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Joseph Sterling Mattoon
Education and Training Consultant

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Rapid advancement characterizes U. S. high-technology industries, and the need for technically qualified employees continues to increase (Riggs, 2000). The increased need for technology education is verified by recent research that indicates graduates of university technology programs are hired immediately after graduation (Nock & Shults, 2001). To maintain a strong technical workforce, there is an increasing need for colleges and training institutes to update their curriculum so that it addresses the latest technologies and industry practices (Frenzel, 2003). The National Science Foundation will provide an estimated $40,000,000 in educational grant funding for projects that team with industry for this purpose (NSF, 2003). Technical subject matter experts will play an essential role in helping achieve this goal, but their role differs from that of the instructional developer (Lee, 1994). While the technical expert provides what becomes the course content material, it is the instructional developer's task to produce instructional components (e.g., lectures, practice, tests) that facilitate and verify the acquisition of the target knowledge (Dick & Carey, 1996). However, development of curriculum is time-consuming, challenging, and costly, therefore selecting a subject matter expert (SME, pronounced "smee") who is capable and suitable for the job is critical.

In this paper, the process of obtaining technical information from a SME is referred to as "knowledge extraction." For each curriculum project, the instructional developer must conduct the knowledge extraction process with at least one SME. Considering the increasing volume of technical curriculum needed, the cost of its development, and the critical role of SMEs

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Mattoon is an independent Education and Training Consultant. He can be reached at joe.mattoon@gmail.com. This material is based upon work supported in part by the National Science Foundation under Grants No. 0302523 awarded to Maricopa Community Colleges.

in this endeavor, it is important to select SMEs who are technically qualified. Yet, is technical knowledge all that is important when choosing a SME to support curriculum development? This study argues that technical expertise is essential but not sufficient for providing the best support. The problem investigated here is the identification of a SME's personal and professional qualities that will provide the instructional developer the most efficient and effective support to the knowledge extraction process and subsequent revision and finalizing of the technical material.

Capability of Subject Matter Experts

SMEs need to possess certain capabilities to effectively communicate and help organize their technical knowledge in a format that is conducive to curriculum production. SME abilities are referred to as "capability factors." The capability represented by SMEs' breadth and depth of knowledge refers to their level of understanding of the topic area and its associated application and practice in the workplace. Breadth and depth of knowledge do not refer to the ability to explain the subject matter. Highly knowledgeable people often have difficulty articulating and explaining their technical knowledge to others who lack a technical background (Gayeski, Wood, & Ford, 1992; Gordon & Gill, 1997). For this reason, industry experience and articulation skills were proposed as important capability factors along with depth of knowledge and breadth of knowledge. When combined with industry experience, articulation skills enable a SME to clearly describe what needs to be taught and can verify and validate content based on actual experience. A fifth capability factor, teaching experience, is proposed on the assumption that a SME who understands instructional practice can suggest effective ways to present the material to learners.

Technical Expertise: The Industry SME

Because companies strive to implement the most advanced technologies and best practices in order to be competitive, currently employed technicians and engineers are often a good source of up-to-date technical knowledge.

Technicians, whose jobs focus on specific tasks and processes, tend to develop in-depth and detailed knowledge in a particular domain or "domain-specific knowledge." Alexander and Judy (1988) stressed the value of someone with domain-specific knowledge for providing expertise in solving problems and performing complex tasks. However, SMEs whose performance and job duties lie within a narrow scope can lack the breadth of knowledge which may be needed to provide students enrolled in college technology programs with both specific knowledge and a general understanding of a technology field. Breadth and scope are necessary for curriculum which is designed to impart both specific knowledge and a broad understanding of the field. Industry SMEs who hold management positions often have a wider breadth of knowledge than technicians and engineers, but acquiring their time to support curriculum development can be more difficult.

When searching for an industry SME, instructional developers should first consult with the SME's employer. Managers can identify technical personnel with specific knowledge sets, and they may be able to point out SMEs who are most qualified and available to help with curriculum development. It may, however, be difficult to get permission to work with the most knowledgeable experts because their time is highly valued by the company. Seeking a manager's approval and advice in locating potential SMEs demonstrates professional courtesy and promotes goodwill which can leverage assistance with future development projects. Developing a good relationship with a local company can pave the way to current and future sources of technical SMEs. In addition, other cooperative agreements such as collaborative training agreements, recruiting privileges, and joint workforce programs can garner curriculum-development support from industry.

Pedagogical Expertise: The Faculty SME

Industry and faculty SMEs may possess different types of expertise, both of which can be uniquely valuable to supporting the curriculum development process. While industry SMEs' knowledge tends to exhibit a highly focused perspective on the target domain and the specific skills necessary to perform a job, a

faculty instructor's knowledge has a broader focus. Faculty promote a macro perspective for students of technology with a balance of emphasis on depth and breadth of knowledge. This is necessary to enable students to make career choices and to build their potential for a range of occupations in the field. Faculty also possess skill in articulating complex ideas and applying pedagogical methods that help students learn. Good teachers can explain difficult concepts using analogies and concrete examples, and they are able to spot particular areas within technical topics where students may stumble and require additional guidance. Faculty can help an instructional developer shape the curriculum and learning activities so that domain-specific information is tied to the larger and broader body of knowledge and is linked to core disciplines such as math, physics, and chemistry. Yet faculty who do not have recent industry experience may not be able to supply as up-to-date and in-depth information as industry SMEs. This is especially true of an area such as electronics which can change significantly in a six-month time period.

When seeking a faculty SME, department chairs, deans, and peer teachers can help identify the best candidates. As in industry, professional courtesy will help develop good relationships that can be leveraged to support future projects. Seeking permission from administrators prior to asking for an instructor's support smoothes the collaboration.

Suitability of Subject Matter Experts

Besides possessing depth and breadth of technical knowledge and being able to articulate and communicate effectively, the SME should be readily available to support the curriculum development project, possess sufficient interpersonal skills to work effectively with others, have a positive attitude toward the project goals and development team, and be affordable relative to the project budget.

Availability

The SME must have sufficient time to devote to the curriculum development process. Even a small body of technical curriculum requires significant time to produce. The SME's availability is especially important in the first stage of

development since learning objectives and other critical instructional components are based directly on the SME's technical content knowledge. Additionally, the SME is usually needed to help revise the curriculum after it undergoes a tryout and evaluation period with students and instructors.

Availability can be a challenge because curriculum development is rarely part of a SME's normal job responsibilities. Short but intensive work sessions of two to three hours with substantial one-or-two-day breaks is often most convenient for an SME who holds a full-time job. Short sessions also reduce the mental and physical stress associated with knowledge extraction. In addition, the breaks provide time for the SME to reflect on the knowledge extraction sessions and may promote recall of important information and trigger ideas on how to structure the course content. The time can also be utilized by the instructional developer to prepare drafts for review by the SME in the next session. SMEs who cannot commit their availability to such a schedule represent a risk to the success of the curriculum project.

Time commitments should be specified in a legal contract or agreement before work on the curriculum begins. Formal contracts yield both legal and psychological value. They state time and task commitments in specific terms that reduce the potential for inaccurate expectations.

Interpersonal Skills

If the SME is unable to "get along" or communicate effectively with the instructional developer or project team members, it will be difficult or even impossible to generate an acceptable curriculum. To assess interpersonal skills, the prospective SME should be introduced to project team members and be closely observed for communication style, mannerisms, sense of humor, level of comfort, and professional courtesy. An SME with experience working in teams is more likely to have developed the interpersonal skills that promote effective teamwork and the ability to manage conflicts or disagreements with others. Such skills may be inferred from a SME's history of past teamwork experiences, or a discussion with the SME's supervisor or coworkers can also provide general information about his or her team performance and interpersonal skills. In

these discussions inquiries should be restricted to general topics. Questions of a highly personal nature should be avoided.

Attitude

A SME's attitude toward the educational product, the instructional developer, and the development team can have a strong effect on his or her performance. If a SME believes the end product will be of little value, he or she will expend less effort in developing a quality product. Conversely, a SME with a positive attitude toward the product is likely to have an elevated personal interest and a sense of pride in the project and pay meticulous attention to the accuracy and organization of the technical information. Attitude can be assessed, to some degree, by asking questions about the SME's perceived value of the target curriculum. Since most attitudes are based on deep-rooted beliefs that develop over a lifetime of experience and are not easily changed (Petty & Cacioppo, 1981), expecting a negative attitude to change during the curriculum development process is not realistic. Asking open-ended questions such as "How do you think the quality of curriculum determines how well technical people perform?" or "What kind of instruction do you think promotes the strongest technical knowledge?" can help assess the SME's attitude toward the product. More information about the SME's attitude can emerge during discussions with the SME about the project and its benefits to its intended users.

Cost

Although the availability of funds will vary greatly across organizations and specific curriculum projects, cost is always a consideration. Cost is accrued almost exclusively from labor hours on curriculum development projects. While some SMEs require significant compensation for their time, others may volunteer their services or be compensated by funds acquired outside of the project budget. Considering the capability and suitability factors already discussed, a SME should not be chosen based on cost alone. If a SME's knowledge and ability is inadequate, knowledge extraction and development of technical content will take longer and cost more, even if the SME agrees to work at a low compensation rate.

When direct compensation for SME support is required, two basic types of contracts can be considered: fixed-fee and hourly rate. Fixed-fee contracts pay a specified amount to the SME for clearly defined "deliverables." The volume of material and consulting time is not always spelled out or even implied in a fixed-fee contract, so this compensation method can be risky to both parties unless very explicit definitions of the deliverables (e.g., specified volume of content on a well-defined topic) are possible. Even when a deliverable is specified, the time required and the quality of the end product are hard to regulate. Fixed-fee contracts work best for projects in which time, resources, and degree of effort can be accurately estimated.

A contract that compensates by an hourly pay rate is often preferable for greater flexibility in adjusting duration of SME support and because a fixed fee is not always acceptable to the SME. On the downside, paying by the hour may reduce the SME's motivation to work efficiently on the project. Also, staying within the limitations of the project budget is more difficult if a maximum number of hours is not specified in advance.

Recruiting recent industry retirees or graduate students may reduce the cost of SME support. These SMEs can contribute two different types of knowledge. Industry retirees are likely to have robust knowledge relevant to the workplace including business culture and industry practices and may be willing to volunteer their time. Graduate students may lack knowledge of industry practices but may possess more up-to-date technical knowledge than the retiree. A graduate student SME may also be more willing to work at lower pay rates than a SME who is employed full-time.

Industry SME support can also sometimes be acquired without direct compensation. Large companies have workforce development funds to support education and training. Some SMEs can acquire release time from their normal job duties via compensation from these funds. In such cases, SME support is obtainable at no cost to the developer or through a cost-sharing agreement. Such a cost reduction is possible particularly if a SME's employer views the curriculum as valuable to their workforce needs.

Instructional Developers' Survey and Results

The capability and suitability factors proposed here were initially based on instructional design theory and the author's experience with SMEs. Additional validity was established by an on-line survey of instructional developers. Seventeen instructional developers who had experience working with SMEs were recruited to respond to the survey. The population of respondents represented instructional development efforts within academe, the military, and industry.

Instructional Developers' Survey Design

An HTML–based survey was created to collect responses via the Internet. HTML, or Hypertext Markup Language, enabled the survey to be posted on the World Wide Web in an interactive format. The curriculum developers' responses were automatically recorded in a database and later downloaded for analyses. Online directions explained the purpose of the survey and how to respond to each of its three parts—(1) demographics, (2) SME capability and suitability factor ratings, and (3) free-responses. The demographic questions inquired about the respondent's type of employment organization, occupation, and years of experience. Choices provided for employment organization were college or university, military, manufacturing, and other. Choices for occupation were curriculum developer, training developer, and other. A numerical field was provided for respondents to enter their years of experience. In the second section, respondents ranked their rating for each SME capability and suitability factor on a five-choice scale, ranging from 0 to 4, in which 0 indicated no importance and 4 indicated high importance. The third, free-response, section was provided for respondents to enter other factors that they felt were important characteristics of a SME but which were not included in the factor rating area of the survey.

Method and Results

Curriculum development experience of the respondents ranged from one to 33 years (M = 14.8, Mdn = 13.0). Participants' employment organizations were identified as follows: nine, college or university; four, military; two, manufacturing; and two, other. Although the purpose of the survey was to examine respondents'

ratings of the SME capability and suitability factors, statistical tests were first conducted to determine if any differences existed as a function of the respondents' demographics. This was accomplished via Statistical Package for the Social Sciences (SPSS) Exact Tests because the respondents were not randomly sampled, and the data could not be assumed to be normally distributed (Mehta & Patel, 1996). All tests employed a standard significance level ($p < .05$). Fisher's Exact Test revealed no significant effects for employment organization or occupation, nor was there a significant correlation between years of experience and ratings of importance on each of the nine SME factors. There was also no significant correlation among factors.

Rating results on factors are shown in Table 1. Results are described in terms of each factor because "capability" and "suitability" were used for organizing the discussion rather than identifying distinct categories. Differences in factors are described by the proportion of ratings that exceeded the midpoint of the survey scale which was labeled as "medium importance" and designated by the number "2" on the 0 to 4 rating scale. The three factors rated highest were depth of knowledge, availability, and attitude. A large proportion of ratings for each of these three factors were above the midpoint of the survey scale (94% > 2), and the mean rating was 3.5 for each of these factors. There seems to be little doubt among respondents that these factors are important in determining how well a SME will support curriculum development. Three other factors received high ratings: breadth of knowledge (88% > 2, $M = 3.5$), articulation skills (82% > 2, $M = 3.4$), and interpersonal skills (77% > 2, $M = 3.2$). Two factors received relatively lower ratings: industry experience (65% > 2, $M = 2.8$) and cost (53% > 2, $M = 2.5$). Teaching experience received the lowest rating (12% > 2, $M = 1.7$).

The free-response section of the survey requested respondents to "enter any factors that you feel are important but were not part of this survey" and to describe each new factor entered. Seven factors were entered in this area of the survey and are reported in Table 2. One response was a duplicate of the

Table 1
Ratings on Capability and Suitability Factors

Factor	* % > 2	*M*	*SD*
Capability: Industry Experience	65	2.8	0.66
Capability: Teaching Experience	12	1.7	0.86
Capability: Breadth of Knowledge	88	3.5	0.72
Capability: Depth of Knowledge	94	3.5	0.62
Capability: Articulation Skills	82	3.4	0.79
Suitability: Availability	94	3.5	0.62
Suitability: Interpersonal Skills	77	3.2	0.81
Suitability: Attitude	94	3.5	0.62
Suitability: Cost	53	2.5	1.10

* Proportion of ratings higher than midpoint ("medium importance") of the survey scale.

capability factor of availability, and the other six were quite similar in meaning to one or more of the factors provided previously in the survey.

Design of SME Scoring Instrument

Considering the high ratings on most of the SME capability and suitability factors, it can be assumed that most of these characteristics are perceived to be important by instructional developers who have worked with SMEs. To identify and evaluate the strength of these factors in prospective SMEs, a SME scoring instrument was developed to help instructional developers select the most capable and suitable SMEs. The SME scoring instrument facilitates systematic aggregation of scores across factors. The additional guidance provided by SME scoring should reduce the risk and guesswork associated with choosing the best SMEs to support curriculum development.

Table 2
Additional SME Factors Identified by Instructional Developer Respondents

New Factor	Description of New Factor	Similarity to Survey Factor
Editor & Reviewer	Ability to accurately review materials produced by other team members	Articulation Skills
Follow Through	Timely responses to requests	Availability
Adult Learning	Appreciation of adult learning methodologies and practices	Teaching Experience
Availability	Can provide training or be available upon request	Availability
Time	Full-time personnel seem to work better than part-time	Availability
Currency	Need folks that are up to date in the area in which they are SMEs	Depth of Knowledge
Dedication	Need folks that are dedicated and willing to go above and beyond	Attitude

Three factors proposed earlier in this paper were eliminated from the SME scoring instrument due to their relatively low ratings on the survey. These included teaching experience, industry experience, and cost. The experience factors may also be limited in their utility, because technical knowledge and the capability to communicate technical information do not always have a direct correspondence to years of experience. Likewise, considerations of cost may not be stable indicators of SME merit since they are likely to vary significantly across projects and organizations that support curriculum and training development.

To produce a profile for the evaluation of a potential SME, the SME scoring instrument was modeled after the "criteria of

merit checklist" (COMlist) proposed by Scriven (2000). To apply the COMlist, a SME's merit must first be estimated using scores on three capability factors: breadth of knowledge, depth of knowledge, and articulation skills and three suitability factors: availability, interpersonal skills, and attitude. Merit scores range from one to 10 on each factor (10 = highest rating.) Potential SMEs can be assigned merit scores based on the instructional developer's observations during an interview or during discussions of the curriculum development project or using additional sources of information. For example, scoring could be completed by more than one SME evaluator, or a supervisor (industry SME) or dean (faculty SME) may agree to score the factors for one or more SME candidates.

To create a ranked profile for each SME candidate, the COMlist can be implemented with a spreadsheet that computes a product score for each factor. This score is the product of the SME's merit score and the factor's weight, assigned according to the instructional developer's survey results reported above. For example, in the survey, 94% of the respondents rated the suitability factor "availability" above the midpoint of the importance scale, so the factor weight was set at 0.94. By assigning weights to each factor, the resulting product score incorporates the degree of the factor's importance as determined by the perceptions of the survey respondents. Finally, when an overall percentage score is determined, factors with larger weights will influence the overall score to a greater degree than those with smaller weights.

If more than one person is rated on the COMlist, individual factor scores and individual overall scores can either be aggregated or examined separately. The spreadsheet also generates a SME profile in the form of a column graph. The profile visually emphasizes strengths and weaknesses according to COMlist scores.

SME COMlist Implementation

Figures 1 and 2 show an example of a completed COMlist and the resulting SME profile, respectively. To provide data for this example, the author evaluated a SME who was currently working on a curriculum development project that required

extensive knowledge of electronics (Mattoon & Frenzel, 2004). A weight for each factor was assigned according to the instructional developers' survey results. Then the weighted score for each criterion was computed as a product of the score (1 to 10) entered by the SME evaluator and the factor's assigned weight.

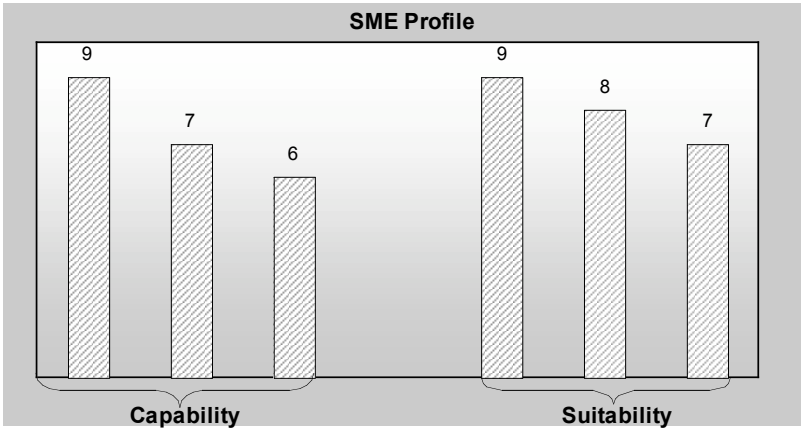
Figure 1
COMlist Factor Product Scores and Overall Score for a Sample SME

Criteria	Score	Weight	Product
Capability			
Breadth of Knowledge	9	0.88	7.92
Depth of Knowledge	7	0.94	6.58
Articulation skills	6	0.82	4.92
Suitability			
Availability	9	0.94	8.46
Interpersonal Skills	8	0.77	6.16
Attitude	7	0.94	6.58
		Overall Score =	**80%**

Besides utilizing the capability and suitability factors identified in this study, the SME COMlist functions in some other useful ways. Like most checklists, the COMlist functions as a mnemonic device to prevent an evaluator from forgetting important characteristics to consider when selecting a SME. Factors in the COMlist help stimulate the generation of useful questions when interviewing a SME. By providing a multiple set of criteria by which to judge a SME's merit, the COMlist reduces the risk of a "halo effect," the tendency to choose a SME who shows great promise in one or two areas but lacks other essential qualities. The COMlist is designed in a flexible format that can easily by altered by users. For example, the spreadsheet provides

for easy entry and deletion of factors and weights as additional data is collected (e.g., a larger instructional developers' survey). Finally, the COMlist could facilitate more research on SME merit factors by providing a vehicle for comparing SME scores to observations and measurements of actual performance on a curriculum development project.

Figure 2
Sample SME Profile Generated from COMlist Rating Data



Precautions for Implementing the SME COMlist

The SME merit factors and example weights illustrated in Figures 1 and 2 reflect data collected from the opinions of a small number of instructional developers. Consequently, the COMlist, in its present form, does not represent a statistically validated method and may not represent the larger population of instructional developers or the needs of all technical curriculum development projects. A more robust survey and additional study of the correspondence between SME scores and actual performance are needed to be sure of the instrument's accuracy

and reliability. Additional research may prompt adjustment of the COMlist in several ways concerning inclusion of factors and assignment of weights to factors.

Summary and Conclusions

Subject matter experts play an essential role in technical curriculum development by providing accurate and up-to-date information that matches education, training, and workforce needs. The SME COMlist is proposed as a tool that enables instructional developers to evaluate a SME's capability and suitability to support curriculum development. The COMlist provides a spreadsheet-based, single-entry scoring system that automatically calculates individual scores on six factors, provides an overall SME score, and generates a profile that illustrates a SME's strengths and weaknesses. The value of the SME COMlist is based on its simplicity of design, ease of use, and usefulness in selecting SMEs who can competently support curriculum development. Choosing the most capable and suitable SMEs holds potential for significant gain in efficiency and effectiveness of curriculum development, which in turn, can improve the quality of technical education and training.

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