



Evolution and Assessment of a Master's-Level Multidisciplinary Regenerative Medicine Program

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Abstract

Over the past five years, we have developed a multidisciplinary Master's degree program in Regenerative Medicine at our university. This program involves faculty and students spanning three academic units at our university - Biomedical Engineering, Biological Sciences, and Animal Science. The goals of our program are to prepare students for careers in regenerative medicine in both academia and industry by providing them with broad technical, critical thinking, and problem solving skills. This paper will discuss the evolution of the program and assessment of the program and our students.

The Regenerative Medicine Program is a two-year program that consists of three components - one year of coursework, a nine-month internship, and a three-month Master's project. Coursework includes intensive lab work and focuses on principles of stem cell biology, cell culture, scaffold development, cell sodding, immunofluorescence, animal surgery and experimentation, therapeutic delivery, fluorescence microscopy, and image analysis. After completing all core coursework, students complete an intensive nine-month internship at one of our partner institutions, which include four academic and four industry partners. Once their internship is complete, students return for one last quarter at the university where they work on a research project and transfer knowledge from their internship back to the university.

Throughout the program, students are given direct feedback on their performance. They are assessed by the instructor of each core course on areas such as motivation, independence, dependability, attitude, quality of work, etc. Students meet with a faculty mentor at least once a quarter to receive and discuss these assessments. When students leave to go on their 9-month internships, they maintain close contact with their faculty mentors, providing monthly progress reports as well as monthly mentoring sessions via phone. Internship supervisors provide performance evaluations every three months. All of these mentoring and feedback mechanisms increase student success and serve to improve performance.

The program has undergone continuous assessment and improvement since the program began in 2009. Faculty and students in the program meet with an advisory board yearly, which is comprised of individuals from each of our partner institutions. The advisory board helps to assess the content of the courses, student preparation for the internship, student performance during the internship, program logistics, future directions of the field of regenerative medicine, and relevance of our coursework and program to ensure we continue to meet the needs of academia and industry. Results of these assessments will be presented in the final paper and demonstrate the success of the program.

Introduction

A Master's of Science degree specialization in Regenerative Medicine was established at our university in 2009¹. This is an interdisciplinary program that is available to Master's students

from Biomedical Engineering in the College of Engineering, Biological Sciences in the College of Science and Mathematics, and Animal Science in the College of Agriculture. The program initially received \$3.6 million from the California Institute for Regenerative Medicine (CIRM) Bridges to Stem Cell Research Award² to establish and run this program. This has been a successful program, and the faculty involved have worked hard to formalize and streamline our program over the years. This continual improvement has been based on feedback from faculty, students, internship mentors, and our Advisory Committee. This paper will give a brief overview of the program and then will describe the processes, assessments, and improvements since the program's inception.

Program Structure

The purpose of the specialization program is to provide students with a foundation for successful careers in the regenerative medicine industry, as well as other related industries. Our goal is to capitalize on our three departments' strengths in medical devices, cell and developmental biology, and veterinary medicine to prepare students for the burgeoning field of biologic devices and products for humans and animals. The program centers on three main components: coursework, a 9-month internship, and a culminating capstone project.

The coursework for the program is laboratory-intensive and designed to prepare students for their 9-month internship. The core courses are taken by all students enrolled in the program. The course topics were selected to develop the technical skills that are important for regenerative medicine, including stem cell and developmental biology, cell culture and tissue engineering, immunofluorescence, cell transplantation and animal manipulation, and microscopy. Through the common core coursework, students develop laboratory skills, while also developing an appreciation for primary literature and stem cell research - from its historical roots to the latest contemporary studies.

After the coursework, the students complete a 1-week intensive Stem Cell Techniques Course at the Scripps Research Institute³. During this experience, students are trained in human pluripotent stem cell culture, embryoid body development, directed cellular differentiation, and other hands-on skills for working with and evaluating stem cells. After the training, students embark on a paid 9-month internship at one of our partner institutions. During this internship, students complete a project related to regenerative medicine or stem cell biology in a rigorous R&D environment under the guidance of an Internship Mentor. Though individual projects vary, all internships facilitate the mastery of broad technical skills, critical thinking & problem solving skills, current primary literature, and presentation and communication skills.

When the program first began in 2009, we partnered with 4 academic partners and 1 industrial partner. Interest and awareness of our program has grown over the years, and we have been able to expand our internship opportunities to 5 additional industrial partners. Our internship partners currently include Capricor Therapeutics, Cellerant Therapeutics, Cytori Therapeutics, Organovo, Vet-Stem, Viacyte, the Salk Institute, the Scripps Research Institute, Stanford University, and UC San Diego.

Following the completion of their internship, students return to campus to complete a capstone project that allows them to transfer their knowledge and experience from their internship to a novel project at our university. The specific projects vary, but all involve experimental design and data collection/interpretation. Students are required to write a report on their internship experience, deliver a 50-minute presentation on their work during the internship, write a final report on their capstone project, and deliver a final poster presentation of their capstone project. Rubrics are provided for the students so they understand the expectations for each deliverable.

Upon completion of the program, students will be able to

1. Demonstrate broad technical skills
2. Think critically & solve problems
3. Discuss current research
4. Discuss the history, theory, & ethics of stem cell investigation
5. Present and communicate effectively
6. Network with professionals in the field

Internship Matching

The centerpiece of this program is the 9-month internship that our students embark on. As such, we worked to develop a formal procedure to facilitate the pairing process to improve success during the internship. Students are often expected to conduct PhD-level research, and their Internship Mentors often have high expectations for the students. Hence, it is extremely important for our students to find a good fit with the internship institution as well as with the mentor.

Prior to internship matching, the faculty work with the internship partners to collect abstracts on available projects the students can work on during their internships. Once collected, students are given all abstracts to review. To assist the students with their rankings, students are given a guide and advice to internship ranking and selection considerations. Areas for students to consider are their long-term professional objectives, techniques used in the lab, the system/organ/tissue of focus, expected deliverables at the end of the internship, lab or group size, mentoring style, lab environment, and experiences of previous interns.

Pairing begins by students submitting to the faculty their top three internship choices. The faculty then organize and discuss the internship rankings and finalize the interview choices. The students arrange for phone interviews with their potential internship hosts to discuss the internship project and necessary skills and techniques. If mutually agreed upon by the internship host and student, an on-site interview is then set up. After completing all on-site interviews, final matching is completed.

Mentoring

After our first round of internships, the faculty decided to implement a formal mentoring process to improve the performance of our students. This also allowed a mechanism for consistent feedback to the students on their performance throughout the entire program and enables them to continue to grow, develop, and contribute professionally.

Throughout the program, students are mentored by the faculty in a number of ways. All students are assigned a Faculty Mentor. Students meet with their mentor each quarter to discuss classes, electives, internship options, progress in the program, etc. At the end of each quarter, the faculty teaching the core courses provides feedback on each student's performance in their class. This is known as the End-Of-Quarter Assessment. Students are assessed in nine different categories: participation, dependability, punctuality, motivation, independence, quality of work, attention to detail, attitude, and communication. Within each category, students are rated as excellent, good, fair, needs improvement, and needs major improvement. Written comments are also included for each category. Students set up a meeting with their mentor to discuss the End-Of-Quarter Assessments and discuss their performance as well as areas of strength and areas of improvement. Since we have implemented these assessments, student performance has improved across their time in the program. Students learn the expectations and get feedback on how they are doing so they have opportunities to continually improve.

While the students are away at their internship, they continue to contact their Faculty Mentor and work with an Internship Mentor from their internship location. Students are required to submit a Monthly Progress Report to their Faculty Mentor and Internship Mentor. This consists of a preexisting form the students fill out that describes their objectives, progress over the past month, and goals for the next month. In addition, the student discusses the Monthly Progress Report with their Internship Mentor and also arranges for a monthly phone call with their Faculty Mentor to discuss their internship progress.

In addition to the Monthly Progress Reports, three Intern Performance Evaluations are conducted by the Internship Mentor. The mentor completes a form assessing the intern's quality of work, organization and efficiency, knowledge base, communication skills, working relationships, strengths, and weaknesses. They also provide an overall performance score as well as suggestions on how the intern could improve their overall score. Internship Mentors have to meet with the interns to discuss their performance evaluations, and Faculty Mentors are provided copies of the evaluations to also discuss with the students during their monthly phone calls. At the same time as the Performance Evaluations, students must complete a form providing feedback to their Internship Mentor and self-reflection on their performance. Students evaluate their Internship Mentor's frequency of interactions, quality of interactions, level of involvement, positive aspects of interactions, and areas for effort or improvement. In the self-reflection portion, students anticipate what their Internship Mentor will say are the intern's greatest strengths and weaknesses as well as overall performance. This is discussed with the Internship Mentor during their Performance Evaluation meeting and also with their Faculty Mentor.

Assessments

Our program relies on feedback from our Advisory Committee, students, and faculty, to allow us to continually improve our program. The Advisory Committee is made up of internship hosts from both academia and industry. Together with the Advisory Committee, the faculty review the program every year. At our annual meeting, we discuss the coursework, program logistics, and quality of our students to ensure the efficiency and efficacy of our program in preparing students for careers in regenerative medicine and related fields.

The Advisory Committee has been consistently impressed with the quality of the students going through the program. Our overall coursework has satisfied the committee, but they have suggested minor changes to fine-tune student preparation for work in the regenerative medicine field or related careers. One suggestion we implemented was to require students to take coursework covering molecular biology. Our students come from diverse undergraduate backgrounds, and adding more molecular biology would be helpful to their understanding of regenerative medicine. Students were also provided with a list of suggested electives to supplement their core coursework. Additional coursework students could choose to take include immunology, gene expression, protein techniques, and developmental biology. Other general topics our Advisory Committee suggested to cover were design of experiments and proper lab notebook documentation. We have found ways to include these topics in our existing core courses, which satisfied the Advisory Committee.

During the Advisory Committee meetings, we also discuss other program assessments. In addition to mentoring feedback and evaluations, the program has formal assessments by both the Internship Mentors and the students.

The Internship Mentors were asked to fill out two assessments: Student Preparation for Internship and also Student Performance During Internship. The students were asked to fill out two similar assessments: Student Perception of Preparation for Internship and also the Student Perception of Performance During Internship. A series of five-level Likert items was used for our assessments. Internship mentors and students were presented with a number of statements to which they responded with Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, or Not Applicable. They could also provide comments on each of the statements. Areas assessed included the following:

- Effective performance of cell and tissue culture
- Ability to perform histological techniques
- Effective work with live animals
- Effective use of microscopy techniques to image cells or tissues
- Comfort in a lab setting, performing basic and advanced lab techniques, and ability to readily learn new techniques
- Ability to critically analyze and present primary literature in regenerative medicine
- Ability to identify and discuss non-technical aspects of regenerative medicine

In addition, students were assessed by their Internship Mentors and also self-assessed themselves in the following categories:

- Professionalism and independence
- Work ethic and motivation
- Performance on internship project
- Preparation for the internship

Both groups were asked to answer freeform questions on suggestions for changes to the curriculum to improve performance during the internship. Students were also assessed on how well they were prepared for their Stem Cell Techniques Course by the instructors for the course.

Results from the assessments performed by the Internship Mentors and students can be seen in Tables 1 through 4. Table 1 shows the results of the assessment by the Internship Mentors on how prepared the students were going into the internship. Table 2 shows the results of the assessment by the Internship Mentors on the students' performance by the end of the nine-month internship. Table 3 shows the results of the self-assessment by the students on their preparation for the internship. Table 4 shows the results of the self-assessment by the students on their performance during the internship.

Table 1. Assessment of student preparation for internship

Criteria	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
At the beginning of the internship, your mentee could effectively perform tissue culture, including culturing cells, using aseptic technique, and assessing cell viability/confluence.	3	6	1	0	0	0
At the beginning of the internship, your mentee could effectively perform histological techniques including sectioning and staining tissues, and staining of cells.	2	1	2	0	0	5
At the beginning of the internship, your mentee could effectively work with live animals; for example, they could perform surgical or experimental procedures on laboratory mice.	1	1	2	0	0	6
At the beginning of the internship, your mentee could effectively utilize brightfield, widefield fluorescence, and confocal microscopy to image cells or tissues.	3	6	1	0	0	0
At the beginning of the internship, your mentee was comfortable in a laboratory setting, could perform basic and advanced laboratory techniques, and could readily learn new techniques.	8	2	0	0	0	0
At the beginning of the internship your mentee was knowledgeable of stem cell biology, including current research, historical aspects, clinical applications, and the differences between various stem cell types.	1	6	3	0	0	0
At the beginning of the internship, your mentee could identify and discuss non-technical aspects of stem cell research/regenerative medicine such as political and ethical issues, patents, and commercialization.	1	2	4	0	0	3
2014	Excellent	Good	Sufficient	Insufficient	Poor	
Over the course of the internship, your mentee's professionalism was:	9	0	1	0	0	
Over the course of the internship, your mentee's independence, motivation, and work ethic were:	7	2	0	1	0	
Overall, your mentee's performance in their Internship Project was:	6	3	1	0	0	

Table 2. Assessment of student performance during internship

Criteria	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
By the end of the internship, your mentee could effectively perform tissue culture, including culturing cells, using aseptic technique, and assessing cell viability/confluence.	9	1	0	0	0	0
By the end of the internship, your mentee could effectively perform histological techniques including sectioning and staining tissues, and staining of cells.	4	1	0	0	0	5
By the end of the internship, your mentee could effectively work with live animals; for example, they could perform surgical or experimental procedures on laboratory mice.	3	0	0	0	0	7
By the end of the internship, your mentee could effectively utilize brightfield, widefield fluorescence, and confocal microscopy to image cells or tissues.	6	4	0	0	0	0
By the end of the internship, your mentee was comfortable in a laboratory setting, could perform basic and advanced laboratory techniques, and could readily learn new techniques.	8	2	0	0	0	0
By the end of the internship, your mentee could critically analyze and present primary literature in stem cell research/regenerative medicine.	2	7	1	0	0	0
By the end of the internship, your mentee could identify and discuss non-technical aspects of stem cell research/regenerative medicine such as political and ethical issues, patents, and commercialization.	1	6	2	0	0	1
I would be happy to serve as a mentor to a future Bridges Trainee from Cal Poly.	8	2	0	0	0	0
Criteria	Excellent	Good	Sufficient	Insufficient	Poor	
Over the course of the internship, your mentee's professionalism was:	8	2	0	0	0	
Over the course of the internship, your mentee's independence, motivation, and work ethic were:	7	3	0	0	0	
Overall, your mentee's performance in their Internship Project was:	7	3	0	0	0	

Table 3. Student Perception of Preparation for Internship

Criteria	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
At the beginning of the internship, you could effectively perform tissue culture, including culturing cells, using aseptic technique, and assessing cell viability/confluence.	6	2	0	1	1	0
At the beginning of the internship, you could effectively perform histological techniques including sectioning and staining tissues, and staining of cells.	1	4	1	1	0	3
At the beginning of the internship, you could effectively work with live animals; for example, they could perform surgical or experimental procedures on laboratory mice.	4	2	0	0	1	3
At the beginning of the internship, you could effectively utilize brightfield, widefield fluorescence, and confocal microscopy to image cells or tissues.	3	6	0	0	1	0
At the beginning of the internship, you were comfortable in a laboratory setting, could perform basic and advanced laboratory techniques, and could readily learn new techniques.	5	4	0	1	0	0
At the beginning of the internship you were knowledgeable of stem cell biology, including current research, historical aspects, clinical applications, and the differences between various stem cell types.	6	4	0	0	0	0
At the beginning of the internship, you could identify and discuss non-technical aspects of stem cell research/regenerative medicine such as political and ethical issues, patents, and commercialization.	5	5	0	0	0	0
	Excellent	Good	Sufficient	Insufficient	Poor	
Over the course of the internship, your professionalism was:	7	3	0	0	0	
Over the course of the internship, your independence, motivation, and work ethic were:	5	5	0	0	0	
Overall, your preparation for the knowledge and skills required for your internship was:	4	3	3	0	0	

Table 4. Student Perception of Performance During Internship

Criteria	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
By the end of the internship, you could effectively perform tissue culture, including culturing cells, using aseptic technique, and assessing cell viability/confluence.	9	1	0	0	0	0
By the end of the internship, you could effectively perform histological techniques including sectioning and staining tissues, and staining of cells.	4	2	1	0	0	3
By the end of the internship, you could effectively work with live animals; for example, they could perform surgical or experimental procedures on laboratory mice.	3	1	0	1	0	5
By the end of the internship, you could effectively utilize brightfield, widefield fluorescence, and confocal microscopy to image cells or tissues.	4	4	1	0	0	1
By the end of the internship, you were comfortable in a laboratory setting, could perform basic and advanced laboratory techniques, and could readily learn new techniques.	7	2	1	0	0	0
By the end of the internship, you could critically analyze and present primary literature in stem cell research/regenerative medicine.	1	7	1	0	0	0
By the end of the internship, you could identify and discuss non-technical aspects of stem cell research/regenerative medicine such as political and ethical issues, patents, and commercialization.	3	4	3	0	0	0
	Excellent	Good	Sufficient	Insufficient	Poor	
Over the course of the internship, your professionalism was:	6	4	0	0	0	
Over the course of the internship, your independence, motivation, and work ethic were:	4	6	0	0	0	
Overall, your performance on your Internship Project was:	4	6	0	0	0	

From our latest assessments, overall, both our Internship Mentors and students either Strongly Agree or Agree that the students had sufficient preparation for their internship in most of the areas. One area that included more Neutral responses from the Internship Mentors was with the discussion of non-technical aspects of regenerative medicine. Based on the comments associated with the statement, the larger number of Neutral responses was because the occasion did not arise to discuss such issues. By the end of the internships, the Internship Mentors continued to feel that the students performed well in all criteria evaluated. Based on discussion of the assessments, the Advisory Committee and faculty were pleased with the results and felt our students had strong preparation for their internships and future careers.

Conclusions

By formalizing our program processes and implementing changes, we have achieved high quality in the students who leave this program. In addition, we have been able to pinpoint any issues or concerns early on and actively make changes or improvements to the experience for the

students. Our program's effectiveness, as a whole, has also been demonstrated by tracking alumni placement and their sense of preparation following graduation. The students who have gone through our program have been provided solid training for careers in regenerative medicine, further graduate education, or other related industries. Of the 40 students who have graduated from our program, 38 have reported their current status. All of those 38 are employed with only one in an unrelated field. Their placement is as follows:

- Regenerative medicine or biotechnology companies – 7
- Regenerative medicine research labs or centers – 9
- PhD programs – 8
- Medical device companies – 8
- Medical field – 4
- Health promotion – 1
- Unrelated field – 1

At this point we are satisfied with the structure of our program and the new processes and changes that have been implemented. Our students continue to improve, and our program consistently receives feedback that our students are highly desired. This is evidenced by students being asked back to their internship labs and companies upon completion of the program. Our careful planning has supported the success of the program and preparation of our students.

Our biggest concern now is how to support this program once funding from CIRM ends. While there are potential workarounds for the cost of running our laboratory courses, our largest costs are associated with the stipend our students receive during their 9-month internship. Students currently receive a stipend of \$2,652 a month for their internship. For 10 students, this cost amounts to \$238,680 for the duration of their internship. From discussions with our Advisory Committee, this is a necessary component of the internship portion of our program. We are currently looking at various alternatives to support the continuation of the program as it is currently structured so that we are prepared once CIRM funding has ended. We are hopeful we will be able to find a scenario that will allow us to continue the program as it is, but we are planning other alternatives so we can adapt to necessary changes.

References

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