Report of the ASA Workgroup on Master's Degrees

06 November 2012

Submitted by

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1.   Charge

Bob Rodriguez, while serving as President-elect of the American Statistical Association, formed a working group to address the following charge:

Develop guidelines, framed as learning outcomes, for master's degree programs in statistics and biostatistics that are responsive to the needs of stakeholders who employ such graduates. These guidelines will reflect discussions with a variety of stakeholders in business and government to determine the needs of their master's degree-level statistical workforces. These guidelines will assist master's degree programs in statistics and biostatistics to align their curricula with desired outcomes.

2.   Executive Summary

A phone interview of 29 recent graduates of Master's programs in statistics and biostatistics and an email questionnaire of 19 employers of such graduates were conducted in 2012. The following seven recommendations emerged from a review of the responses to these surveys.

Recommendation 1:   Graduates should have a solid foundation in statistical theory and methods.

Recommendation 2:   Programming skills are critical and should be infused throughout the graduate student experience.

Recommendation 3:   Communication skills are critical and should be developed and practiced throughout graduate programs.

Recommendation 4:   Collaboration, teamwork, and leadership development should be part of graduate education.

Recommendation 5:   Students should encounter non-routine, real problems throughout their graduate education.

Recommendation 6:   Internships, co-ops or other significant immersive work experiences should be integrated into graduate education.

Recommendation 7:   Programs should be encouraged to periodically survey recent graduates and employers of their recent graduates as a means of evaluating the success of their programs and to examine if other programmatic changes are warranted.

The first five recommendations might be translated into learning objectives in graduate programs while the sixth recommendation suggests an experiential requirement that might be built into graduate programs and the seventh recommendation encourages continuing attention to workforce needs when reviewing graduate curricula.

3.	Process Timeline and Details

March 2011 -   Workgroup formed

Sept. 2011 –   Began to compile a list of recent graduates compiled from solicitation from ASA Caucus of Academic Reps and from other schools not covered by the Caucus

Nov. 2011 -   Survey form constructed and evaluated by the ASA Survey Committee

Jan. –   Sample of recent graduates selected and contacted for phone surveys
   July 2012

Aug. 2012 –   List of employers of MS/MA Stat and Biostat compiled from solicitation from ASA Board of Directors, Caucus of Academic Representatives, and other contacts

Sept. 2012 –   Oct. 2012 - Survey emailed to employers for responses. Reminder email sent approximately two weeks after initial contact.

Oct. 2012 -   Responses compiled and analyzed.

Nov. 2012 -   Report generated.

Recent graduate interview details:

Names of 366 recent graduates were provided by 21 different schools. The number of graduates provided ranged from 1 to 110 (median=12, Q1=7, Q3=17). Workgroup members were assigned a set of schools from which they were to take a sample of 2 recent graduates. Workgroup members then attempted to contact recent graduates to schedule a phone interview. Interviews were completed for 29 recent graduates (out of 115+ contacted) from 13 different schools. The responses to the interview questions were then grouped into common topic categories and summarized.

Employer email questionnaire details:

An email was sent to 68 employers of Master's graduates. A follow up email reminder was sent two weeks later. A reply was received from 19 (28%) of these employers. Two of the employers opted to respond with a general email that did not explicitly address the specific questions.   As with the recent graduate responses, the employer responses were grouped and summarized.

4. Recent Graduate Survey Responses

We completed 29 surveys of recent graduates of Master's programs of statistics/biostatistics. Their responses are summarized in this section with an expanded description given in Appendix G.

Knowledge/skills learned in graduate school that helped get first job [Q1] – Appendix Table G.1

The responses to this question divided into two main groups. The largest response categories were: 1) programming; 2) general statistical/mathematical background; and 3) specific statistical tools/methods. These three categories were mentioned by 10-12 of the 29 recent graduates.

The second group included three different categories: 1) communication skills; 2) other statistical experience; and 3) graduate/teaching assistantship experience. These categories were mentioned by 3 of the 29 recent graduates.

The modal response category to the follow-up question about knowledge / skills that helped get a job after the first job [Q1 follow-up] was programming (mentioned by 3 recent graduates). Note that many of the respondents were still in the first job that they took after graduating.

Knowledge/skills that helped you perform your first job [Q2]:

Broadly speaking, the respondents focused on three general areas:

Programming/Computing tools - The majority of respondents specifically mentioned SAS as important in performing their first job. Five respondents mentioned R, two mentioned SQL, and five mentioned programming skills generally.

Statistics - The majority of the respondents mentioned something about having skills across a range of statistical models and methods. Specific areas mentioned more than once included linear and logistic models, data mining, Bayesian methods, time series, and survival analysis. GEE and mixed models were also mentioned. A couple of respondents discussed data preparation and data cleaning.

Real-world skills - Most respondents discussed the importance of communication skills such as project reporting and presentation and dealing with clients, especially in the face of competing demands and deadlines. Several mentioned the usefulness of a statistical consulting class in this regard. One respondent also mentioned teaching skills.

Knowledge or skills graduates wished they had more of in school [Q3] – Appendix Table G.3

Additional programming skills was the modal category (9 responses) to this question with specific statistical methods background (7 responses) and experience with 'real data'/'big data' (5 responses) following. Here, 'programming' referred to knowing other tools better (e.g. SQL, Excel) or deeper knowledge of a particular tool (e.g. 'knew SAS better'). Other responses included people and consulting skills including communication/presentation skills (3 responses), project and time management (3 responses) and problem solving/strategies for approaching complex problems (2 responses).

Swapping courses out/in graduate studies for different courses [Q4] – Appendix Table G.4

It is encouraging that the modal category for the "swap out" courses in the graduate curriculum was "none" (9 of 29 students) [includes 'not enough depth'/ 'same course-better coverage']. A few students

(3 of 29) mentioned a genetics or bioinformatics but this appeared to reflect courses that were not relevant for the jobs that the students took after graduation.

The "swap in" courses mentioned by students included: programming [includes SAS, R, other languages, databases] (7 of 29); longitudinal (or multilevel analysis) (3 of 29) and nonparametrics (3 of 29).

Experiences outside of formal coursework helped prepare for the first job [Q5] – Appendix Table G.5.

Work experience between the BS and MS/MA (12 of 29) or internship experience (10 of 29) was highly valued by the recent graduates.   Assistantships were mentioned by 6 of 29 recent graduates and other topics (seminars, programming skills, other) were each mentioned by a couple of respondents.

A summary of the responses to these recent graduate questions are given in the summary table below

Question	Programming	Stat/bkgd/math	Specific stat methods	Communication	Experience (includes project mgmt., consulting	Thinking/ problem solving
Knowledge/skills to GET first job [Q1]	12	10	10	3	3	
Knowledge/skills to PERFORM first job [Q2]	XXX	XXX	XXX	XXX	XXX	
Knowledge/skills to WISHED had more of [Q3]	9 + 3		7	3	3	2
Swap in more [Q4]	7		6			
Experiences outside of formal coursework [Q5]	2 (skills)				12 (work) + 10 (intern) + 6 GA/RA	

5. Employer Survey Responses (19 surveys completed)

Nineteen employers responded to the email survey (see Appendix E.0). Organizations reflected in our employer surveys include university-based collaborative study centers/academic medical research settings (5 of 19), federal government (3 of 19), contract research organizations (2 of 19), survey organizations (2 of 19), and financial/banking (2 of 19). The remaining organizations were represented by 1 of 19 respondents: clinical trials consulting, pharmaceutical, public policy non-profit, consumer products, clinical research organization, or manufacturing. Some employers responded based on experience in hiring for two different industry types.

Characteristics of the top 2 candidates when interviewing 10 [Q1] – See Appendix Table E.1

Communication was mentioned by 14 of 19 employers with programming and statistical background mentioned by 11 and 10 employers, respectively. Communication reflected proficiency in written and oral reporting.   Programming topics most commonly mentioned by respondents were SAS skills; but database skills and skills with other statistical programming environments, e.g. R, were mentioned by a few respondents. Statistical methods may have been a prerequisite before interviews were conducted.

Attitude, thinking/problem solving and teamwork/collaboration/leadership followed in terms of frequency of being mentioned. Attitude was a category that included enthusiasm, interest, passion, professionalism and attention to detail. Thinking/problem solving addressed critical thinking skills applied to conceptualize and implement analyses in a logical flow.

The final categories reflected experience, specific advanced coursework or topics, and a couple of additional categories.

What made past hires successful [Q2a] – See Appendix Table E.2a

Attitude/personality was the top factor identified by 14 of 19 employers, with communication skills (12 of 19) and statistical knowledge (10 of 19) nearly as popular. Attitude/personality reflected a variety of characteristics including: passion, desire/interest in learning more, detail-oriented, initiative, flexibility, organization and work ethic.   One respondent noted that: "*when an issue arises they take ownership and work to rectify any mistakes that have been made. Employees who challenge themselves and those around them to be better are also much more successful in our organization.*" Communication and statistical knowledge are defined as above.

Programming (10 of 19) and collaboration/teamwork/leadership (10 of 19) were also part of this top tier of category responses. Teamwork captured working in teams with non-statisticians and PhD level statisticians along with the ability to work independently as part of a team. Thinking/problem-solving (6 of 19) also was a common response.

These two questions suggest that the same dimensions that make a candidate stand out in interviews are also tied to successful work performance.

Deficits in past hires [Q2b] – See Appendix Table E.2b

Not surprisingly, categories as defining strengths in successful candidates would be mentioned as deficits when absent. The top category was programming (9 of 19 employers mentioned) with communication (6 of 19) and statistical knowledge (5 of 19) also frequently mentioned. Programming needs involved more than "PROC" invocations in SAS, including more involved data manipulations.

The absence of relevant coursework (5 of 19) or real project experience (4 of 19) was a concern for about ¼ of the employers. Relevant coursework tended to be linked to employers with specific emphases, e.g. clinical trials background for CRO, survey research methods for a survey research organization. Not knowing a particular technique was not viewed as a tremendous limitation for graduates from programs with a solid statistics background who possessed an interest in learning.

Thinking / problem solving (4 of 19), attitude / personality (3 of 19) and collaboration / teamwork / leadership (3 of 19) were mentioned with similar frequency. One respondent noted that failure to work effectively on a team could be a fatal flaw.

One employer noted in reference to consulting classes in graduate programs that this is "nice, but it does not help if you don't have a good statistical toolkit, are not a good problem solver, and cannot think about or apply logic to problems."

REQUIRED and CRITICAL skills [Q3a] – See Appendix Table E.3a

Statistical knowledge stood out as a required, critical skill for 16 of 19 respondents. Communication (12 of 19) and programming (10 of 19) were next in priority in the top three categories. The next tier of responses were given by 3-5 respondents: collaboration/teamwork/leadership; attitude; thinking/problem solving; relevant coursework; and project work. The expanded descriptions of these categories captured the same ideas as described above for the previous employer questions.

DESIRED skills [Q3b] – See Appendix Table E.3b

Programming (13 of 19) and advanced methods/relevant coursework (10 of 19) were the two most frequently mentioned categories of desired skills. Communication (5 of 19), problem solving (4 of 19), collaboration/teamwork/leadership (3 of 19), personality (3 of 19) and experience (2 of 19) were mentioned less frequently.

Add to graduate programs to better prepare graduates [Q4] – See Appendix Table E.4

Communication skills (written: 5 of 19; verbal: 4 of 19) were the top additions suggested by employers. Project participation (4 of 19); work on real, significant data analyses (4 of 19); and preparation for problem solving when faced with non-textbook, non-routine problems (3 of 19) were also mentioned. Programming (4 of 19) captured data management and good programming practice along with advanced SAS skills.

A summary of the responses to these employer questions is given in the summary table below.

Question	Programming	Stat/bkgd/math	Adv. or specialized stat methods	Communication	Experience (includes project mgmt., consulting)	Collaboration, teamwork, leadership	Attitude / personality	Thinking/ problem solving
Top two candidates	11	10	4	14	3+2	5	8	7
What made hires successful [Q2a]	10	10		12	2	10	14	6
Deficits in recent hires [Q2b]	9	5	5	6		3	3	4
Knowledge / skills REQUIRED and CRITICAL [Q3a]	10	16	5	12	3	5	4	3
Knowledge / skills DESIRED [Q3b]	13		10	5	2	3	3	4
Add one thing to programs	4		2	5+4	4+4			3

6.	Recommendations and Learning outcomes

Recommendation 1: Graduates should have a solid foundation in statistical theory and methods

> Comment: Graduates mentioned this as knowledge that was needed to both get their first job and to perform their first job. In addition, employers assumed this to be a given and was viewed as a foundation required for learning new methods. The workgroup views this as an affirmation of the core that is taught at Master's programs.

Recommendation 2: Programming skills are critical and should be infused throughout the graduate student experience

> Comment: Graduates viewed programming skills as necessary to get and perform their first job but they wished to have better programming skills and would like to see more programming added in their programs.   Employers stated this more strongly and noted that programming differentiated top candidates for jobs from others, made hires successful, and reflected a required, critical and desired skill, but that it was a deficit in recent hires. SAS was mentioned more frequently than other environments. General programming skills beyond applying templates was a key feature that should be developed.

Recommendation 3: Communication skills are critical and should be developed and practiced throughout graduate programs

> Comment: Graduates mentioned that these were skills needed to perform their first jobs. Employers stated that they viewed these skills as differentiating between top candidates, that these skills are part of what makes hires successful, and that these were required and critical skills that were also a deficit in recent hires.

Recommendation 4: Collaboration, teamwork, and leadership development should be part of graduate education.

> Comment: Employers noted that being able to function in a team environment was observed in the most successful hires.

Recommendation 5: Students should encounter non-routine, real problems throughout their graduate education

> Comment: The ability to think carefully through such problems and to develop an analysis strategy was highly valued among employers. Schools should consider how to nurture and develop such skills.

 Recommendation 6: Internships, co-ops or other significant immersive work experiences should be integrated into graduate education.

> Comment: Recent graduates and employers commented on the value of such experiences that might involve consulting, project management and teamwork experiences. Graduate programs might look to develop internships with local employers or on-campus with other offices that might appreciate the assistance that a statistics intern might provide. These experiences would help accomplish and reinforce previous recommendations, particularly Recommendations 2-5.

Recommendation 7: Programs should be encouraged to periodically survey recent graduates and employers of their recent graduates as a means of evaluating the success of their programs and to examine if other programmatic changes are warranted.

> Comment: This workgroup report is a snapshot of the impressions of recent graduates and their employers. Employer needs will likely evolve over time, and while it is hard to imagine that good statistical thinking will ever lose value, it is easy to imagine that electives and other experiences in the graduate program also will need to evolve over time.   The workgroup believed this should be a review that would occur every 3-4 years. We encourage departments to maintain and update contact information for recent graduates to facilitate this survey.

Caveats:

We are reporting the results of interviewing recent graduates and employers of such graduates. These were not probability samples from their respective populations and we may not make inferential claims about the population of recent graduates of Master's programs in statistics or the population of employers of such graduates. We did attempt to select graduates from a large number of schools with varying types of programs and from a collection of employers that spanned many different types of organizations. As such, we hope that these responses will provide some sense of the breadth of skills and knowledge that are desired for Master's graduates.

7.   Appendix 1: Survey form for recent graduates [cover letter example]

Good morning:

The American Statistical Association Workgroup on Master's Degrees is trying to understand the types of knowledge and skills needed for Master's level employees to succeed in today's statistical workforce. You were identified as someone with a Master's degree in statistics or biostatistics, and your help in this important effort is greatly appreciated. We would like to call you to discuss your perspective on the knowledge or skills that are desired and valued in your current position or previous positions that you may have held. We are conducting interviews between January 23 and January 31. The interview will take between 15 and 30 minutes, and I will be calling you.

   To help us schedule an interview with you, please reply with times/days when you would be available for a 15-30 minute conversation. We have listed questions below that we would like to address as part of our conversation. Your participation is voluntary, but cooperation would be greatly appreciated. Notes from the phone interview will be kept in a locked office and, as per ASA requirements, shredded after a period of one year. In addition, electronic versions of the information will be stored excluding any identifying information. Summary information will be reported from this survey be used to improve Masters' level education by better aligning the skills that are taught and the skills that are required in practice."

Thank you,
John Bailer

ASA Workgroup on Master's Degrees
John Bailer (baileraj@muohio.edu) – Chair of the ASA Workgroup on Master's Degrees
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Background:
Bob Rodriguez, President-elect of the American Statistical Association, formed a working group to address the following charge:
Develop guidelines, framed as learning outcomes, for master's degree programs in statistics and biostatistics that are responsive to the needs of stakeholders who employ such graduates. These guidelines will reflect discussions with a variety of stakeholders in business and government to determine the needs of their master's degree-level statistical workforces. These guidelines will assist master's degree programs in statistics and biostatistics to align their curricula with desired outcomes.

Questions:
We would like to start with a few questions about your educational and work experience.

 [D1] Name, Male/Female, Contact information (email/telephone number)

 [D2] Undergraduate Major, Degree, University, Year Degree Received

[D3] Graduate Major, Degree, University, Year Degree Received

 [D4] First Position after receiving the MS/MA
          Title:
          Employer:
          Duties:
          Year Started:

[D5] Current Position
        Title:
        Employer:
        Duties:
        Year started:

We would appreciate your perspective on the following questions that address this charge. In particular, we ask that you consider your responses in the broadest terms possible, with "knowledge and skills" including that which was learned both inside and outside of the formal classroom.

 [Q1] What knowledge or skills did you learn in graduate school that helped you get your first job following receipt of your Master's degree?

 [Q1 Follow-up if applicable] Are there specific areas of knowledge or skills that helped you get another job(s) after your first job?

 [Q2] What knowledge or skills did you learn in graduate school that helped you successfully perform this first job?

 [Q2 Follow-up if applicable] What knowledge or skills helped you perform the job(s) after your first job?

 [Q3] What knowledge or skills do you wish you possessed before starting this first job?

 [Q3 Follow-up if applicable] What knowledge or skills do you wish you possessed before starting the job(s) after your first job?

 [Q4] If you could have swapped one course in your graduate studies for a different course (either an existing course or one that you wish your department offered), what course would you swap out? What course would you add?

 [Q5] What experiences outside of formal graduate school coursework helped you prepare for your first job? What knowledge or skills did these experiences provide?

 [Q5 Follow-up if applicable] What experiences while in graduate school but outside of formal graduate coursework helped you get another job(s) after your first job?

 [Q6] Would you be comfortable providing the name and contact information for the first/most recent person who hired you?

8.	Appendix 2: Survey form for employers – Emailed: September 18, 2012

TO: Colleagues who hire or manage Master's degree statisticians
FROM: Members of the ASA Workgroup on Master's Degrees

Dear colleague:

The American Statistical Association Workgroup on Master's Degrees is trying to understand the types of knowledge and skills needed for Master's level employees to succeed in today's statistical workforce. You were identified as someone who hires or manages Master's degree statisticians, and your help in this important effort is greatly appreciated.

We would like for you to share your perspective on the knowledge or skills that are desired and valued in successful hires. We have listed questions below that we would like to address. We would appreciate it if you would enter your responses to these questions and send your reply to statistics@MiamiOH.edu. Your participation is voluntary, but cooperation would be greatly appreciated. Notes from your responses will be kept in a locked office and, as per ASA requirements, shredded after a period of one year. In addition, electronic versions of the information will be stored excluding any identifying information.

Summary information will be reported from this survey and will be used to improve Masters' level education by better aligning the skills that are taught and the skills that are required in practice." The results of this study will be used to improve Master's level education, and thus produce better-trained statisticians for the workforce. A response by **FRIDAY, October 5** is requested. Your responses are important and will be incorporated in our report. Feel free to contact the chair of the workgroup, John Bailer (513-529-7828; baileraj@MiamiOH.edu) if you have any questions. Finally, feel free to forward this to colleagues who might be involved in hiring or managing Master's degree statisticians.

Thank you,
John Bailer (baileraj@MiamiOH.edu) – Chair of the ASA Workgroup on Master's Degrees
Ron Wasserstein (ron@amstat.org) – Staff liaison to the ASA Workgroup on Master's Degrees
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Questions:

We would appreciate your perspective on the following questions that address this charge.

Questions about your institution.

[D1] What is the name of your institution?

 [Response]

 [D2] What is the nature of your institution's work?

[Response]

[D3] Contact Name and information?

[Response]

Questions related to what characterizes a successful Master's graduate in statistics/biostatistics

[Q0] Are you responsible for hiring or supervising Master's graduates in Statistics/Biostatistics? If not, can you forward this questionnaire to the person responsible for hiring / supervising Master's graduates? Please email us with the contact information for colleagues in your institution with this responsibility.

[Response]

[Q1] If you are interviewing 10 people for a Master's level position, what makes the top 2 stand out for you?

[Response]

[Q2a] Of the Master's level employees you have hired in the past, what has made them successful?

[Response]

[Q2b] Of the Master's level employees you have hired in the past, what deficits did they have to address after starting work with you or your institution?

[Response]

[Q3a] Can you list particular knowledge or skills that are REQUIRED and CRITICAL for Master's level positions?

[Response]

[Q3b] Can you list particular knowledge or skills that are DESIRED for Master's level positions?

[Response]

[Q4] If schools could add one thing to their programs to better prepare graduates for work with your institution, what would that be?

[Response]

[Q5] Can you provide the name and contact information for a recent Master's level hire whom we could contact?

[Response]

9.	Appendix G: Summarized responses from recent graduates

Table G.1:   Graduate responses to Q1] What knowledge or skills did you learn in graduate school that helped you get your first job following receipt of your Master's degree?

Summary Response Category	Number of Respondents*
Programming	12
General math/stat coursework/background	10
Specific areas of statistical analysis/statistical "tools"	10
Communications/writing skills	3
Other statistical experience (consulting, practicum, etc.)	3
Graduate/teaching assistantship	3
Other--Working to be a good student (grades, performance, study habits)	1

*Respondents could report responses falling in multiple summary response categories

Table G.1a: Graduate responses to Q1 Follow-up] **Are there specific areas of knowledge or skills that helped you get another job(s) after your first job?**

Summary Response Category	Number of Respondents*
Programming	3
General math/stat coursework/background	1
Specific areas of statistical analysis/statistical "tools"	1
Communications/writing skills	2
Other statistical experience (consulting, practicum, etc.)	2
Graduate/teaching assistantship	0
Other	0

*Respondents could report responses falling in multiple summary response categories

Table G.3: Graduate responses to Question 3, concerning knowledge or skills graduates wished they had more of in school.

Response	**Freq.**	**Comment**
R, Excel, and other software - including SQL	9	"Everyone here uses Excel"; wish I knew SQL", "more on SAS"
Specific technical areas (regression, categorical data, time series, etc.)	7	"Deeper in regression", "survival analysis", "not enough time series"
Analysis of "real data", including "big data"	5	"computational skills in handling massive data", "hands on applications"
"Soft skills", such as people and consulting skills	3	"interpersonal skills", "communication skills", "presenting and writing"
Project and time management - balancing completeness with accuracy	3	"doing your best given a deadline", "managing a project", "time management"
Problem solving - how to attack a complex problem	2	"the book *Problem Solving* by Chris Chatfield"

Table G.4: Graduate responses to **[Q4] If you could have swapped one course in your graduate studies for a different course (either an existing course or one that you wish your department offered), what course would you swap out? What course would you add?**

Student	Swap OUT	Swap IN
1	none	Longitudinal data analysis
2	No content (maybe instructor)	Genomics
3	Methods in finance	Multilevel models, more "play" with data
4	'how to' write	Missing data
5	Bayesian methods	Experimental design, sampling, structural eq.
6	Propensity scores/latent variables	nonparametrics
7	Math modeling	Biostatistics
8	Real analysis	Programming
9	Accelerated version of programming class	Programming in java
10	none	n/a
11	none	Time series, another machine learning course
12	none	Categorical data analysis, survival analysis
13	Consulting course (not in-depth enough)	SAS/R taught with more computing skills
14	Survey sampling	Longitudinal data, Bayesian methods
15	none	Machine learning/big data/data mining
16	Survival analysis (maybe)	Databases
17	Ethics for medical research	Nonparametrics
18	Genetics/bioinformatics	Simulations
19	Genetics (don't use in current role)	Another SAS class
20	Stat theory/prob	Higher level epidemiology
21	genetics	Generalized linear models
22	One of theory courses	Nonparametrics (applied)
23	none	Repeated measures
24	One of math analysis courses	Logistic / Poisson regression
25	Stat computing(graphical models)	Survival analysis/designing clinical trials
26	none	Advanced time series; more financial or applied or programming
27	Stat computing (3 courses)	Courses in SAS and R
28	Bayesian methods intro	Survival analysis
29	Linear models 2nd courses (insufficient coverage)	Linear models 2nd course (sufficient coverage)

10.	Appendix E: Summarized responses from employers

Table E.1: Employer responses to [Q1] If you are interviewing 10 people for a Master's level position, what makes the top 2 stand out for you?

Response	Freq	Comment
Communication - [C]	14	"[C] skills"; "explain stat methods orally and in writing"; "writing skills"; "both written and verbal"; "verbal and written"; "provide brief, clear, and technical explanations of analysis" "[C]"; "excellent [C] skills"; "great [C] skills"; "good oral and written [C]"; "[C] stat knowledge and/or techniques in a sensible manner"; "written and verbal [C] skills"; "strong [C]skills"; "effectively [C] complex topics"; "[C] skills- ability to relay info at appropriate technical levels to reports, peers, and senior execs";
Programming – [P]	11	"[P] skills"; "elegance in [P]"; "experience [P] data collection surveys"; "using statistical analysis software, especially SAS"; "strong [P] background"; "SAS [P] skills"; "extensive computer [P] experience"; "SAS [P] course"; "[P] experience in SAS"; "familiarity with stat software, including SAS and R"; "strong database access and data manip. abilities (we use SAS)"
Statistical knowledge	10	"applied analysis skills"; "strong statistical background"; "thorough statistical understanding"; "strong statistical background (courses and grades)"; "strong technical ability"; "better technical skills"; "solid understanding of statistical methods and procedures"; "knowledge of MS level statistics"; "technical skills"; "able to build models"
Attitude	8	"enthusiasm"; "professionalism"; "work ethic, emotional intelligence"; "good personality"; "interpersonal skills, work ethic"; "interpersonal skills"; "attention to detail"; "passion and excitement when they talk about their interest in analysis";
Think/ problem solving	7	"logic and thinking"; "can think through problems"; "use stat analyses in critically thinking through a research design and subsequent analysis"; "good intuition for data and for statistical thinking"; "ability to conceptualize and implement an independent project"; "solid critical thinking abilities – logical flow to problem solving"; "strategic sense – understand why analysis is important to the business"
Collaboration/ teamwork / leadership	5	"collaboration skills"; "experience working in teams"; "leadership potential"; "management skills"; "leadership – don't just take orders but own projects"
Relevant specific coursework/ experience	4	"clinical trials and relevant disease areas"; "coursework and work experience in survey research"; "good knowledge of sampling theory and sample survey design"; "more advanced statistical knowledge"
Recommendations / academic record	3	"letters of recommendation"; "emphasis on GPA"
Project work	3	"will take ownership of assignment"; "track record of working independent"; "demonstrated creativity";
Experience	3	"work experience/internships"; "relevant experience"; "some external work experience like internships [beyond stat consulting experiences;
Real project experience	2	"cleaning, managing and analyzing real data"; "solving real world problems"
Faculty reputation/ rep.	2	"… of the faculty in survey research"; "quality and reputation of the academic organization they attend"
Research	1	"record of publications";

Table G.5: Graduate responses to **[Q5] What experiences outside of formal school coursework helped you prepare for your first job? What knowledge or skills did these experiences provide?**

Response Category	Frequency	Comments
1. Work Between BS and MS	12	"(worked) between BS and MS degrees"; "worked as nanny…learned how to deal with younger people"; high school football coach"; project management as a superintendent on a construction worksite"; "Interactions with folks…other than statisticians"; "SAS in a job…before graduate school"; "taught high school mathematics…before returning to graduate study"; data management from previous jobs"; "doing some free-lancing (in statistics)"
2. (Summer) Internship	10	"(helped me) do stuff on (my) own"; "collaborative experiences working with folks who weren't statisticians"; "…helped with the development of teamwork (skills)…"
3. Teaching Assistantship	3	"…made (me) more comfortable dealing with people"
4. Research Assistantship	3	"provided real world experiences"
5. Seminar Attendance	3	
6. Programming Skills	2	"learned to work with real data and its messiness and anomalies"
7. Other	2	"Network of graduates from the Ma program has been very useful"; "extracurricular activities".
TOTAL	35*	

*Some of the 29 respondents mentioned more than one experience.

| 10. Appendix G: Summarized responses from recent graduates |

Table E.0: Type of institution for employers responding to questionnaire.

Type of organization hiring MS Stat graduate	n
University-based collaborative studies/academic med. research [2]	5
Federal government	3
Contract research organization	2
Research / survey organization	2
Financial / banking	2
Consulting (clinical trials)	1
Public policy non-profit	1
Pharmaceutical	1
Consumer products	1
Clinical research organization	1
Manufacturing	1
Market research	1

[1]Some employers responded based on experience in hiring for two different industry types
[2]Includes academic departments, coordinating centers, research hospital

Table E.1: Employer responses to [Q1] If you are interviewing 10 people for a Master's level position, what makes the top 2 stand out for you?

Response	Freq	Comment
Communication - [C]	14	"[C] skills"; "explain stat methods orally and in writing"; "writing skills"; "both written and verbal"; "verbal and written"; "provide brief, clear, and technical explanations of analysis" "[C]"; "excellent [C] skills"; "great [C] skills"; "good oral and written [C]"; "[C] stat knowledge and/or techniques in a sensible manner"; "written and verbal [C] skills"; "strong [C]skills"; "effectively [C] complex topics"; "[C] skills- ability to relay info at appropriate technical levels to reports, peers, and senior execs";
Programming – [P]	11	"[P] skills"; "elegance in [P]"; "experience [P] data collection surveys"; "using statistical analysis software, especially SAS"; "strong [P] background"; "SAS [P] skills"; "extensive computer [P] experience"; "SAS [P] course"; "[P] experience in SAS"; "familiarity with stat software, including SAS and R"; "strong database access and data manip abilities (we use SAS)"
Statistical knowledge	10	"applied analysis skills"; "strong statistical background"; "thorough statistical understanding"; "strong statistical background (courses and grades)"; "strong technical ability"; "better technical skills"; "solid understanding of statistical methods and procedures"; "knowledge of MS level statistics"; "technical skills"; "able to build models"
Attitude	8	"enthusiasm"; "professionalism"; "work ethic, emotional intelligence"; "good personality"; "interpersonal skills, work ethic"; "interpersonal skills"; "attention to detail"; "passion and excitement when they talk about their interest in analysis";
Think/ problem solving	7	"logic and thinking"; "can think through problems"; "use stat analyses in critically thinking through a research design and subsequent analysis"; "good intuition for data and for statistical thinking"; "ability to conceptualize and implement an independent project"; "solid critical thinking abilities – logical flow to problem solving"; "strategic sense – understand why analysis is important to the business"
Collaboration/ teamwork / leadership	5	"collaboration skills"; "experience working in teams"; "leadership potential"; "management skills"; "leadership – don't just take orders but own projects"
Relevant specific	4	"clinical trials and relevant disease areas"; "coursework and work

coursework/ experience		experience in survey research"; "good knowledge of sampling theory and sample survey design"; "more advanced statistical knowledge"
Recommendations / academic record	3	"letters of recommendation"; "emphasis on GPA"
Project work	3	"will take ownership of assignment"; "track record of working independent"; "demonstrated creativity";
Experience	3	"work experience/internships"; "relevant experience"; "some external work experience like internships [beyond stat consulting experiences;
Real project experience	2	"cleaning, managing and analyzing real data"; "solving real world problems"
Faculty reputation/ rep.	2	"… of the faculty in survey research"; "quality and reputation of the academic organization they attend"
Research	1	"record of publications";

Table E.2a: Employer responses to [Q2a] Of the Master's level employees you have hired in the past, what has made them successful?

Response	Freq	Comment
Attitude / Personality	14	"passionate about the job … want to know/learn more… to dig deeper into the data to find hidden insights … desire to own and hold themselves accountable to their projects"[1]; "strong attention to detail and initiative do well"; "meet deadlines consistently"; "willingness to learn, being a quick learner…He or she was self-motivated and had good interpersonal skills"; "Flexibility, willingness to learn"; "desire to learn new statistical methods and clinical issues "; ability to adapt to changing topical areas of study" ; willingness to learn new things"; "personal organization, motivation … , flexibility to adapt to changes"; "good interpersonal skills"; "ability to quickly learn and apply new methodologies; versatility"; "Ethic of hard work … Well organized …Interested in growing their skills"; "care and attention to detail … interest in research, assertiveness and willingness to grow technically and to take on more responsibility, organization skills" ; "Attention to details. Organized and disciplined"; "interpersonal skills, work ethic";
Communication - [C]	12	"[C]"; "good oral and written [C} skills"; "[C] skills"; "Very good writing skills … Excellent command of the English language"; "Clear [C] skills"; "[C] skills"; "writing skills, and ability to explain technical concepts in a nontechnical manner"; "Excellent verbal and written [C] skills"; "ability to [C]"; "Good [C} skills"; "good oral and written [C]" ; "able to [C} statistical knowledge and/or techniques in a sensible manner";
Statistical knowledge	10	"solid knowledge of statistics"; "knowledge of statistical techniques"; "solid educational background with the right mix of statistics, science, and programming classes"; "strong statistical background"; "strong analytic abilities"; "sound statistical knowledge"; "Technically competent in basic and intermediate statistical methods"; "MS Level stat knowledge"; "strong stat bkgd"; "Degree of understanding of methods";
Programming – [P]	10	"at least some SAS [P] experience beyond writing short snippets of code for course work"; "strong data management skills with SAS [P] expertise"; "… and [P] classes … initiative to learn new statistical and SAS [P] techniques"; "Very good [P] skills"; "strong SAS [P] skills"; "SAS skills"; "Willing and interested in cleaning and managing data and [P] online surveys"; '{P] experience in SAS"; "extensive computer [P] experience"; "Elegance in [P]"
Collaboration/ teamwork / leadership	10	"ability to adjust to a business environment quickly and work in a team setting"; "leadership skills that make them a good team player"; "ability to work cooperatively and effectively on a team"; "ability to work as part of a team"; "ability to work increasingly independently alongside Ph.D. researchers"; " leadership skills", "Teamwork"; "Ability to work independently, but knowing when to ask questions of PhD statisticians and PIs"; "Team-player"; "take ownership of his or her assignment";
Think/ problem solving	6	"creativity"; "Ability to develop innovative solutions to new and existing problems"; "ability to "see the big picture" , ability to problem solve and "think outside the box"; "creative thinking in terms of research design"; "use logic and think … ability to see the potential of linking solutions, systems and people"; "sense that the person can think through problems"
Experience	2	"some internship experience"; "external work experience"
Other	1	"interest in the organization's mission";

Other comments:
[1] – when an issue arises they take ownership and work to rectify any mistakes that have been made. Employees who challenge themselves and those around them to be better are also much more successful in our organization

Table E.2b: Employer responses to [Q2b] Of the Master's level employees you have hired in the past, what deficits did they have to address after starting work with you or your institution?

Response	Freq	Comment
Programming – [P]	9	"Lack of good [P] skills"[1]; "lack of SAS [P] skills"[3]; "often needed time to learn SAS"; "Lack of data management / documentation skills"; "Limited computer [P] skills, which are needed to disseminate results of innovation"; "Some need to build up their statistical [P] knowledge"[4]; "Success was perceived if a program "ran" successfully, regardless if it ran on the wrong data or was not the most effective way to gain insight on the research problem at hand"; "SAS [P] skills"; "Needing to learn more than one [P] language";
Communication - [C]	6	"lack of written [C] skills (especially for non-US born MS)"; "[C] skills, particularly written"; "technical writing skills"; "Poor writing"; "Writing and verbal skills"; "How to [C] results … write a memo … give a presentation …listen …to be heard … interact with a client";
Statistical knowledge	5	"Not having firm grasp of basic statistical knowledge is another"; "Learning when to apply particular techniques and the nuances of analysis"; "general knowledge about how to collect data and identify/correct dirty data issues"[5]; "not able to apply theory to specific problems"; "shallow understanding of methods";
Relevant specific coursework/ experience	5	"limited training in survey research"; "not taken a rigorous sampling course as well as variance estimation"; "often lack understanding of the basic components of pharmaceutical clinical trials"; "less technical training and experience in survey research, gaining those skills"; "Lack of medical background knowledge";
Real project experience	4	"not much real world application of statistical methods and procedures in classwork"[2]; "Lack of experience with real world, messy data sets"; "Inability to assess how long an assignment will take"; "Real-world experience";
Think/ problem solving	4	"strong attention to detail"; "was lack of discipline in checking their own work"; "Illogical thinking"; "How to find the right problem to solve … think about the big picture … move from an individual contributor (transactional consultant) to a strategic thinker … need to double check your work from a technical and a 'does it make sense' perspective";
Attitude/ Personality	3	"Inability to work independently – needing too much structure"; "Failure to take responsibility for their work"[6]; "Timid about speaking-up";
Collaboration/ teamwork / leadership	3	"Developing leadership/management skills"; "Cultural issues in working in a group or with clinicians"; "Failure to be able to work effectively in a team … often a fatal flaw";

Other comments:

[1]"Another thing I have noticed in interviewing is that many schools are now using R for most of the course work. This is a disadvantage to a candidate, because the industry is still heavily using SAS. It also makes it difficult to assess a candidate, if the interviewers do not have experience with R. Having taken a one semester SAS programming course does NOT help, because the interviewers expect a more thorough knowledge of SAS/STAT."

[2] "what would be helpful to students (and I would have liked more of this while I was in graduate school) is a class related to receiving "random" projects (possibly work brought in from other departments) that challenge students to internalize the question and then identify the right solution to solving the problem"

[3]Most MS level employees spend a significant amount of time doing SAS programming and some of the programming can be very complex.   This programming isn't "PROC" programming but more involved with data manipulations and simulations and producing report ready tables, figures, and listings

. Though new hires must have at least some statistical programming expertise, we hire people primarily for their ability to be strong analysts and expect they will pick up enough programming skills to be efficient. However, other more programming-oriented positions would require strong programming skills from day 1.

[5] Those who worked in a research setting while in graduate school tend to have the data cleaning knowledge, and ALWAYS start out with an advantage.

[6] This is the most serious failing and not something we have been able to fix. It seems to be an integral part of some people's personality.

… Employees who didn't know a specific statistical technique (e.g. Poisson regression) can be taught this fairly easily so that hasn't been as much of an issue, as long as the employee came from a program that had a solid statistics program (e.g. stat theory, linear models theory, etc)

… deficits in particular needed statistical techniques, but that knowledge set was not necessarily expected in a masters level candidate. As long as the candidate was willing to learn on-the-job, these technique deficits could be easily overcome. Poor communication skills or a hard time in seeing the larger picture were harder to address.

… We have seen a rise in the emphasis on consulting skills in many Master's programs. This is nice, but it does not help if you don't have a good statistical toolkit, are not a good problem solver, and cannot think about or apply logic to problems.

Table E.3a: Employer responses to [Q3a] Can you list particular knowledge or skills that are REQUIRED and CRITICAL for Master's level positions?

Response	Freq	Comment
Statistical [S] knowledge	16	"variability and sources of variability .. sensitivity and robustness … difference between an experimental unit and an observational unit .. to model even in situations of high correlation among predictor variables"; "Good [S] training is essential"; "prob selection methods – survey estimation – sampling errors"; "understand survival analysis"; "basic through intermediate [S]methods"; "basic stat inf."; "ability in [S] models"; "solid knowledge of …"; "strong bkgd fundamental coursework"; "good grounding in [S]"; "Extensive knowledge of the application of mathematical [S], probability theory, and sampling"; "math/stat theory … linear models theory … [S]methods"; "Exposure to a variety of [S]techniques, and the ability to identify the correct procedure to use when presented with a business case"; "Solid knowledge of basic [S], linear models, …"; "strong technical bkgd"; "strong stat bkgd"
Communication - [C]	12	"able to summarize their results in words"; "ability to write and speak clearly"; "good oral & written skills – expertise in 'effectively' creating tables and visual display of data"; "verbal and written [C] skills"; "[C] skills are important"; "technical writing and oral presentation skills"; "Good [C] skills"; "Able to [C] complex or technical information in a straightforward manner"; "Written [C] Skills…Oral [C] /presentation skills"; "Interpretation of output – what does it mean? What story does this tell?"; "[C]"; "excellent [C] skills";
Programming – [P]	10	"knowledge of at least one mainstream stat pkg"; "proficiency with SAS"; "stat software acumen (SAS, Stata, R, etc.)"; "SAS [P] skills"; "Facility with some advanced statistical software (SAS preferred but not required)"; "ability to use computer software to analyze data"; "SAS [P] including data manipulations, macro language, graphics, report generation, simulation"; "Good knowledge of Base SAS including basic data manipulations and

		formatted report generation, macros and SQL. SAS/STAT procedures relevant to …"; "strong data mgmt. skills with SAS [P] expertise"; "strong [P] bkgd"
Collaboration/ teamwork / leadership	5	"Team player"; "well organized … meet deadlines"; "interpersonal skills"; "Ability to work both independently and as part of a team"; "leadership skills that make them a good team player"
Attitude	4	"Positive, 'can-do' attitude"; "Good attitude. Ability to adapt and grow (if they have this then they can get most of the other necessary skills)"; "willingness to clean, manage and analyze data AND to learn how and to program online surveys"; "good personality"
Think/ problem solving	3	"Attention to detail"; "understand the structure of a study so that they can formulate a sensible analysis plan'; "strong attention to detail and initiative do well"; "know how to look at data & recognize problems"
Relevant specific coursework/ experience	5	"analyze survey stat from complex designs"; "thorough understanding of systems … depending on area of application … biological and ecological systems"; "background in time series"; "Study design/sample size calculations for non-complex studies"; "construct (and understand the pros and cons) of Fractional Factorials, CCDs, PBs …"
Project work	3	"fully engaged with projects and operate proactively, asking questions when instructions are not clear or results do not make sense"; "good project development and management skills";
Other	2	"relevant experience"; "Excellent recommendations"

Table E.4 Employer responses to [Q4] If schools could add one thing to their programs to better prepare graduates for work with your institution, what would that be?

Response	Frequency	Comment
Writing	5	"better writing"; "able to write more clearly"; "technical writing"
Speaking	4	"ability to 'talk' about statistical issues"; "better speaking"; "oral communication"; "presenting results"
Project participation	4	"attention to detail"; "analysis planning"; "initiative"; "organizational skills"
Programming	4	"SAS programming"; "good programming practice (…error free … easy for others to access"); "data management"; "working with large data sets"; Advanced SAS certification"
Real, significant data analysis	4	"applied training on a real project"; "in depth data analysis project"; "more practice with actual data"; "exposure to real world business problems"
Problem solving	3	"emphasis on how to think [about problems]"; 'when problems are not textbook"; "innovate [for non-routine problems]";
Statistical content	2	"survey sampling"; "emphasis beyond analysis (design)"