Opinions and trends in biomaterials education: Report of a 2003 Society for Biomaterials survey

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Abstract: The Society for Biomaterials (SFB) aims to serve its members through acting as a forum for the exchange of information and ideas. To aid in the practical development of the SFB and more specifically biomaterials education, all active, associate, and student members were surveyed. In general, the survey asked questions regarding respondent demographics, experiences and activities with the SFB, and opinions about biomaterials education. Perceptions and needs of biomaterials-related education and career-related training practices were a specific focus of the survey. A total of 140 individuals responded to the survey for a response rate of 18%. Members from industry felt that new hires, in general, should be better trained in product development, regulatory issues for new materials and devices, and in the relevant testing required. When asked what was missing from their professional education, many respondents commented that business training in areas such as negotiations, management, and understanding the needs outside of academia was lacking. Also, many respondents seemed to have trouble identifying with what they were supposed to know and felt a "lack of set professional knowledge." This study has raised many ideas and questions that require further discussion. The results should ultimately be useful for helping the SFB decide how best to focus future efforts in biomaterials education. © 2004 Wiley Periodicals, Inc. J Biomed Mater Res 70A: 1–9, 2004

Key words: biomaterials education; Society for Biomaterials (SFB); Survey

INTRODUCTION

Since its inception in 1975, the Society For Biomaterial's (SFB's) aim has been to proactively aid in the development of the field and its members through serving as a forum for the dissemination of information and ideas. Over the past 3 decades the field has rapidly evolved, with biomaterials programs being initiated worldwide. To help ensure that the educational demands and needs of the biomaterials community were met, a new SFB subgroup named the Education Special Interest Group (EDU-SIG) was established in 2001. The EDU-SIG mission is to affect quality of teaching and learning through the discussion, generation, and implementation of innovative ideas in coordination with the SFB Education and Professional Development Committee. The EDU-SIG seeks to advance the interests and goals of the biomaterials community by attempting to bridge the gap between classroom theory and clinical application. To assist in the practical development of the SFB, and more specifically, biomaterials education, the EDU-SIG recently surveyed all SFB members (for the list of questions, see Appendix 1). This initiative was designed to compile current opinions regarding biomaterials education practices and the needs of industry. The results of this survey are reported in this publication. There are only a few publications related specifically to biomaterials education,[1–6] one of which documents a 1980–1981 US/Canadian survey that evaluated the number of biomaterials programs being offered and the scope of biomaterials instruction at these institutions.[3] The present study reports on the most comprehensive education-related survey of SFB members to date. One of the main goals of this survey was to determine how the EDU-SIG should focus and align efforts with members' needs. Respondents were

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asked a series of questions related to the role of the SFB and their present institution in their biomaterials education. Areas of discussion were identified and used to define questions for future initiatives and study.

MATERIALS AND METHODS

An e-mail message containing a link to an on-line survey was sent to all active, associate, and student members of the Society For Biomaterials (SFB) with email contact information on file at the main SFB office (776 addresses). A numerical code, provided in the message, was necessary to access the survey. A reminder e-mail message was sent to the same population 1 week prior to the survey being taken off-line.

The survey was accessible for 2 months (April 24–June 24, 2003), and consisted of multiple-choice and short answer questions (see Appendix 1). In general, the survey asked questions regarding respondent demographics, experiences, and activities with the Society for Biomaterials, and regarding opinions about biomaterials education. Perceptions and needs of biomaterials-related education and career-related training practices were a particular focus of the survey. Text, numerical, and yes/no responses were solicited. Numerical responses were based on fixed rankings with single point increments from 1 (poor) to 5 (excellent).

Crosstabulations were used to eliminate errors arising from respondents who answered questions specified for a different portion of the population (e.g., a professor who responded to a question for students or vice versa). For these respondents, only answers to the specific inappropriate questions were discarded.

Demographics of the overall SFB population from November 2003 were used to help indicate the representativeness of the sample. The overall SFB population demographic data from April 24 to June 24 2003 could not be obtained at the time of manuscript preparation due to a recent SFB management change.

Single comparisons were statistically analyzed using a paired Student's *t*-test at significance levels of 95%.

RESULTS

Demographics

A total of 140 individuals responded to the survey for a response rate of 18%. Of the respondents, 86 (61%) were male and 54 (39%) were female. 117 (84%) of respondents were from the United States (US), 10 (7%) were from Canada, and the remainders were from either Australia, Austria, Germany, India, Ireland, Italy, Japan, South Korea, and Taiwan. Over 55% of the states in the US were represented, while in Canada respondents were either from Ontario or Quebec. Fifteen (11%) respondents were members of the EDU-SIG. To determine the career-related position of the respondents at the time of survey, respondents were asked to identify with one of the career positions found in Figure 1. The top three categories of respondents were academic professors (34%), graduate students (27%), and industry representatives (21%).

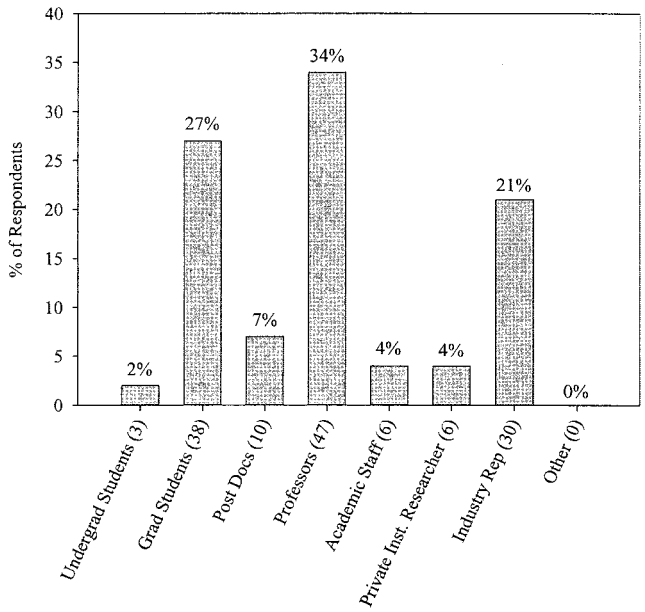

Figure 1. Career-related position of respondent at time of survey. The percentages of the total number of respondents and the absolute numbers of respondents holding different career positions are displayed above and below each bar, respectively.

Academic supervisor performance

Students (both graduate and undergraduate combined, $n = 41$) ranked the performance of their supervisor in the classroom with an average of 3.6, with a standard deviation of $\pm$ 0.9. The students ranked the performance of their supervisor in research with an average of 3.9 $\pm$ 0.8. The ratings for research supervision and classroom performance were not statistically different at $p > 0.16$.

Preparation for careers in industry

Respondents who identified themselves as industry representatives ($n = 29$) rated the preparation of their new hires with respect to product development, with an average of 2.6 $\pm$ 0.9. With respect to research, these respondents rated their new hires' preparation, with

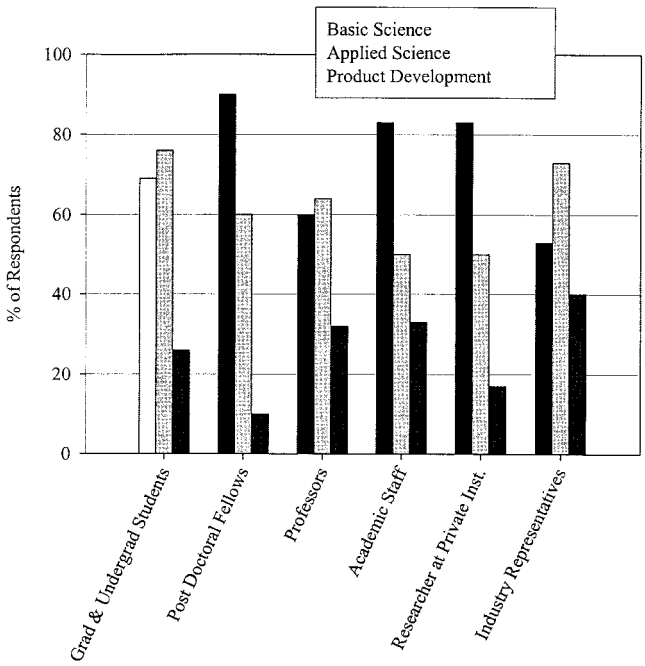

Figure 2. Percent of respondents, with respect to their career-related position, who felt that *undergraduate* students should be educated in specific areas.

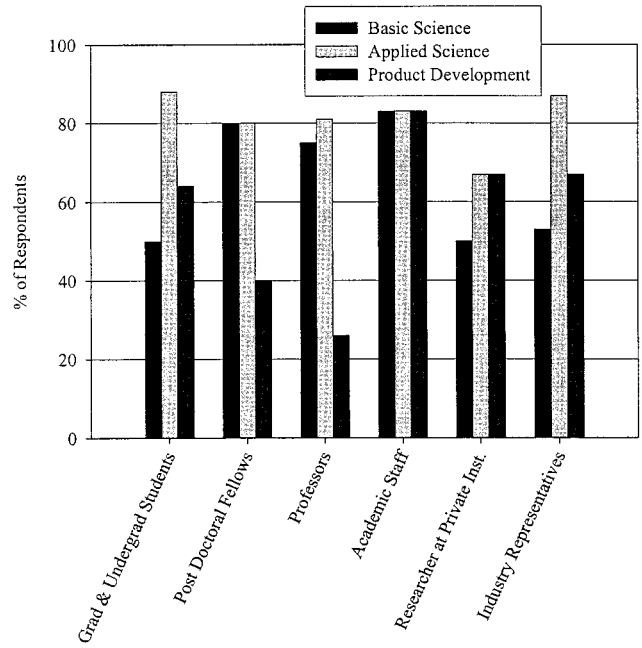

Figure 3. Percent of respondents, with respect to their career position, who felt that *graduate students* should be educated in specific areas.

an average of 3.4 ± 0.9. This difference was statistically significant at $p < 0.004$.

Training areas for undergraduate and graduate students

Respondents with different career positions responded quite differently when asked in what areas they felt students in biomaterials undergraduate programs (Fig. 2) and graduate programs (Fig. 3) should be primarily educated. The main differences in responses pertaining to undergraduate education were between those in academia or private research careers versus those in industry careers. Industry representatives in most cases showed a higher level of support for applied research and product development (73 and 40%, respectively) as opposed to basic science (53%) compared to those in other career positions. With regard to graduate programs, respondents in all career positions viewed applied research education either on par with, or more positively than, training in product development and basic research education. Professors viewed training in product development for graduate programs the least favorably (26%). Interestingly, student respondents indicated much stronger support for training in product development at the graduate level (63%) versus the undergraduate level (25%). In fact, respondents from every career position category except professors ranked product development training at the graduate level much higher than at the undergraduate level.

Strengths and weaknesses of the respondents institution

Respondents were asked to give their opinion of the two greatest strengths and weaknesses of their present institution. Frequently occurring comments were collected and organized under general areas (Fig. 4) The

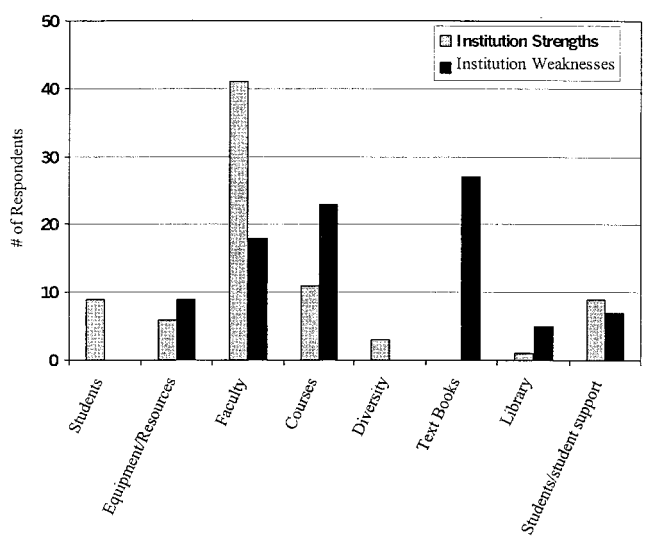

Figure 4. Institution strengths and weaknesses.

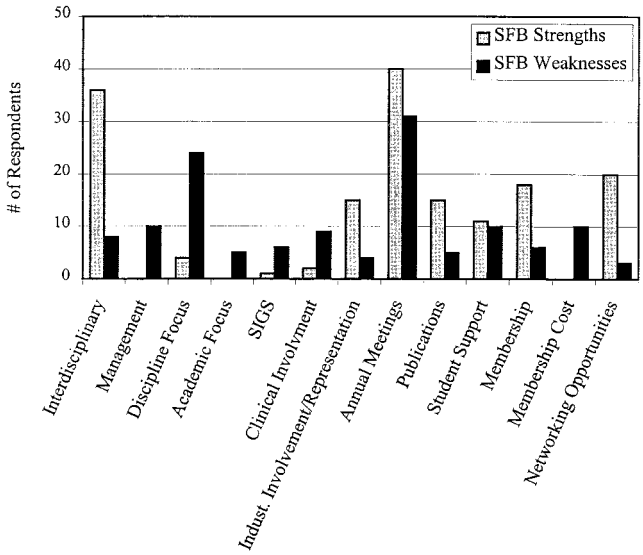

Figure 5. SFB strengths and weaknesses.

categories receiving the most response were "faculty," "courses," and "textbooks," with both "faculty" and "courses" receiving a large percentage of votes as both a strength and a weakness. "Textbooks" were reported only as a weakness, by over 25% of respondents.

Strengths and weaknesses of the SFB

Respondents were asked to give their opinion of the two greatest strengths and weaknesses of the SFB. Frequently occurring comments were collected and organized under general areas (Fig. 5). Strengths with at least 10 responses (>7% of total respondents) were the interdisciplinary nature of the SFB (36), industry involvement. (15), annual meetings (40), publications (15), student support (11), membership (18), and networking opportunities (20). Weaknesses with at least 10% response were management (10), discipline focus (e.g., "biology-focus"), annual meetings (31), student support (10), and cost of membership (10).

Student and post-Doc response to how their supervisor could improve

When graduate and postdoctoral students were asked how their supervisor could improve, a recurring theme emerged. Students felt that their supervisors, in general, do not spend enough time with or offer enough support to their students. Twenty respondents (39% of all students/post-docs) indicated that more joint communication was needed with their supervisor. A recurring response from students was the need for their supervisor to act more like a mentor. Although some respondents commented that they needed more freedom to pursue their own ideas, others expressed a need for more direct supervision.

Some recorded criticisms included: [the supervisor should]

- be more interested and proactive to help his students;
- have more initiative and ideas;
- not completely let student flounder on ideas;
- listen to student's ideas;
- be approachable;
- be more willing to collaborate with other researchers

Other comments included: "My supervisor could give me more constructive criticism on how I am doing," and "My supervisor could let me be involved in the process of grant writing."

Input from industry representatives of how their new hires can be better trained

Five members from industry (17% of industry respondents) commented that new hires, in general, should be better trained in regulatory issues for new materials and devices, and two (7%) felt training in relevant testing (ISO 10993) was required. Four industry respondents (13%) felt more training in statistical experimental design was important. Some felt that new hires should have experience in patent writing, while others thought experience in keeping an organized lab book was important. Other comments included:

- greater emphasis on design of experiments and statistics
- need greater understanding of preclinical and clinical trials
- need to understand the regulatory requirements for new materials and devices
- class on design control activities, international standards, risk assessment, regulatory standards, patent writing, etc.
- encourage internships for advanced students in industrial settings
- more emphasis on applied work directed at financial gain as opposed to strictly knowledge building
- academics often only produce more academics—not the best engineers
- utilization of volunteers from industry in the educational process
- joint discussion groups to bring the industrial needs to the academic drivers

- expand on joint programs between academic institutions and companies in the field.

Respondents' view of what is missing from their professional education

When asked what was missing from their professional education, seven respondents (5% of total respondents) commented that business training in areas such as negotiations, management, and understanding the needs outside of academia was lacking. Others commented that general areas of knowledge were missing, such as "formal training in molecular biology," "drug delivery as pertaining to biomaterials (degradable, controlled release," and "polymer chemistry knowledge. . .". It seemed as though respondents, in general, had trouble identifying with what they were expected to know. As one respondent stated, there is a "lack of set professional knowledge." Regarding this issue, another respondent declared: "[I have] no area of specialty. I do not feel like I match any requirements of jobs available. Not enough hard core engineering or science. Only know a little about polymers, biocompatibility, etc. but about a lot of areas."

A number of respondents suggested that SFB should offer continuing education opportunities. Some specific suggestions were for courses, either at annual meetings or online, in biostatistics/statistics and standardized biocompatibility testing—ISO 10993.

Workshops that respondents would like to see at annual meetings

Eighteen respondents (13% of the total respondents) expressed a desire for more education-oriented workshops, such as: "How to develop courses related to biomaterials and integrate skills needed in industry," "standardization of curriculums," "Innovative teaching methods," "my best classroom session ever—best problems, projects, lectures, etc.," "how to implement and support internship liaisons with industry," and "how to use the Internet effectively in instruction." Twenty-three respondents (16%) voiced their need for more workshops geared towards specific areas of research such as "Nano-biomaterials related research and applications," "Gene Expression Analysis/Bioinformatics," "stem cell bioengineering," "gels, hydrogels, fibrin workshop," and "Clinical state of the art in Clinical Cardiovascular Biomaterials." Other responses included: "FDA regulatory approval process would be a great seminar for students to attend," "How to design and conduct animal study," Understanding and Interpreting the ISO 10993 standard Assessing/addressing ISO 10993 requirements," and "problems in scaling up a process/bringing a product to market."

A number of respondents suggested that there should be more effort to encourage more interaction between members of the Society outside the annual meetings. One respondent suggested that the SFB initiate and maintain a supervised e-mail discussion list similar to the Purdue Flow Cytometry list or the Biomechanics listserve.

Biomaterials education and the role of SFB in respondents' education and professional development

Because comments from aspects of respondents' biomaterials education and the role of the SFB in their education and professional development were mixed, it was difficult to group the comments into specific areas. Therefore, they were grouped into general areas with frequently occurring and thought provoking comments listed below:

Comments on the SFB

Specific comments regarding the SFB were mixed, but generally positive. Some typical comments include:

- "I think the Society needs to take a more active role in preparing biomaterials scientists and researchers to be more effective managers and business leaders, should they choose to opt for a career path in industry."
- "The Society For Biomaterials has provided a professional home for my academic activities and helped immeasurably in establishing a professional network of colleagues."
- "The Society of Biomaterials and the Journal of Biomedical Materials Research have been immensely helpful in providing a continuing education for someone like me who is in a nonacademic environment."
- "As a student, SFB helped me practice speaking about my research and has provided me with money to travel to the conferences where I am exposed to areas I may be interested in but wouldn't have otherwise known existed."
- "The SFB has been a great source to gain exposure and network."

University biomaterials programs

Comments regarding university biomaterials programs were mixed, and in general, not positive. Two

typical comments include: (1) "[The] pitfall of many Biomaterials programs is that they try to cover such a wide range of disciplines the students are left without a viable specialty"; (2) "need more help to develop educational techniques and methods."

General comments

General comments were solicited in question 20 of the survey (Appendix 1) on aspects of biomaterials education or on any aspect of the role of the SFB on the respondent's education and/or professional development. Typical comments from professors include: (1) "Like to see SFB collaborate more with industry to provide training in biomaterials design, manufacturing and product development," (2) "SFB should become a supporting member society of the ABET board for biomedical engineering and provide ABET reviewers."

General comments from Industry Representatives were mixed, with typical comments as follows: (1) "My company is unwilling to send me to annual meetings because they believe SFB is too far removed from product development; (2) "[The] society needs to take a more active role in preparing biomaterials researchers to be more effective managers and business leaders, should they choose to opt for a career path in industry; (3) "because SFB is perceived as 'too academic,' I have not been able to secure funding to attend the annual meetings for the past several years."

General comments from all other career areas were mixed, with typical comments as follows: (1) "I would have benefited from training in microscopy etc., rather than basic theory, which is readily absorbed from the literature as needed. Locating instruments and obtaining training has been a large obstacle." (2) "Leaders of biomaterials programs should not only possess a vision, but also should be highly dynamic and actively engage the students. It is important for a leader to strive to create an educationally conducive environment where everyone feels a sense of belonging."

DISCUSSION

The survey outcomes presented in this paper are the result of an SFB EDU-SIG initiative. The EDU-SIG felt the survey was important to help elucidate the disparity of academic education and/or training and the needs of industry. Identifying the concerns of SFB constituents on this subject may provide a gateway to suggestions for improving our biomaterials education system.

The data from the survey details many aspects of

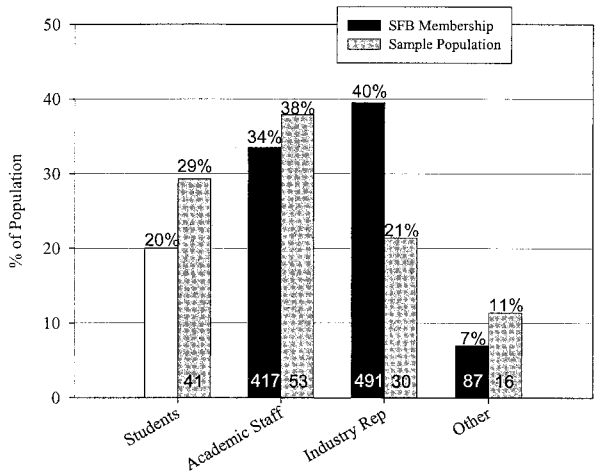

Figure 6. Survey sample population category percentages as compared to SFB overall membership category percentages.

biomaterials education that its members may generally accept as true, but rarely acknowledge. Documenting the perceptions of biomaterials education at this point in time will provide preliminary evidence on which changes can be based. Others can cite this work in their efforts to study and define the needs in biomaterials education. It is, however, difficult to comment decisively on the true representative nature of the sample measured in this study. Figure 6 shows a comparison of overall SFB population distribution in various careers (as of November 2003) in comparison with the respondents to this survey. Perhaps the most notable disparity was with the lower percentage of industry respondents (21%) compared with the overall SFB population (40%). In addition, 11% of survey respondents were EDU-SIG members, whereas the EDU-SIG membership only comprises approximately 2% of the SFB membership. In this study it is assumed that the collective responses of the individual groups represented the overall feelings of the SFB group. However, as with any survey, it is possible that many of our respondents represented a misrepresentative population of SFB members who are disconcerted on this subject.

If we assume that the data in this survey are representative of the SFB population, several trends can be identified and discussed. With regard to the perceived needs of students, it may be concluded that students feel that their academic supervisors need to be more connected with them in both their research and coursework. In general, there was a desire for increased communication between student and supervisor, even if more independence in research direction was wanted. No distinction was made in this survey between M.S. level and Ph.D. level graduate students, which is a limitation of the study. It is likely that these two groups of students would require and/or want different levels of supervision.

Industry representatives expressed concerns that their new hires were not sufficiently prepared to enter the industry workforce after a strictly academic preparation. Industry representatives rated their new hires as being significantly more prepared for research than for product development ($p < 0.004$). The role of the university in educating students is questionable and often debated. Should universities educate students in basic and applied principles only? Is it the role of the university to train students for industry with emphasis on product development? Are the two goals counterproductive or can they be meshed together in a university education that will effectively prepare students for research and interaction with industry? The results of this survey indicate that these questions are not yet resolved.

For both the undergraduate and graduate levels, industry representatives indicated the strongest support for education in product development and applied research. A striking difference was seen in this category when comparing the response of professors versus industry representatives for graduate level education. Industry support for graduate student product development education was at 67%, while professor support fell to 26%. Students' responses sided with industry at 64%. It is possible that this disparity between academic professor opinion and student/industry opinion reflects the difference in desired outcomes (research vs industry employment) between the different career track individuals and reflects the perception that academic professionals hold scientific training as paramount in education. A workshop presented at the 2003 SFB meeting "Workshop 1. Pathways to Successful Careers, Part A: Improving the Interface Between Industry and Academia Through Education" explored this division in perceived needs. Ideas for achieving both goals simultaneously through active learning techniques were discussed.

An example of this active learning technique was described at the workshop by Dr. Anne Meyer. She presented concepts used in her team taught course entitled "Evaluation of Biomedical Materials," which is described at http://www.sdm.buffalo.edu/ods/bma520/. Further exploration on this subject is planned by the EDU-SIG through initiatives such as sharing a project and team-based approaches to learning and inclusion of industry involvement in the classroom.

Respondents gave a wide variety of responses regarding what is missing from their biomaterials education. These comments may reflect the diverse nature of the biomaterials field. Many respondents commented on the lack of a set of professional standards in the biomaterials field. One question to be addressed is if it is possible to define a set of standards in a field that is so diverse.

The strengths and weaknesses of respondents' institutions involved in biomaterials education were varied. The most prominent perceived strength (faculty—41%) was also one of the major perceived weaknesses (18%). This finding may be reflected in the high rate of dissatisfaction of institutional courses (23%). The institutional weakness most frequently identified was textbooks (27%). It is likely that this weakness reflects, in general, the low number of high quality textbooks in the biomaterials field. In addition, this finding may reflect the numerous comments that indicated that the standards for what is needed for a comprehensive biomaterials education is not defined. This may reflect the diverse multidisciplinary nature of the biomaterials field. The SFB Education and Professional Development Committee is starting an initiative to assist educators to review textbooks, and point out the strengths of the various texts so that the desired course content can be better matched to the text selected.

Overall survey responses pertaining to the SFB indicated that the strengths outweighed the weaknesses. It is likely that some of the perceived weaknesses (discipline focus, annual meeting) reflect the diverse nature of the biomaterials field.

Thirteen percent of respondents (18 respondents) stated their desire to increase the education related workshops at the SFB annual meeting. The SFB EDU-SIG will attempt to respond to this request by proposing more education-related workshops. One issue in providing this type of workshop is that the cost must be kept low so that students (future educators) and those in academia can afford to attend. Based on the results of this survey, it is hoped that the biomaterials industry will be supportive of such educational initiatives.

CONCLUSIONS

The biomaterials education survey conducted by the EDU-SIG raised many issues worthy of thought and discussion. These questions include:

1. Should biomaterials programs at the undergraduate and/or graduate levels include aspects of product development and business skills?
2. Should the SFB work with universities to create standardized biomaterials curricula? Alternatively, should the SFB work with university programs and/or the Accreditation Board for Engineering and Technology to define biomaterials-related course content and desired educational outcomes?
3. How can we create teaching materials that are up to date with current biomaterials science, for use in both introductory and advanced courses?

4. How can we improve the mentoring of biomaterials students? Can the SFB assist in mentoring and/or student networking?
5. How can faculty and/or institutions efficiently and effectively disseminate their best biomaterials education-related practices?
6. How can the SFB provide aid in the professional development and continuing education of students, doctors, professors, and industry representatives?

It is the goal of the SFB Education Special Interest Group to work with the SFB Education and Professional Development Committee to address these issues and to help educators at all levels in preparing our future generations of biomaterials scientists while also improving ourselves as researchers and educators.

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APPENDIX 1

SURVEY QUESTIONS

#1. Please indicate which answer best describes your current position (No response, Undergraduate Student, Graduate Student, Post Doctoral Fellow, Professor, Academic Staff, Researcher, Private Institution, Industry Representative)

#2. Gender—Please check one (No response, Male, Female)

#3. Which country are you currently studying/practicing biomaterial science? (choose from list)

#4. If USA or Canada, which state/province? (choose from list)

#5. The Society For Biomaterials Education Special Interest Group (Education SIG) has recently been formed. Its mission is to help promote proactive and innovative learning in the biomaterials field. Would you consider joining the Education SIG? (Text Response) (Yes, No, Undecided, Already a member)

#6. What do you perceive as the two greatest strengths and weaknesses of the Society For Biomaterials? (Please answer in point form) (Text Response)

#7. What do you perceive as the two greatest strengths and weaknesses of biomaterials education at your institution (i.e., overall program, teaching, books available, etc.)? (Please answer in point form) (Text Response)

#8. Please rate the overall performance of your supervisor in your research (for Undergraduate students, Graduate students, and Post Doctoral Fellows only). 1 = poor 5 = outstanding

#9. Please rate the overall performance of your supervisor in the classroom (for Undergraduate students, Graduate students, and Post Doctoral Fellows only). 1 = poor 5 = outstanding

#10. Please describe ways in which your supervisor can better work with you and suggest strategies that might improve his/her efforts (for Undergraduate students, Graduate students, and Post Doctoral Fellows only) (Text Response).

#11. Please rate the preparation of your average new hire employee in terms of research activities (for Industry Representatives only). 1 = poor 5 = outstanding

#12. Please rate the preparation of your average new hire employee of product development activities (for Industry Representatives only). 1 = poor 5 = outstanding

#13. Please describe areas in which your new hire employees can be better trained in academia to best suit your needs for industry. Please suggest strategies for implementing those areas (for Industry Representatives only). (Text Response).

#14. Do you feel that there is anything missing in your overall professional education? Please comment. (Text Response).

#15. The Society for Biomaterials council is considering endorsing a surgical video library that could be used as a teaching tool. For example, professors could enhance their lectures by showing videos that would help students appreciate the clinical side of biomaterials research and would help students augment their biomaterial design criteria. Students, postdocs, and professors at each institution that subscribed to the library would have unlimited access. This library would contain full videos and video clips of clinical and animal surgeries

involving biomaterials. Would a biomaterials surgical video library be useful at your institution? (No Response, Yes, No, Undecided).

#16. Would you endorse the surgical video library if student fees were increased by $10 per year? (No Response, Yes, No, Undecided)

#17. In what areas do you think students in biomaterials graduate programs should be primarily trained? (No response, Basic Science Research, Applied Research (engineering and problem solving), Product Development (scaling up a process/bringing a product to market), Other.

#18. In what areas do you think students in biomaterials undergraduate programs should be primarily trained? (No response, Basic Science Research, Applied Research (engineering and problem solving), Product Development (scaling up a process/bringing a product to market), Other.

#19. What workshop or symposium topics related to Biomaterials Education would you like to see at the annual SFB meeting? (Text Response)

#20. Please comment (positively or negatively) on aspects of your biomaterials education or on any aspect of the role of the Society for Biomaterials in your education/professional development. (Text Response)