How Much Science is Necessary?

Training and Educating Firefighters in the 21st Century

Introduction

The question of how much science is necessary in firefighter training and education confronts fire services across the world. Firefighters are often practical people with little patience for theory. However, a sound understanding of theoretical concepts can have a major influence on how firefighters process experience and develop competence in their craft.

Figure 1. Theory and Practice in Ventilation

Note: Steve Kerber (Underwriters Laboratory) and Stefan Svensson (Swedish Civil Contingencies Agency) conduct a demonstration at the 2008 International (Fire Behavior) Instructors Workshop in Revinge, Sweden.

The fire service has its roots in blue-collar, manual labor as evidenced by observations by fire chiefs in the June 1938 *Fire Engineering* roundtable discussion of qualifications for entry level firefighter.

> The college man is difficult to educate to our standards, because of his advanced education… I do not find that the man with a college or high school education is necessarily better adapted to the fire service…My experience in the fire service has been that the best material comes from the ranks of the laboring class, with grammar school education. (Sheppard, 1938, p. 253-256)

While most fire service agencies have a considerably different perspective on entry level educational requirements, prerequisite education and the appropriate scope and depth of fire service training continue to be a contentious issue.

In 2006, the International Fire Service Training Association (IFSTA) validation committee working on revision of the Essentials of Firefighting (5^{th} ed.) struggled with the question of how much science was necessary for firefighters to understand fire behavior and ventilation. By association policy, training manuals must be written at the eighth grade reading level, but there is no guidance regarding academic level or the depth to which scientific concepts should be addressed.

The question of how much science is not unique to the fire service, secondary schools (Malvin, 1990), universities (Westheimer, 1994) and even the medical profession (Eisenberg, 1988) have, and continue to struggle in finding the appropriate scope of scientific education.

Fire Behavior

While firefighters' understanding of fundamental scientific concepts impact many aspects of fire and emergency services work, nowhere is it more important than fire behavior and the influence of firefighting strategies and tactics.

Gorbett and Hopkins (2007) reviewed literature, textbooks, and standards used in fire behavior training and reached the conclusion that "many in the fire safety profession (i.e. fire service personnel, fire investigators, fire protection engineers) do not understand these very important enclosure fire progression phenomena [backdraft, flashover, and smoke layer ignitions]" (p. 1)." Gorbett and Hopkins strongly emphasize that "to effectively perform their duties fire safety professionals *must achieve a solid theoretical knowledge* of fire behavior, more specifically enclosure fire behavior [emphasis added]" (p. 2).

While applicable across the fire service curriculum, this paper will focus specifically on the criticality of scientific literacy in the area of fire behavior and compartment fire dynamics.

Vocational Education

Fire service training has its roots in vocational education and even deeper in the passage of craft knowledge and skill from master to apprentice. Vocational education prepares learners for careers that are based in manual or practical activities, traditionally non-academic and totally related to a specific trade, occupation, or vocation. It is sometimes referred to as technical education, as the learner directly develops expertise in particular technical skills. Vocational education might be contrasted with education in a usually broader scientific field which might concentrate on theory and abstract conceptual knowledge characteristic of postsecondary education.

Quoting Charles Allen (no citation given), Hudiburg and Smith (1960) describe good teaching as "putting into the hand and head of another that which he did not previously have, with the least amount of time and effort on the part of the teacher and the learner" (p. 5). This quotation provides a substantive clue to the connection between the text and the philosophy of vocational education that evolved in the United States in the early 1900s.

The position that "learning is accomplished through a step-by-step procedure in an orderly manner and logical sequence" (Hudiburg & Smith, 1960, p. 6) maintains direct linkage with the perspectives on vocational education articulated by Charles Allen and Charles Prosser. Allen and Prosser were key figures in the development of vocational education in the early 1900s (Moore & Gaspard, 1987). The essentialist philosophy of vocational education that evolved in the first half of the 20th century proffered a mechanistic view of training and vocational education in which the goal is efficient production of trained individuals (Allen, 1919; Prosser & Allen, 1925). Allen provides a example by comparison of the commonality of teaching and production (see Table 1).

Table 1. Production and Instruction

	Production	Teaching
Purpose of Aim	To turn out a definite article from a given piece of stock	To instruct a given individual in a definite thing
Man Responsible	Workman	Instructor
Material Worked Upon	Stock, new or partially worked up	Learner, green or partially trained
Procedure	Successive production operations in a determined order	Successive instructional steps in a determined order
Means Used	Suitable tools and machines	Suitable methods of instruction
Character of Product Tested by	Inspection of product	Inspection of learners' ability to do the thing that the lesson was to teach him

Note. From *The Man the Instructor and the Job* (p. 120), by Charles R. Allen, 1919, Philadelphia PA: J. B. Lippencott Company. Copyright 1919 by J. B. Lippencott Company.

While a vocational approach can have tremendous value, is it sufficient to develop the knowledge, skills, and abilities required of today's firefighters? In 1876, Eyre Massy Shaw, Chief of the Metropolitan London Fire Brigade wrote:

> It is only the superficial and half-educated who, in such cases, announce everything in detail beforehand, and thus find themselves, for years afterwards, working in a false position, endeavoring, contrary to experience and their improved information, to justify announcements made by them while laboring under that most unsatisfactory, but perhaps *most common, form of ignorance, which consists of practical knowledge, absolutely alone, without the aid of theory,*

> *and which is consequently to a great extent antagonistic to all useful development* [emphasis added] (Shaw, 1876, p. vii)

Examining science teaching and curriculum in secondary schools, Malvin (1990) quotes a teacher as stating "Too often the teacher aims the course and educational material so as to answer the frequent question asked by students, 'but what is the right answer?' (p. 85). This is also the case in fire service training where teaching generally focuses on what and how, rather than why and assessment generally requires recognition or recall, rather than higher level analysis or synthesis.

Unlike other technical or professional occupations where entry-level personnel must have specific training and education, fire service agencies typically provide comprehensive entry-level training after employment. Development of the knowledge and skills necessary for advancement is generally accomplished through some combination of organizationally provided training, continuing education (at a college or university), and on an experiential basis. (Clark, 2004). To what extent does entry level training and ongoing professional development meet the need to develop scientific literacy? While some firefighters pursue engineering or other education providing a strong emphasis on science, most do not.

How does our occupational or professional paradigm influence the content and form of fire training curriculum? A paradigm is an "entire constellation of beliefs, values, techniques, and so on shared by members of a given community" (Kuhn, 1970, p. 175). While the fire service has progressed considerably since the 1930's and an elementary education is generally not considered to be sufficient for entry level firefighters, the scientific foundations provided in fire training are often overly simplistic and fail to provide a basis for understanding fire behavior phenomena and the influence of firefighting strategy and tactics.

What is the Aim

As stated earlier, the *Essentials of Firefighting* (IFSTA, 2008) validation committee struggled with the question of how much science should be included in the text. The committee engaged in substantive discussion of the need for increased emphasis on applied science related to fire dynamics, but expressed concern about the learners' (and instructors') abilities to understand this new material. In the end, the new edition of the text was considerably improved, but still failed to adequately address many critical concepts necessary for an adequate understanding. This unfortunate outcome was likely in part due to lack of consensus on the desired outcome of fire service science training and education.

It is all well and good to advocate for a stronger scientific foundation in fire service training and education, but to what end? Burbles and Linn (1991) provide a starting point:

> Science education should help students a) acquire a basic knowledge and understanding of ordinary scientific phenomena; b) develop the ability to generate fruitful and relevant questions and frame them in an effective way for investigation; c) learn to select and apply appropriate methods from a range of options in answering those questions; and d) evaluate and synthesize the scientific information gained as a result (p. 227-228).

It is reasonably easy to see how this concept of science education could apply in the context of primary, secondary, and post-secondary education in a general sense. However, how does this apply to the training and education of firefighters? I propose the following goals:

> Fire training should 1) build a scientific foundation for understanding fire behavior phenomena and the impact of firefighting strategies and tactics, 2) develop firefighters' ability to generate useful and relevant questions based on their experience and the experiences of others, 3) provide a basis for integrating fire related research and practical fireground application.

Adaptive Expertise

Firefighters are generally skilled in performing the routine task level activity involved in firefighting operations and many firefighting operations are defined in standard operating procedures or guidelines. These tasks and procedures are often based on prior experience and commonly required strategies and tactics. Individuals who are particularly skilled have expertise. However, "Past successes, no matter how numerous and universal, are no guarantee of future performance in a new context" (Petroski, 2006, p. 3).

Hatano and Inagaki (1986) describe the evolution of knowledge as proceeding from a heuristic or procedural basis to one that is more conceptual. Conceptual understanding requires more comprehensive knowledge of the object of practice and its surrounding world. An individual may develop routine expertise (a high level of skill when the object and context remain constant) using procedural knowledge. However, adaptive expertise (the ability to adapt to changing conditions) requires conceptual knowledge and a higher level of intellectual flexibility.

Adaptive expertise in firefighting requires that firefighters not only be proficient in firefighting tasks and tactics, but that they have a scientific basis to understand fire behavior and the impact of strategies and tactics in a dynamic environment.

Firefighters Epistemology

Epistemology is a branch of philosophy focused on the nature and justification of knowledge. This inquiry may be divided into three general questions (Arner, 1972): a) What are the limits of knowledge, b) What are the sources of knowledge? c) What is the nature of knowledge? While not the everyday subject of firefighters conversation, epistemology has far reaching consequences within the fire service discipline!

Beliefs are influenced by the specific experiences and development of the individual. However, within a given community of practice, there is likely to be a shared paradigm influencing beliefs about what knowledge is valued and how we come to know. These individual and commonly held beliefs influence both the perception and outcome of experience.

> Confidence in scientific research, in turn, may ultimately depend on epistemological beliefs: Someone who believes that the most valid source of knowledge about some issue is intuition, commonsense, or personal experience is unlikely to be influenced by evidence from scientific research (Estes, Chandler, Horvath, & Backus, 2003, p. 640).

How do firefighters view theory and practice? Is there a chasm between theory and fundamental scientific concepts and practical application? How might this influence firefighters' engagement with science in formal and informal learning?

While a substantive discussion of firefighters' epistemological beliefs and their influence on both formal learning and processing of everyday experience is beyond the scope of this paper, firefighters' perception of science may have a significant effect on their engagement with scientific theoretical constructs and their ability to integrate the findings of scientific research into practical firefighting applications.

Professional Qualifications

A great deal of fire service training is guided by the provisions of professional qualifications standards such as National Fire Protection Association (NFPA) 1001 *Standard for Fire Fighter Professional Qualifications* (2007). and NFPA 1021 *Standard for Fire Officer Professional Qualifications* (2008). However, these standards provide vague and limited guidance regarding the breadth and depth of scientific knowledge that should underlie the firefighters' or fire officers' practice.

NFPA 1001 *Standard for Fire Fighter Professional Qualifications* (2007) and NFPA 1021 Standard for Fire Officer Professional Qualifications (2008) Edition provide general guidance regarding the requisite knowledge of fire behavior and fire dynamics for firefighters and fire officers. This guidance is all specified in the context of requisite knowledge, defined by the NFPA as the "fundamental knowledge one must have in order to perform a specific task" (NFPA 1001, Chapter 2).

As illustrated in Table 2, some of the requisite knowledge is quite specific (e.g., physical states in which fuels are found; signs, causes, effects, and prevention of backdraft). However in other cases the recommendations are so general as to provide little guidance (e.g., fire behavior in a structure, fire behavior). In addition, many critical concepts such as other types of extreme fire behavior (e.g., flashover and the various types of fire gas ignition), fuel and ventilation controlled burning regime, heat of combustion, and heat release rate are not mentioned at all. These concepts may fall under the more general framework of fire behavior in a structure, but it is just as likely that they may not be addressed in Firefighter I, II, and Fire Officer I training curriculum.

Table 2. Professional Qualifications Scope and Requirements for Fire Behavior Knowledge

Firefighter I	Firefighter II	Fire Officer I
Has demonstrated the knowledge and skills to function as an integral member of a fire-fighting team under direct supervision in hazardous conditions	Has demonstrated the skills and depth of knowledge to function under general supervision	Fire officer, at the supervisory level, who has met the job performance requirements specified in this standard for Level I
• Observable results that a fire stream has been properly applied • Dangerous building conditions created by fire • Potential long-term consequences of exposure to products of combustion • Physical states of matter in which fuels are found • Fire behavior in a structure • The products of combustion found in a structure fire • The signs, causes, effects, and prevention of backdraft • The relationship of oxygen concentration to life safety and fire growth • The methods of heat transfer • The principles of thermal layering within a structure on fire	• Fire growth and development is continuously evaluated • Dangerous building conditions created by fire	• Basic fuel loading, and fire growth and development • Fire behavior

Note: Excerpted from *NFPA 1001 Standard for Fire Fighter Professional Qualifications*, Chapters 5 and 6 (NFPA, 2007) and *NFPA 1021 Standard for Fire Officer Professional Qualifications* Chapter 4 (NFPA, 2008).

The greatest limitation of these professional qualifications standards is that they focus on specific bits of information, rather than the basic scientific literacy necessary to understand fundamental concepts and the ability to apply those concepts in a practical context.

Integrating Science

Development of competence and scientific literacy cannot be addressed by development of a new course or training program for firefighters and fire officers, it requires a fundamental shift in perspective. "New technologies have generated increased and varied application of scientifically based materials in the world of work, thereby increasing the importance of science and math skills for workers" (Lankard, 1993). As in other disciplines, this holds true for the fire service as well.

> Science is the quest to find out how things work, how they are connected and how they look from the tiniest detail to the most tremendous forces in the biggest systems.
>
> I am amazed every time I learn something new. Often, these new things are unexpected.

> If we can give a name to something, it makes us appreciate it from a different, much deeper, perspective. With every bit we discover about how things 'work' we gain a deeper understanding of the world around us.(Shur, 2009).

How much science is necessary for firefighters and fire officers to safely and effectively serve their communities in the 21st century? There may not be a definitive answer to this question, but those seeking an answer may be inspired and guided by the observations of Massey Shaw:

> In order to carry on your business properly, it is necessary for those who practice it to understand not only what they have to do, but why they have to do it…No fireman can ever be considered to have attained a real proficiency in his business until he has thoroughly mastered this combination of theory and practice (Shaw, 1876)

This paper serves as a call to action. It is easy to decry the current state of affairs, but considerably more difficult to determine and implement actions to effect improvement. Changing standards and practices requires commitment and considerable effort. If you accept (or better yet embrace) the concepts and ideas presented in this paper, what can you do to effect the necessary changes in our profession?

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