Industry and Higher Education - Meeting the Needs of the Mining Engineering Sector

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Abstract

An industry survey has been conducted by the Queen's University Mining Engineering Department of 30 Canadian mining organizations to determine how effectively newly graduated mining engineers meet the needs of the industry. The principal objectives of the survey were to evaluate, and thus provide focus on change for, curricula being taught at Canadian mining engineering schools in service of the industry's needs; to provide feedback on current industry expectations; and to reinforce contacts with the industry as a means of providing future collaboration. A strong focus of the survey was placed upon industry's perception of the special attributes of engineering hires and applicability of student academic training to meet their industrial requirements. In providing this detailed summary of corporate responses, a clearer understanding of the mining industry's expectations of engineering training at Canadian colleges and universities has been gained.

Introduction

A recent Canadian mining industry survey, modeled upon an effort originally conducted by the Mackay School of Mines, was undertaken during the fall of 2001 and first half of 2002. The original survey was commissioned in the United States by the Mackay School of Mines, and was conducted in 2000 by C. J. Robson of Kennecott Utah Copper Corporation to assess how effectively newly-graduated mining engineers meet the perceived needs of mining industry operators (Mackay School of Mines, 2000). The Mackay survey comprised 23 questions, which were designed to assess industry sector demographics as well as the engineering educational needs of this industry sector. In this U. S. survey, a total of 35 responses were received from mining corporations which were active primarily in open pit or strip mine operations (67%), with the remainder sourcing from underground operations. Approximately 57% of responses derived from U.S.-based operations, with the remainder being received from foreign (i.e.- non-North American) sources. No responses were submitted to nor received from Canadian mining organizations. 50% of respondent mines were noted to be active in precious metals production; 31% in coal production; 17% in industrial mineral production; and 11% in base metals production. Specific demographic information concerning employment needs of these mines, including the type of

engineering hire sought (by discipline), country of origin, inventory requirement for hiring and initiating salary levels, was also accumulated through this survey process.

The principal area of focus of this survey was, however, upon the perceived levels of educational training that are acquired by young mining engineers and performance requirements of mining companies for these engineers. Corporate respondents were requested to rate a total of 58 academic subjects, separated into 8 general curriculum categories. Each of the eight categories, varying from general engineering to specific computer application skills, were asked to be rated in terms of importance and quality ranking factors which ranged from (not important) through (extremely important) to (low quality) through (high quality), respectively. In each category, a variety of typical subjects were included. The mining engineering curriculum category, for example, included traditional discipline-specific subjects such as open pit mining methods, mine surveying, mining law and mining health, safety and industrial hygiene.

Based upon responses received, an efficiency rating for each subject was assessed to provide a measure of the effectiveness of university training to meet an individual company's perceived needs in each area. Efficiency ratings were determined as:

$$\text{Efficiency of Subject Training} = \{\text{Quality Ranking}\} / \{\text{Importance Ranking}\}$$

It was inferred that subject over-training exists if the subject quality ranking exceeds its industry importance ranking, thus yielding an efficiency rating of 1.0 or greater. Where the efficiency rating for a subject is determined to be less than 1.0, mining engineering graduates are perceived to be deficient in their training relative to the mining industry's perceived needs in that area. Therefore, for subjects in which efficiency ratings are > 1.0, too much training is being received by mining engineering graduates relative to proficiency level expectations of the industry sector. Conversely, where efficiency ratings are assessed at < 1.0, too little training is being received by mining graduates. The efficiency ratings for subjects in each category were also combined and utilized to assess average group ratings, thereby establishing a ranked order of importance of curriculum categories deemed necessary by the mining industry to be taught to its member engineers. The sum of information acquired from the Mackay School of Mines survey has been previously published (Mackay School of Mines, 2000). The results, based largely upon responses from U.S.-based and affiliated multi-national corporate respondents, provide insight into the U. S. industry's focussed view of the educational requirements of mining engineering graduates seeking employment within the mining industry sector which was interviewed (i.e.- largely open pit-based).

Queen's Survey (2002)

In order to provide information pertinent to the needs of the Canadian mining industry and teaching effectiveness of Canadian universities, a second industry survey was conducted by Queen's University in the Fall, 2001. This survey, identical in form to the previous U.S. survey, was submitted to a total of 150 Canadian mining companies with the kind permission of the

Mackay School of Mines. It was designed to review the general needs of the industrial mining sector and specifically to determine how effectively newly graduated Canadian mining engineers meet the current needs of the Canadian mining industry. This information could be used by Queen's University, and therefore any of the eight associate university institutions in Canada which provide mining engineering educational training, for several purposes, these being:

•to evaluate and possibly modify its engineering curriculum to better serve industry's perceived needs

•to provide feedback to the University's graduating mining engineers as to current industry expectations, and

•to reinforce industry links for promoting future academic collaboration.

The survey, completed by August, 2002, received a total of 30 responses solely from Canadian mining corporations. No input from other North American of foreign-affiliated source operations was included. Although yielding only a 20% return rate, the responses provided information from a broad variety of mining operations with respect to type, size and geographic distribution. In several cases, responses represented summarized information from multiple mining operations existing within singular corporate organizations. In various areas of the survey response, therefore, replies from up to 35 separate Canadian mine operations were received. A detailed summary of the results of this Canadian survey, including a full listing of survey questions, has been compiled in the B.Sc. thesis document of one of the co-authors (Heuchan, 2002) and will not be reproduced in this publication summary. This information is, however, available for public review upon request (Department of Mining Engineering, 2002).

Canadian Industry Demographic Summary

Of the total of thirty corporate responses received in this survey, all but one classified its operation as being of the "mining - traditional metal and non-metal" type. The exception to this reply was from a single operation which classified itself under the category "project management/development". Of this total, sixteen responding companies operated underground mines, thirteen operated open pit mines, and one operated a strip mine, this being exclusively for tar sands extraction. No responses were received from quarrying or highway/dam/tunneling operations. The range of mine operations and mineral types associated with each are illustrated in Figure 1. The data which is included in this figure indicates that 36% of the responding Canadian mines produced precious metals, 16% produced base metals, 28% produced coal, 28% produced other industrial minerals, and 12% produced uranium or other mineral commodities.

Of the reporting population of thirty-five mines, 5.7% reported being located within urban environmental, 51.4% within isolated/rural environmental and 42.9% within remote environmental settings within Canada. Engineering employment turnover data was also provided coincident with this demographic information. The great majority of companies, approximating 60%, reported operational turnover as being low, with 34% reporting medium turnover, and only 5.7% (those sites being located primarily in remote mining locations) experienced high mining engineer turnover rates. Mine location and turnover rate information is presented in Figure 2.

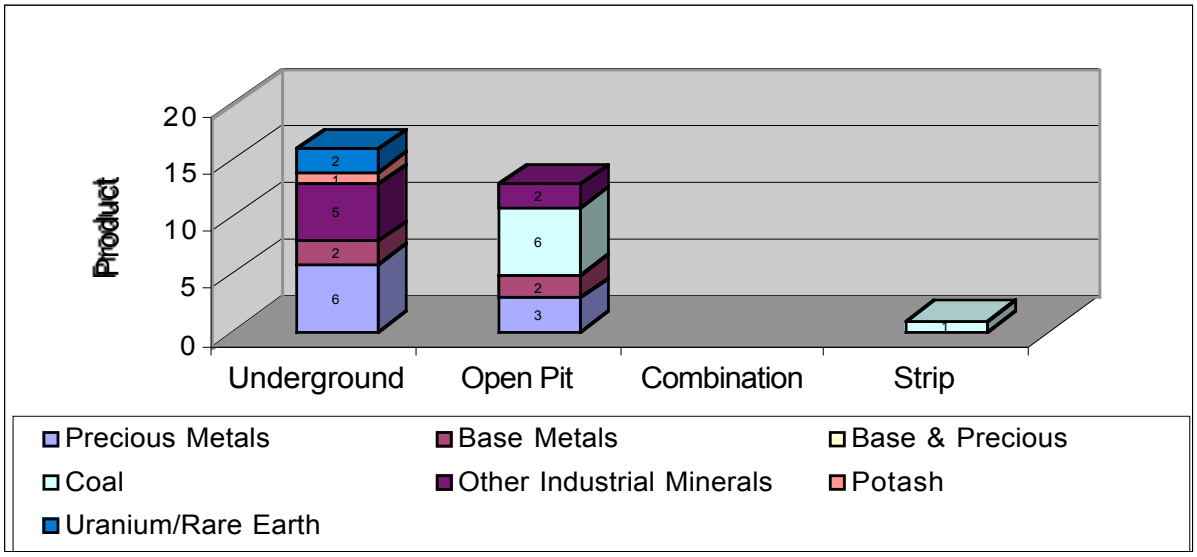

Figure 1 - Mine Operation Type versus Mineral Commodities Produced

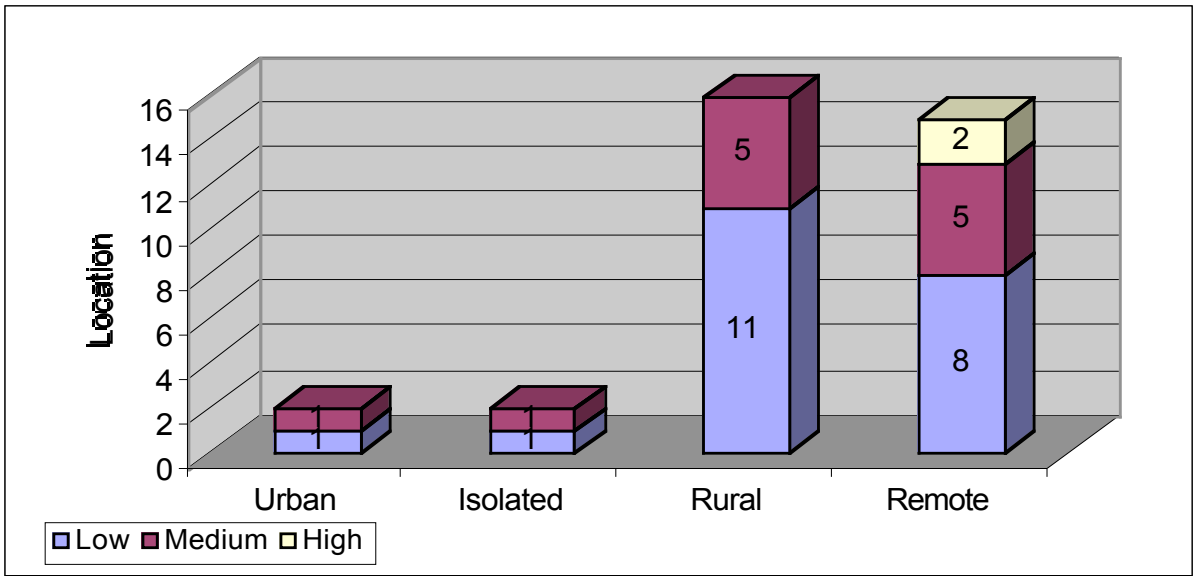

Figure 2 - Mine Location versus Mining Engineer Turnover Summary

Specific information was also solicited concerning the hiring status of newly- and previously-graduated mining engineering staff who had been employed at each of these mine sites during the past five year interval. Of the total of one hundred and sixty-four mining graduates who had been hired by the responding mining companies during this interval, one hundred and fifty-two (92.7%) held a Bachelor of Science degree at the time of hire. Only nine (5.5%), possessing M.Sc., and three (1.8%), possessing Ph.D., degrees in Mining Engineering were shown to have been hired at the mine operational level during this same time interval. Upon gaining

employment, mining engineering graduates were found to be almost uniformly distributed in employment between traditional open pit and underground mine operations (Figure 3). Further assessment of employment information also revealed that a majority of recently-hired mining engineering staff (97.6%) were employed directly in technical or operational areas of mine activity, with the remaining 2.4% being employed in maintenance or environmental work roles (Figure 4).

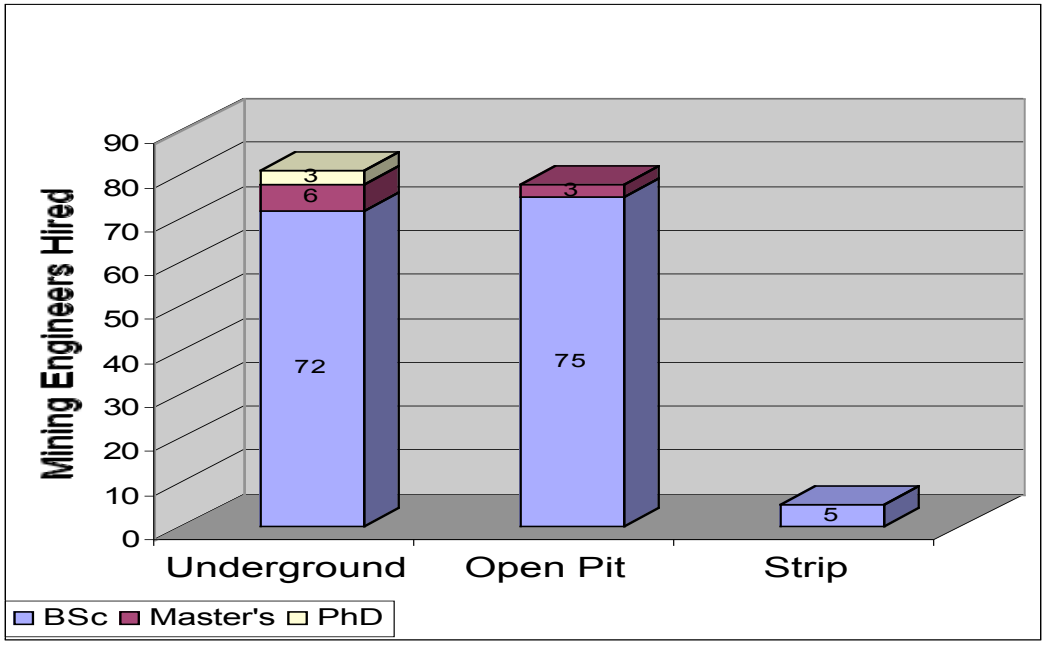

Figure 3 - Mining Engineer Employment versus Mine Operation Type

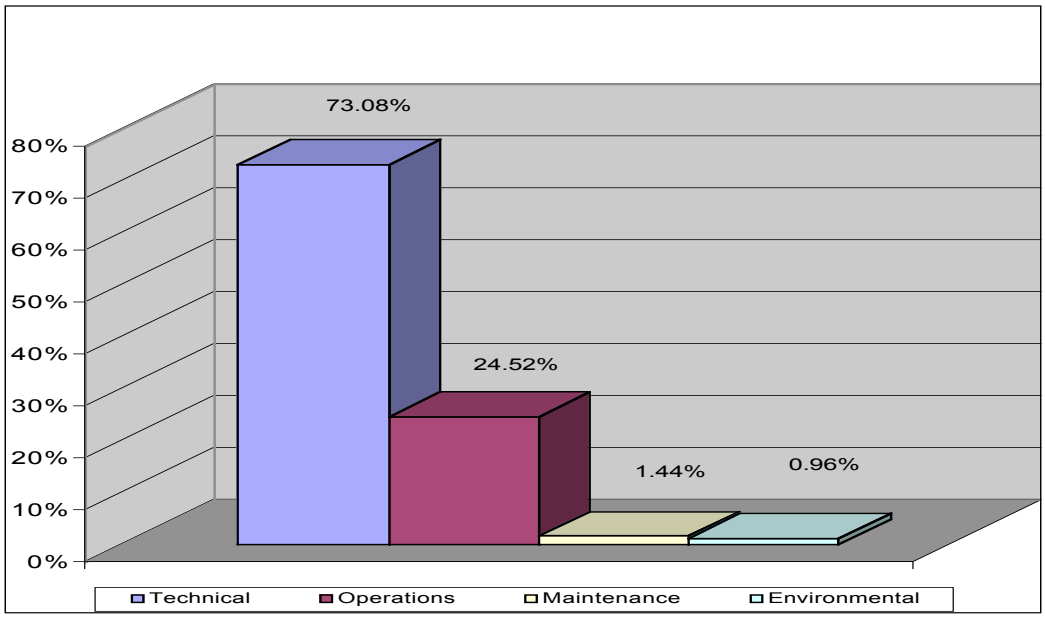

Figure 4 - Mining Engineer Operational Employment Roles

It is interesting to note from respondent submissions that a very close range of starting salaries exists across all levels of mining engineering education. Based upon data obtained from this survey, industry salary levels averaging $45,949, $49,150 and $50,800 were obtained through direct employment within the mining sector by recent Canadian mining engineering graduates at the B.Sc., M.Sc. and Ph.D. levels, respectively.

Other demographic information compiled in this survey included assessment of mining engineer employment with respect to mineral production commodity mined (i.e.- data concerning employment by product sector) as well as specific mining engineer employment levels per product site. This data, not fully included in this paper, combines employment information for both newly graduated and older, previously hired mining engineering staff. The largest concentration of employment for mining engineers in Canada appears to be focused within the base and precious metals sector of the industry. This accounts for the employment of approximately 74% of all new mining engineering graduates. Additionally, those mining operations which concentrate production largely upon base metals, precious metals or some combination of both provide employment for a larger number of mining engineers per site (averaging 18.7 per site) than all other mineral-type operations. At the opposite end of the mining engineer employment scale, industrial mineral operations are shown to employ the fewest graduates per mine site (averaging 2.7 per mine site).

It was also indicated by mine respondents that a number of engineers from other disciplines, these being primarily metallurgical, mechanical and electrical engineers, are typically hired to provide specialized services for mining operations. Nonetheless, all surveyed companies expressed a very strong preference for the hiring of graduates who possess traditional mining engineering training. This was inferred to mean that mines prefer to hire engineers holding traditional mining engineering degrees to perform mining engineering-type work and that, given a choice, mines do not generally prefer to hire other engineering discipline staff to perform mining engineering work at mine sites. Based upon survey responses received, 68.6% of mines indicated that employment of traditional mining engineering graduates is much preferred and of strong interest in their hiring decision. The remaining 31.4% of respondents reflected that a mining engineering degree is a significant and necessary feature of employment of engineers at operating mine sites.

Canadian Industry Consensus on the Adequacy of Engineering Training

The primary focus of the 2002 Canadian mine survey was upon assessing industry's valuation of the adequacy of university curriculum and mining engineering training for meeting its operational needs. This survey focussed directly upon mining engineering training which had been received by graduating engineers during the most recent five-year period. Fifty-eight curriculum subjects, covering eight general categories, were rated by industry reviewers and accorded efficiency ratings, as discussed previously in the introductory section of this paper. The eight general categories that were evaluated, and examples of courses included in each, consisted of:

•mining engineering curriculum (i.e.- underground mining methods)
•general technical skills (i.e.- differential equations)
•general computing applications (i.e.- spreadsheets)
•general engineering skills (i.e.- chemistry)
•mineral science skills (i.e.- structural geology)
•communication skills (i.e.- presentations)
•specialized computing applications (i.e.- Computer-Assisted Drawing (CAD))
•non-core curriculum (i.e.- social sciences)

As indicated in the efficiency factor assessment section, any curriculum subject receiving an efficiency rating of 1.0 or greater is derived from industry's perception that mining engineering graduates are "over trained" in these subject areas relative to their job needs. Efficiency ratings lower than 1.0 indicate that training deficiencies in engineering skills relative to industry's perceived needs exist. It should be noted, however, that high importance ratings (strong perception of industry training need) will automatically lower a subject's efficiency rating, even where high quality training has been received by engineering graduates.

For thirty Canadian corporate responses received, a summary of average importance, quality and factored efficiency ratings for a total of fifty-eight curriculum subjects has been compiled, and is illustrated in Figures 5 through 7.

In terms of curriculum importance, operators ranked the teaching of spreadsheets, verbal communications skills and Computer-Assisted Drawing (CAD) as being high (each having average importance ratings = 3.72; rank = 1). Of least impotence to operator needs were curriculum concentrations relating to the teaching of social sciences, history (mining or other subjects) and political science. The range of importance ratings for these least important subjects varied between 1.22 and 1.31.

When evaluating the quality of education thought to be received by graduating Canadian mining engineers, industry's assessment rankings rated highest achievement in the subjects of spreadsheets, word processing and Computer-Assisted Drawing (CAD). These subjects, concentrating upon curriculum categories of communications and specialized computing skills, received quality rating values ranging between 3.39 and 2.97. The lowest perceived curriculum subjects in terms of quality were found, as with importance rankings, to also relate to subjects pertaining to political/social sciences and history, with quality ratings averaging between 1.22 and 1.25 for these subjects. Based upon operator responses for the rating of individual curriculum subjects, it is apparent that the social sciences are considered to be least important to the operational needs of the industry. It was also judged that the poorest quality of knowledge and educational training is received by students in these same courses. Alternately, subjects which concentrate upon data communications and interpersonal communication skills are considered to be most in demand by mine operators and to be subjects which are generally well taught to mining engineering students at Canadian universities.

In terms of the efficiency ranking of subjects, a compilation of rating values (Figure 7) indicates that a wide range of subject assessments exists. Subject efficiency ratings were seen to range from as low as 0.60, for computer maintenance/planning curriculum, to as high as 1.14, for the subject of differential equations. For only three subjects (basic chemical engineering, advanced mathematics and differential equations) were efficiency ratings in excess of 1.0 determined to exist. This would indicate that, for these three subjects only, mining engineering graduates are perceived to be overly well trained. Additionally, eight other subjects, of a group of fourteen which were included in the categories of general technical and engineering skills, also received efficiency ratings slightly less than 1.0, indicating that the Canadian mining industry is well satisfied with basic engineering training which has been received by its graduating mining engineers in these subject areas. This infers that significant basic science and engineering training accomplishment is being offered by Canadian universities to its mining engineering graduates.

Of twelve subjects which were determined to have the lowest educational efficiency ratings (that is, lying well below a rating value of 1.0, and indicating a need for enhanced university training in these subjects), six are centered within subject categories of communication skills and specialized computer applications. The low efficiency rating values for these subjects indicate that, though they are considered by industry to be of significant importance to operational activity, mining engineering graduates are receiving less than adequate training in these subjects.

Additional assessment, by grouped subject category, was also performed. Specific information for each category was used to indicate which subjects within each area held predominant ranking importance for mining operators. Of the eight evaluated curriculum categories, respondents placed the highest importance rating for curriculum on the teaching of Specialized Computer Applications (average category importance rating = 3.199). Figure 8, for example, illustrates industry perception of the necessity for teaching specialized computer application skills within this category area. Similar factored ranking distributions were compiled for seven additional curriculum categories.

Based upon importance and quality assessments made for the range of subjects existing within each category, average efficiency ratings were determined for these categories. Table 1 presents averaged efficiency ratings for the sum of subjects considered in each of eight curriculum categories. The lowest category efficiency rating was assessed for Specialized Computer Applications. This indicates that industry respondents believe that the general educational quality of newly graduated engineers in this specific curriculum area is poor in comparison with the perceived importance of the subjects which comprise this curriculum category. On average, all subjects which were reviewed within this singular category, with one exception, received relatively high importance rankings overall, lying well within the upper half of importance rankings for all curriculum subjects reviewed. Unfortunately, quality assessment of three traditional and mining-specific category subjects (surveying, geotechnical studies and mine ventilation) realized low values, thus yielding very low efficiency ranking for this category overall.

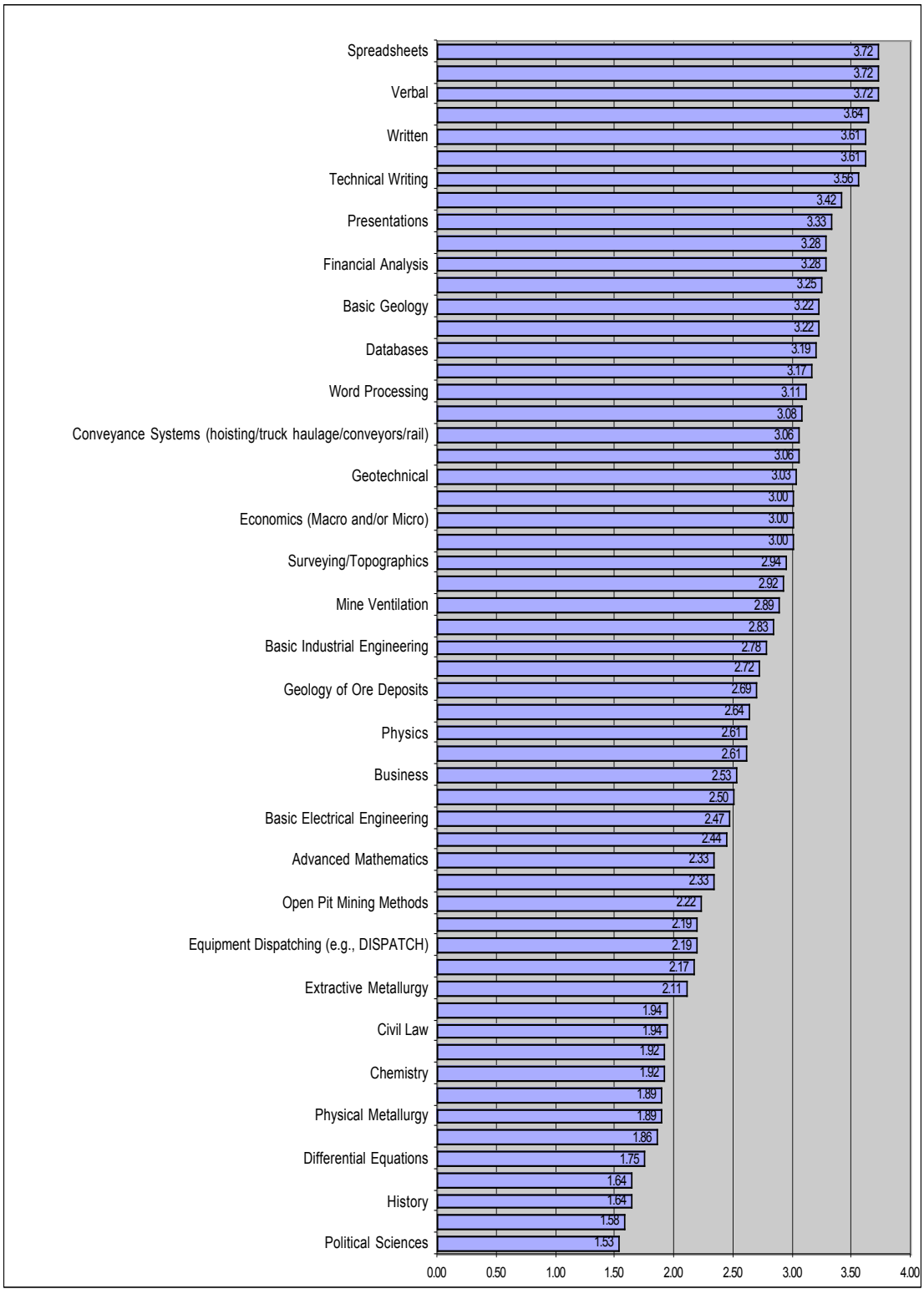

Figure 5 - Curriculum Summary Ordered by Rated Importance

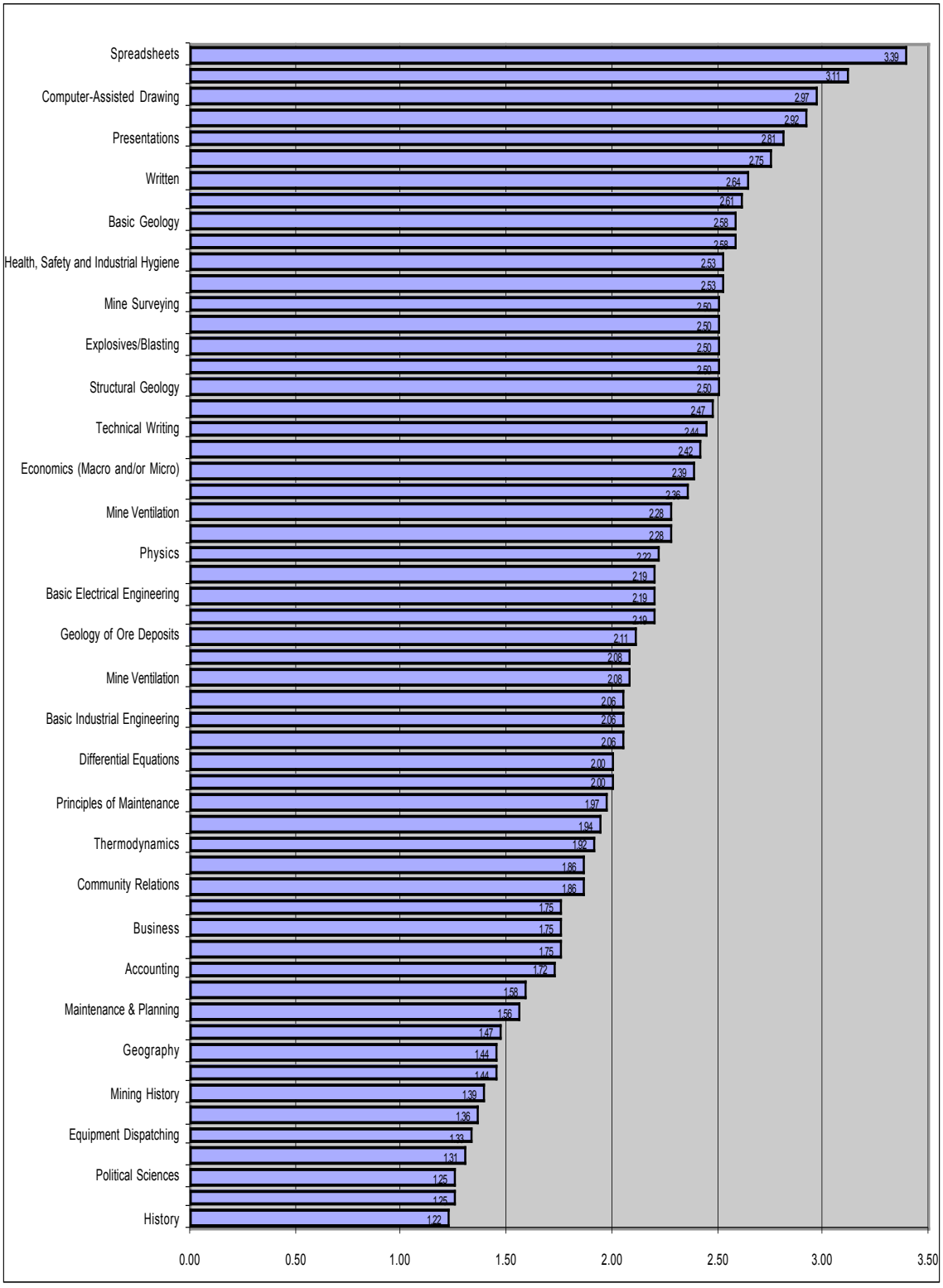

Figure 6 - Curriculum Summary Ordered by Rated Quality

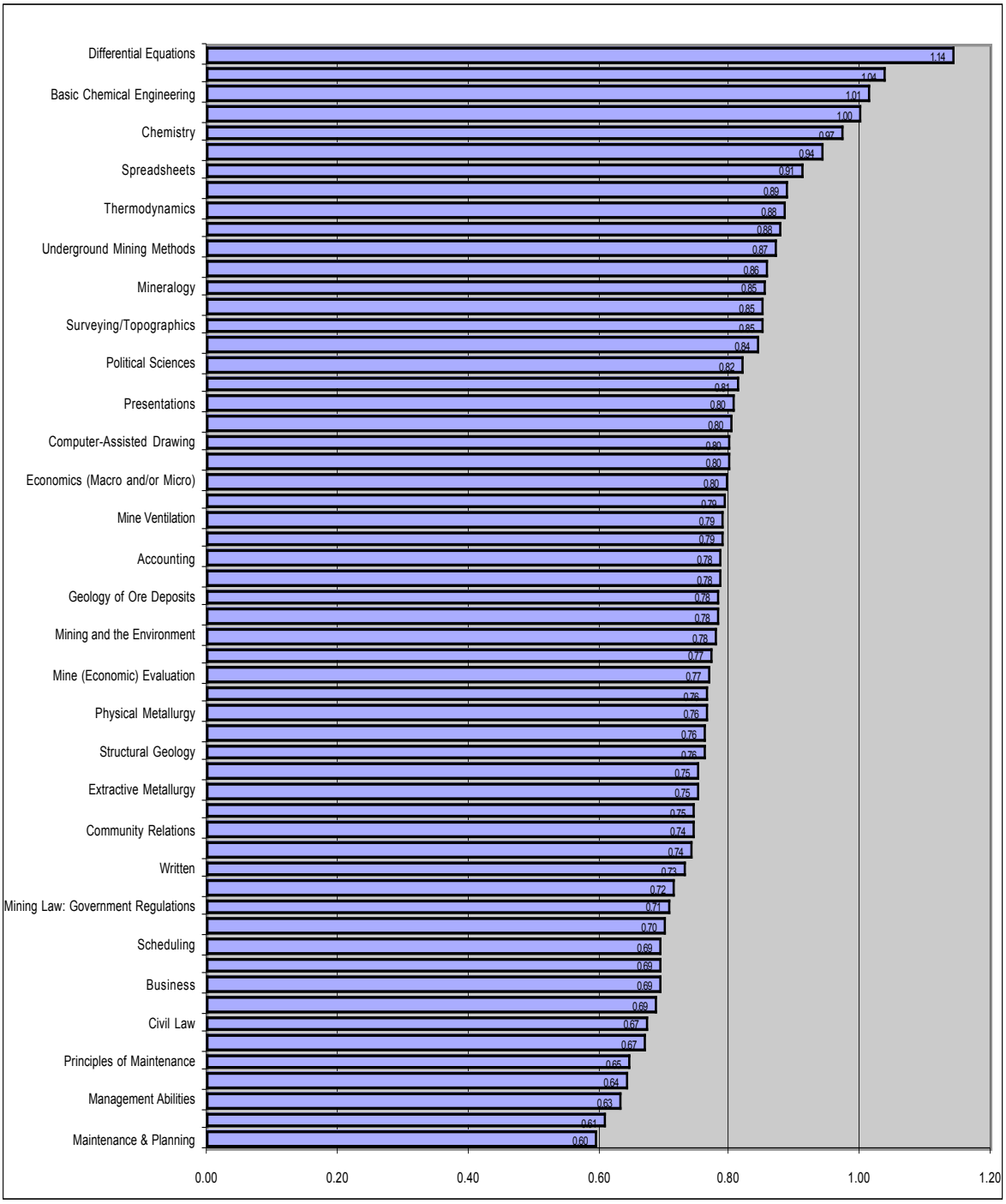

Figure 7 - Curriculum Efficiency Ratings by Ordered Importance

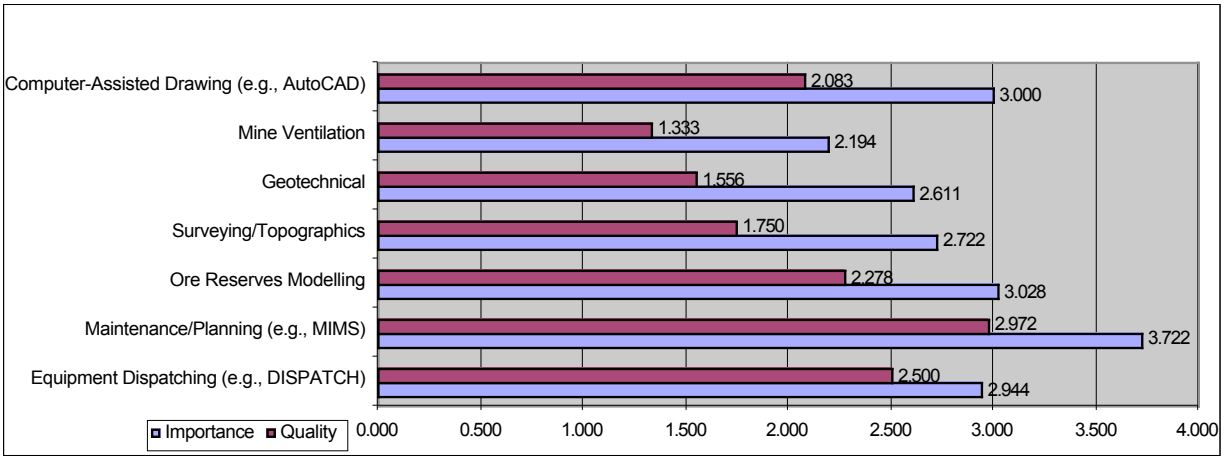

Figure 8 - Specialized Computer Applications Subject Average Ratings for Importance and Quality

Curriculum Category	Average Efficiency Rating (all subjects)
General Engineering Skills	0.867
General Computing Applications	0.836
General Technical Skills	0.814
Mining Engineering Curriculum	0.801
Non-Core Curriculum	0.776
Mining Science Skills	0.771
Communication Skills	0.720
Specialized Computer Applications	0.706

Table 1 - Average Efficiency Ratings by Curriculum Category

Conversely, within the category of non-core curriculum, for which averaged data is shown in Figure 9, both low importance and quality ratings were consistently expressed for all category subjects by industry respondents. The result of this category review was that generally low, though uniform, efficiency rating performance was attributed for all category subjects (ranging from 0.82 to 0.75). The low efficiency performance obtained for non-core subjects, when coupled with noticeably low industry importance ranking appreciation, indicates both that graduates are deficient in non-core skills in these specific subjects and that less effort in training engineers in these subjects should also be expended by universities, in the opinion of industry.

Desired Attributes of Graduating Canadian Mining Engineers

As part of this industry survey, Canadian mining companies were requested to rate the most valuable or desirable character attributes of newly-graduated mining engineers who would be sought for hire by these same companies. A listing of twenty-nine character attributes were provided for review. Responses received from a total of thirty-six operations are illustrated in

the data of Figure 10. The ranking of character attributes was done on a scale ranging from (4 - Extremely Important) to (1 - Not Important), with all responses for each attribute being summed and averaged.

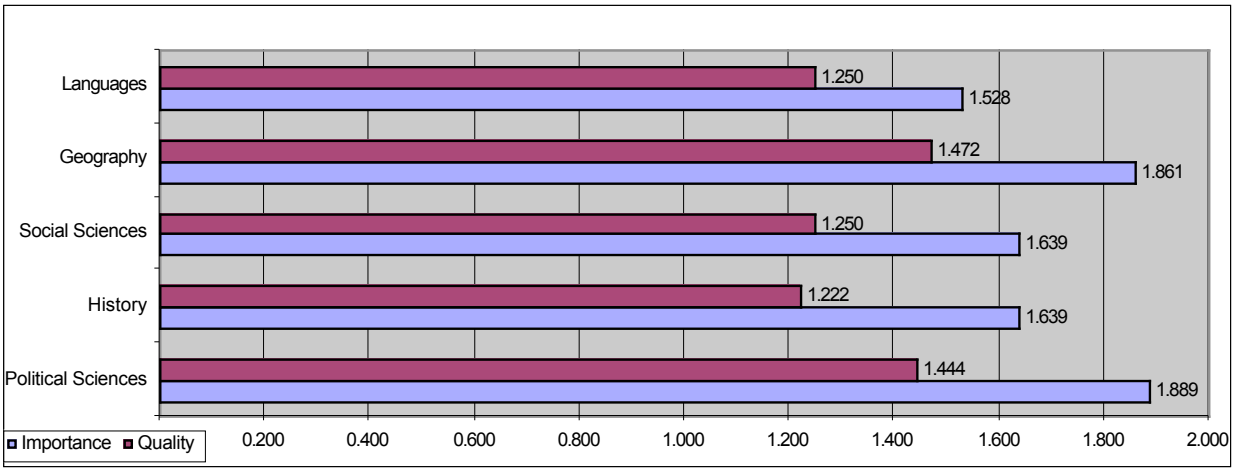

Figure 9 - Non-Core Curriculum Subject Average Ratings for Importance and Quality

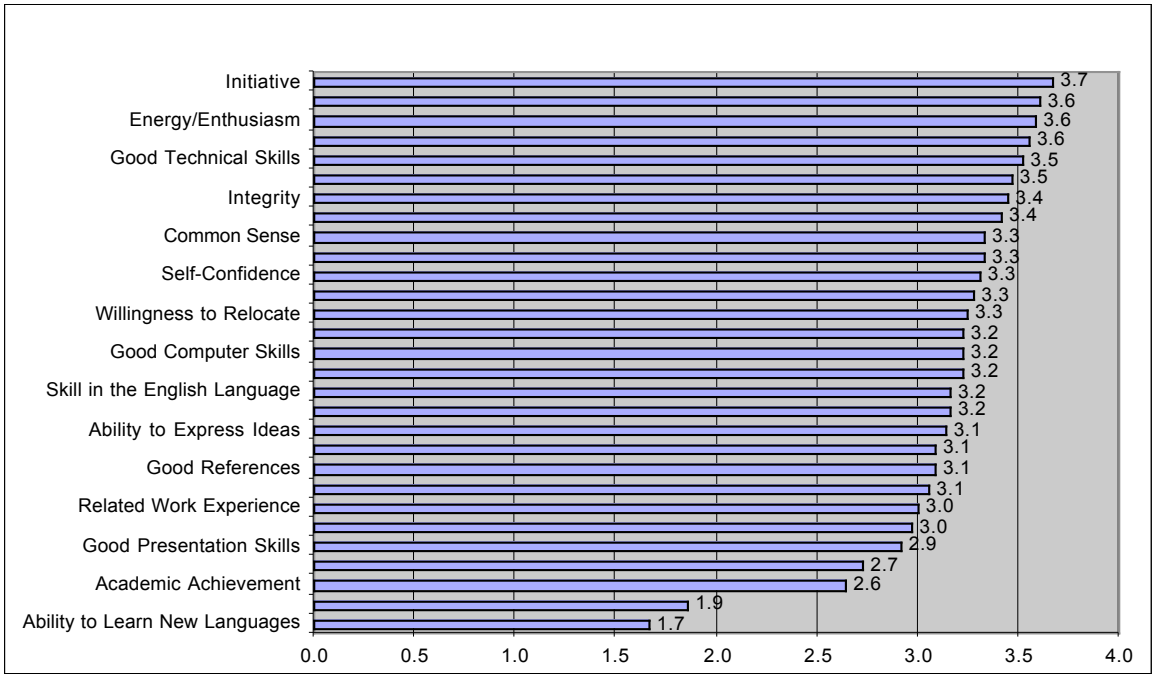

Figure 10 - Attribute Importance of Newly Graduated Canadian Mining Engineers

Based upon replies received, the single most important attribute of any newly hired mining engineer is "Initiative", for which a mean importance rating of 3.67 was assessed. For this attribute, 75% of respondents judged an importance rating of (4 - Extremely Important), with the remainder judging this attribute to be (3 - Somewhat Important). The two least desirable character attributes of newly hired mining engineers, as judged by industry respondents, were "Ability to

Learn New Language" (importance rating = 1.67, rank = 29th) and "Non-Related Work Experience" (importance rating = 1.86, rank = 28th). Within this broad range of character review, the next lowest ranked attribute (ranking 27th) was a mining engineering graduate's "Academic Achievement". This low ranking order of importance infers that student academic performance at university is not a significant factor in hiring desirability for mine operators.

The upper half of the attribute ranking list, comprising the most desirable character attributes of new hires, was observed to focus primarily upon strong personal skills development. Skills that are most appreciated by the mining industry include Initiative, Energy/Enthusiasm, Integrity and Attitude/Personality. Development of good technical and communication skills, in addition to strong character potential, were also judged to be valuable attributes for employment. This is attested to by the high ranking of Technical Skills attributes, rated at 3.53 (rank = 5), and Good Verbal Communication Skills attributes, rated at 3.47 (rank = 6).

Conclusions

Analysis of data, received from thirty corporate responses to a Queen's University survey of industry hiring and curriculum needs, has been used to assess the capabilities of Canadian universities to effectively train young mining engineers for careers in the mining industry.

In terms of curriculum suitability to meet industry's needs, it has been demonstrated that the general engineering skills of young graduates meshes well with the training expectations of mine operators in Canada. Unfortunately, it has also been demonstrated that the capacity of universities to provide adequate training in subject categories such as Specialized Computer Applications and Communications is deficient in terms of the quality of education that is being received by young mining engineers. In most category areas evaluated, the efficiency of training has been indicated to be less than ideal. In order to enhance the viability of young engineers for future employment, and to satisfy industry educational requirements, a focus on several areas of training enhancement must be strongly encouraged. In areas where the mining industry has demonstrated that curriculum is of low importance (i.e.- social and political sciences), less training effort might be encouraged to occur. Where, however, significant industry expectation for the educational training of its young engineering hires exists (i.e.- in specialized computer applications and communications studies), additional educational effort for training enhancement must be facilitated.

Based on responses received, specific character attributes of new engineering hires have also been identified. The most important attributes which Canadian mining companies seek are typically personal qualities, such as initiative, the ability to work effectively with others, energy, enthusiasm, positive attitude and effective personality. Conversely, attributes such as the capability to develop specific skill sets and demonstrate high levels of academic achievement have been indicated to be less important. Within the mining industry, mining engineering degrees are very favourably viewed for engineering hires relative to those of other degree disciplines. For

employment within production roles, however, advanced degrees (at the M.Sc. and Ph.D. levels) are also not typically viewed as being necessary or relevant factors for successful employment.

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