-wording the question as follows: *Does your training school offer any courses which* ***involve the study of*** *building construction and/or structural hazards? Please check the choices that apply.* Such wording is all encompassing of any courses that emphasize building construction, and reduces, if not eliminates any confusion as to exactly what the question is asking.

10.3 Interviews

The interview process was conducted in a very careful manner in that our project team set out to collect data but made sure to never ask questions that would compromise the trust of the fire professionals we interviewed. Although the ambition of this project is to improve the occupational safety of Fire Investigators, the fact of the matter was that we were students who were interviewing individuals who had established themselves with

decades of work in their field. So it was important in the interview process to realize that we were simply inquiring into the interviewee's knowledge, and that the generosity and service was towards our project team, not the other way around. The downside to this mindset was that our project team felt somewhat tentative into delving deep into the knowledge base of the individuals we interviewed. Our fear was that aggressive questions could result in defensive responses and even create a feeling that our project team's goal was to expose deficiencies in the practices of the profession. If our project team was given total freedom in this situation, we would have asked more questions that specifically investigated what structural concepts they were familiar with. In a perfect world, we could have discovered exactly what concepts related to building construction were conceptually strong, and conversely which concepts could benefit from reinforcement from some sort of educational supplement.

10.4 Strengths and Weaknesses of the Interactive Tutorial

Now that the development of the interactive tutorial is complete and testing results have been derived, our project team can assess its strengths and weaknesses. Extensive investigation into the training of Fire Investigators pertaining to principles of building construction and structural hazards has revealed that added supplementation would be beneficial. In response to this identified opportunity, the goal of our project team was to develop an interactive tutorial that will help training Fire Investigators identify building collapse dangers and thus increase their occupational safety. In order to achieve this goal, our project team intended to expand upon the many positive aspects of

current educational literature within the Fire Service, as well as find innovative ways to overcome their drawbacks.

The first version of the interactive tutorial has many strong attributes that our project team believes will enhance the educational database of the Fire Service as it pertains to principles of building construction and structural hazards. The interactive tutorial explains all of the topics without referring to mathematics. In this regard, the tutorial is almost entirely visual and relates complex concepts to familiar everyday occurrences. For example, discussion of moment force is related to changing a tire of a car. Moreover, the animation used in the tutorial helps to represent material behaviors that would otherwise be difficult to portray with only a written explanation. For example, the tutorial presents the transmission of loads throughout a flooring system by means of color emphasis and motion path animations.

Since the interactive tutorial is almost entirely visually-based, the attention of the user is maintained throughout its duration (*see Chapter 9*). Moreover, the light-hearted nature of the presentation helps to make the user comfortable during the learning process. Additionally, the table of contents was designed as a convenience to the user, in which he or she may freely link to any section of the tutorial at any time. Moreover, every page of the tutorial contains a "home" icon for added convenience to the user. The running time of the tutorial is approximately one hour, so the user will not have to devote an excessive amount time in order to learn the concepts contained.

Unlike many articles of educational literature reviewed by our project team, the tutorial contains indicators within most of the pictures presented in order to focus the user's attention to key parts of the photographs. Moreover, emphasis animations are used

throughout the duration of the tutorial in order to reaffirm the importance of certain points being presented. Lastly, the tutorial relates general principles of building construction to scenarios that a Fire Investigator may possibly encounter during his or her work, and recommendations for added safety are expressed.

In retrospect of the first version of the tutorial, certain drawbacks become readily identifiable. First, the tutorial is not compatible with versions of PowerPoint prior to the 2002 edition. This is a major drawback because it automatically limits the prospective audience for the tutorial. During the first phase of tutorial testing (*see Chapter 9*), the participating Fire Investigators only had the 2000 edition of PowerPoint on their computers. Another major drawback of the tutorial is it contains no audio commentary during its duration. After testing the tutorial, Fire Investigators at the Worcester Fire Department mentioned that the addition of audio commentary would make the tutorial more effective. Our project team recommends that added research be conducted that pertains to compatibility issues and the possible addition of audio commentary to the tutorial.

Overall, our project team firmly believes that this tutorial represents an innovative article of software to enhance the educational database of the Fire Service as it pertains to principles of building construction and structural hazards. Post-tutorial questionnaire results reveal that participating Fire Investigators have never encountered software that resembles our interactive tutorial. Moreover, the participating Fire Investigators commented that the interactive tutorial would be very beneficial to training Fire Investigators (*see Chapter 9*). Our project team believes that the interactive tutorial has

many strong attributes, as well as some weaknesses that deserve specific attention in the future.

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Appendices

A.1: Background:

- NIOSH Fire Investigator fatality reports.

A.2: Initial Research – Review of Texts and Other Available Resources:

- Course Listings (John Jay College of Criminal Justice, National Fire Academy (N.F.A.), Massachusetts Firefighting Academy (M.F.A.), Anna Maria College).
- Information about the M.F.A.
- E-mails to instructors concerning course content.
- Fire Investigator Certification System (Commonwealth of Massachusetts).
- Information about the National Institute of Standards and Technology (N.I.S.T.) DVD about structural collapse.
- Francis L. Brannigan's brief autobiography entitled "Sixty Years."
- Information about the *InterFIRE VR* Fire Investigator training software.
- Results from the virtual reality fire investigation conducted by project team members (*InterFIRE VR*).
- Information about the N.F.A. handoff course entitled *Principles of Building Construction: Combustible*.
- Interesting slides and activities from the N.F.A. handoff course.
- The final exam (with answers) of the N.F.A. handoff course.

A.3: Interviews – Research of the Work Environment:

- Questions for various interviewees (e.g., practicing Fire Investigators).
- Documentation of interviews conducted.

A.4: Local Surveys – Understanding the Current Knowledge Base:

- Various versions of the local survey.
- Preliminary analysis of the local survey results.
- Actual local survey responses.

A.5: National Survey:

- Various versions of the national survey.
- List of potential national survey locations.
- Sample statistical calculations (for analysis of results).
- Actual national survey responses.

A.6: Development of the Interactive Tutorial:

- Outline of principles derived from courses at Worcester Polytechnic Institute.
- Tutorial user guide.
- Post-tutorial quiz (text-based version) with answers.

A.7: Tutorial Testing:

- Post-tutorial questionnaire responses.

A.8: Miscellaneous:

- Various letters of transmittal.