

## Industry Supported Semiconductor Test Engineering Academic Survey and Round-Table at Texas A&M University

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### Abstract

This paper describes the research and process involved in validating the academic relevance of a University level curriculum in Semiconductor Test. Several universities have found educational benefit and Industrial support in a focused curriculum and study of Semiconductor Digital and Mixed Signal Test. Texas A&M University Electronics Engineering Technology (EET) Program, within the Dwight Look College of Engineering, has a world class Test lab. This lab, supported by Texas Instruments and Teradyne Inc., has been teaching Mixed Signal test at the undergraduate level for over 12 years. The Lab faculty and staff were interested in the technical relevance of their curriculum and engaged an Industry standards organization to co-sponsor an industry-based survey. SEMI's Collaboration of Automated Semiconductor Test (CAST) was chosen and agreed. This survey polled engineers, managers, and professionals within the semiconductor industry with Test Engineering questions, which revealed specific feedback on what they would like college new hires to know before reporting to work. Feedback and results from 144 mostly senior level Industry colleagues are summarized.

To help understand the significance and validity of the survey itself, the survey was presented at the Industry and Academia Roundtable (IAR) at Texas A&M in May 2010. The process reviewed the survey questions, discussed the raw responses, debated the analysis and condensation of data, and approved the final summary statements derived from the survey. The mixed audience, thirty one in all, Test professionals from eight different companies and test aware faculty from four Universities were all part of this review. The survey questions covered the topics of programming languages, test tools, test concepts, and the repertoire of test devices. The Roundtable was also a forum for debate of other academic topics, but those discussions are left for a subsequent paper.

## **Introduction**

A major tenet of any physical system or engineering design is to keep the system under control with some kind of feedback or control loop. The same philosophy can be used to monitor and improve other less physical systems in our environment. This basic engineering principle was the driving force behind a closed loop review and monitoring of the Semiconductor Test industry employment skill needs, and the Test Engineering curriculum output at Texas A&M University. This closed loop review resulted in a complex and detailed data intensive result. We decided to break the loop into two topics. This paper reflects the first topic: the research and process involved with soliciting industry feedback and validating it.

A second paper will take the validated data from industry and correlate it with the Texas A&M University/ETID Electronics Engineering Technology curriculum, and seek validation of the curriculum with industry needs.

Texas A&M University chose to partner with the standards body called CAST (Collaboration of Automated Semiconductor Test) under the organization of SEMI. The industry based survey, created and co-sponsored by these two organizations polled engineers, managers, and professionals within the semiconductor industry. Industry was to provide specific feedback on what they would like Test Engineering new hires to have learned before reporting to work.

## **Industry Survey Commissioned**

To provide the broad Industry feedback necessary for a reliable survey and study, we needed to partner with an organization that had the infrastructure, and similar educational interests to support our goals. We were delighted to work with Paul Roddy, chairman of CAST, operating under the SEMI standard's organization. Paul, with the Texas A&M Mixed Signal Test lab staff, authored a set of five polling questions. These questions were reviewed several times for understanding and purpose. One review cycle even included select members of the CAST membership. Once the questions were optimized, the survey was web posted for availability to full CAST membership. We were pleased to have 144 responses, especially after review of the credentials of the respondents. Thirty replies came from members with titles of either Director or VP. Thirteen were from company Presidents. Twenty-one claimed a position of manager, twenty-nine listed Engineer within title, and three were listed with the prestigious title of Fellow. Within the same population of 144 responders, a group of 20 were also identified as working directly for the hardware vendors that supply the capital equipment for the ATE market. For a deeper understanding of the polled responses, statistics were calculated separately and tallied uniquely for this subset of the responder's population.

## **Industry Survey Analysis**

To help understand the significance and validity of the survey itself, the survey was presented at the Industry and Academia Roundtable (IAR) at Texas A&M University in May 2010. The process reviewed the survey questions, discussed the raw responses, debated the

analysis and condensation of the data, and approved the final summary statements derived from the survey. Thirty-one test professionals and test aware faculty were in attendance at the May 2010 IAR. The Roundtable had a total attendance/representation of nine companies and seven universities. The survey questions polled responses from the topics of programming languages, test tools, test concepts, and repertoire of DUTs (Devices Under Test) experiences.

### **Survey Analysis Methodology**

The questions of the survey were written in such a way as to gain a relative priority of the reported answers. We asked for the responders to rank each answer with a priority number. The first survey question is copied below as an example of the style and wording used in the survey. The question opens the topic, and then a list of answers is supplied to gather the technical significance and priority of each.

#### **Example survey question (question number 1)**

**If you had a choice of the tools you would like your college new hires to already be conversant with – what would those tools be? (Select and rank the top 5.)**

- PC board design rules and constraints
- Software for test development (Identify type: IG-XL, etc.)
- Software for validation and analysis
- CAD tools overview
- Testers and automated test methods
- Bench tools and basic electronic measurements (Scopes, meters, signal generators)
- Other

Survey questions 1, 2, and 5 have between seven and eight answers, but we requested the responders to prioritize only the top five with a number between 1 and 5. Questions 3 and 4 have many polling answers, so we requested a priority of only the top ten. We expected a value that rated that particular answer as a number between one and ten (for questions 3 and 4). This was a benefit to the understanding of the survey, but did cause some extra complication in the data condensation.

The result of each question's data condensation is a detailed chart that summarizes several complementing methods of data analysis. To help with explanation of these methods, question 1's summary chart is copied below as an example (see Figure 1). A brief description of the calculation and analysis methods will follow.

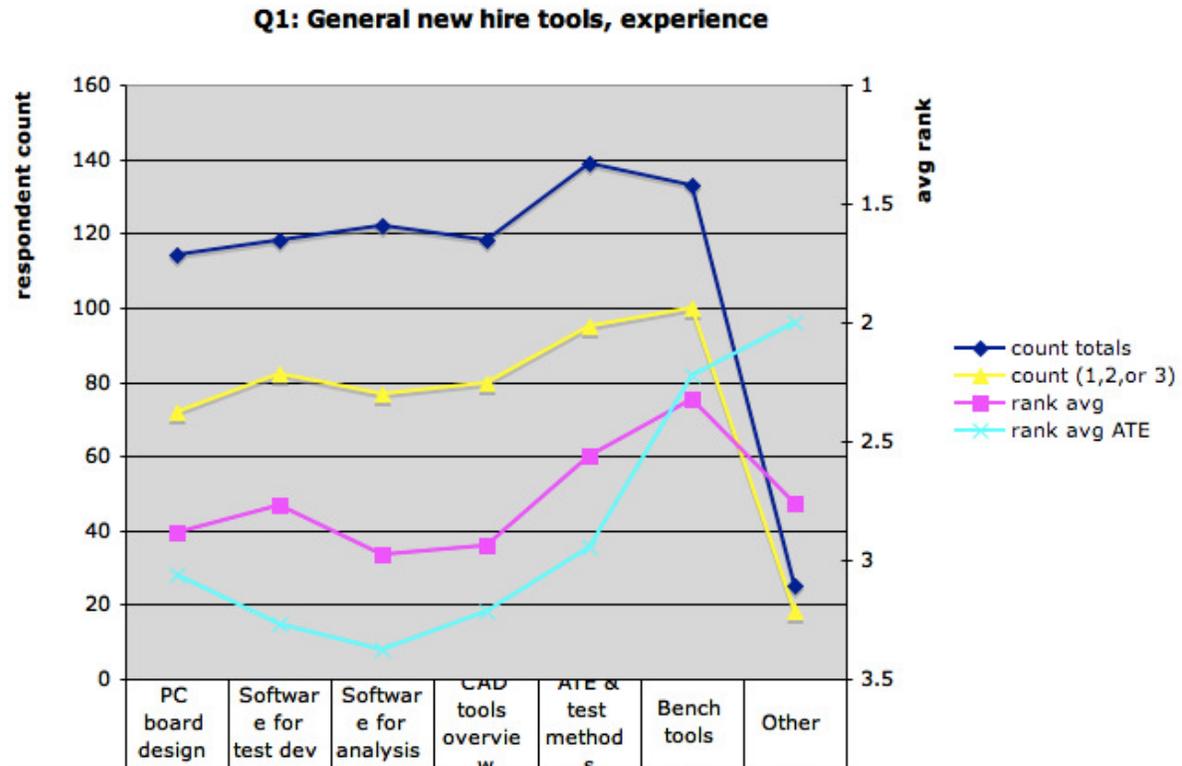


Figure 1: Example of Summary Chart

The four analysis methods:

1. Chart total respondents count (respondent cared to give any vote). (population 144)
2. Chart respondent's count that were either a 1, 2, or 3 (top priorities).
3. Chart the average score (rank or priority) of each answer. (=sum /count)
4. Chart the average score (rank or priority) of ATE vendor professionals only. (=sum/count of ATE population 20)

We then charted the top 3 selections of each analysis method using black dropping arrows in order to report the overall weighted score (using overlap of all 4 methods listed above). In general, the 4 methods of summarizing the raw data were used to help validate the data itself. In nearly every case, that is for all 5 questions, the summary trend using any one of the analysis methods was very similar. The dropdown arrows that mark the top 3 selections from each analysis method for question #1 is shown in Figure 2 on a following page. In general this visual mapping overlap tool did help to make the IAR audience more comfortable with the overall consensus of the data.

## **Detailed Methodology using Question 1 as our example**

The first calculation within the summarization of the polled data was to sum up the answers that were given any vote at all, no matter the priority. If the respondent took the trouble to give the answer any numerical vote, that answer was tallied. Looking at the summary chart for question #1 (Figure 2), notice the top line (blue) on the chart that has a total count of 139 for the fifth answer annotated as “ATE & test methods”. This answer was the top selection using this analysis method. From the population of 144 respondents, 139 selected this answer with some level of priority. The second highest choice using this total count method is answer six, “Bench Tools”, with 133 votes, and the third highest selection was “Software for Analysis” with 122 votes. Figure 2 also has the count of answers that were voted with a priority ranking of at least a 3, 2, or 1. The second graphed line from the top (yellow) has a max or high point of 100 on the sixth answer annotated as “Bench Tools”. One hundred of the 144 respondents selected answer six within their top three priorities. Second choice using this method of only counting the vote if the priority was 3, 2, or 1 was answer five “ATE & Test methods” with 95 votes, and third place with 82 votes was answer 2, “Software for Test Development”.

The next two graphed responses (purple and light blue) are attempts to summarize the relative priority value of the answers that were reported on the survey. These lines are mapped to the right axis, and are the calculation of “average” of all the values that were reported for the element. Because there are 7 answers for the first question, the priority could be a number between 1 and 7 (however we requested only a ranking of 1 through 5). The calculation of “average” was accomplished with a simple sum of all numerical values entered, divided by the count of responders that entered any value for that answer. By design the respondent that did not annotate any response for a particular answer did not influence the numerator or denominator of the SUM/COUNT equation. The last charted line is similar to the average rank calculation, but uses data only from the subset of the 20 voting members that were denoted as working for an ATE vendor company.

The survey questions will be copied into this report in a very similar format and style as they were listed on the actual survey website. The final numeric priority given to each answer is listed in red font to speed the readability for the interested reader. Of course, the red annotation was not available at the time of original survey posting. Following the survey question with red font annotating overall rank order is the detailed chart with responses and analytical summary per question.

## **Industry survey of New Hire Test Engineering Technology Questions and results:**

On the following pages you will see the questions and results as returned from the survey.

Question 1:

**If you had a choice of the tools you would like your college new hires to already be conversant with – what would those tools be? (Select and rank the top 5.)**

- 5 PC board design rules and constraints
- 3 Software for test development (Identify type: IG-XL, etc.)
- 4 Software for validation and analysis
- 6 CAD tools overview
- 1 Testers and automated test methods
- 1 Bench tools and basic electronic measurements (Scopes, meters, signal generators)
- Other

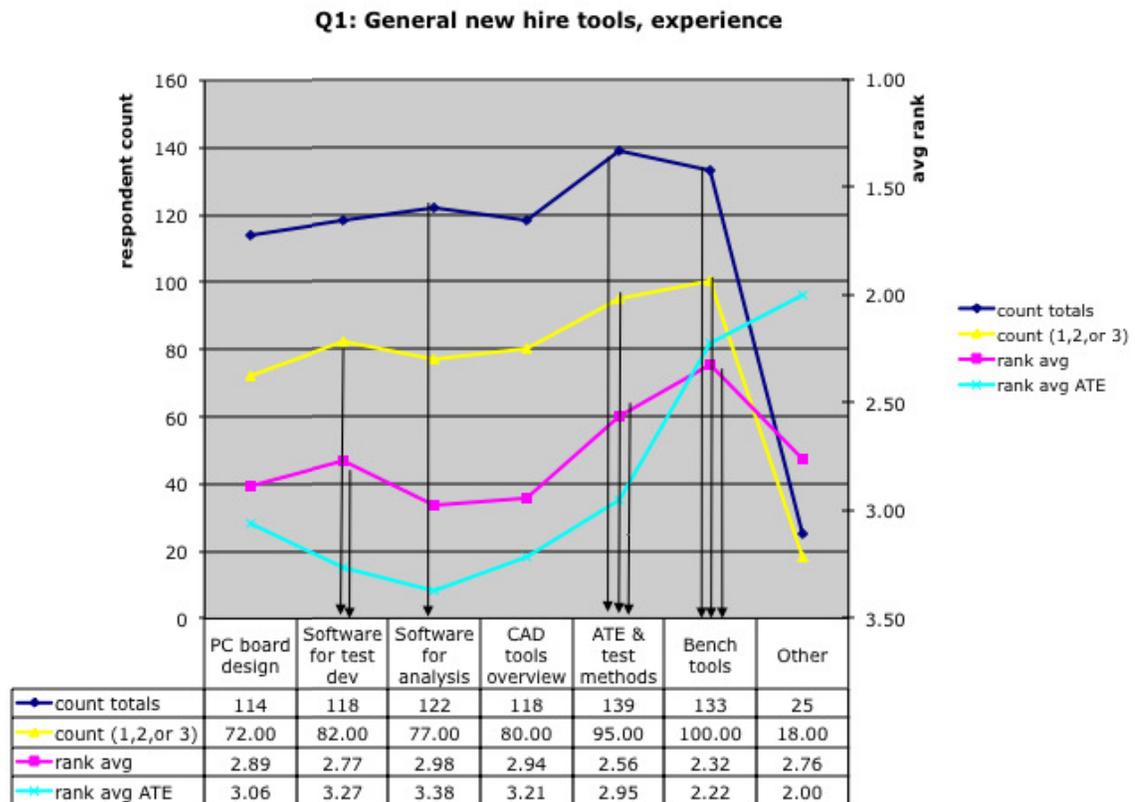


Figure 2: Results of question #1, General New Hire Tool set.

Question 2:

**If you had a choice of the programming languages you would like your college new hires to be conversant with – what languages would you choose? (Select and rank the top 5)**

- 2 C
- 1 C++
- 4 Java
- 5 Perl
- 3 Visual Basic (Identify type: VB, VBA, VBT)
- 6 Ruby ( open-source, multi-paradigm, interpreted programming language)
- Other

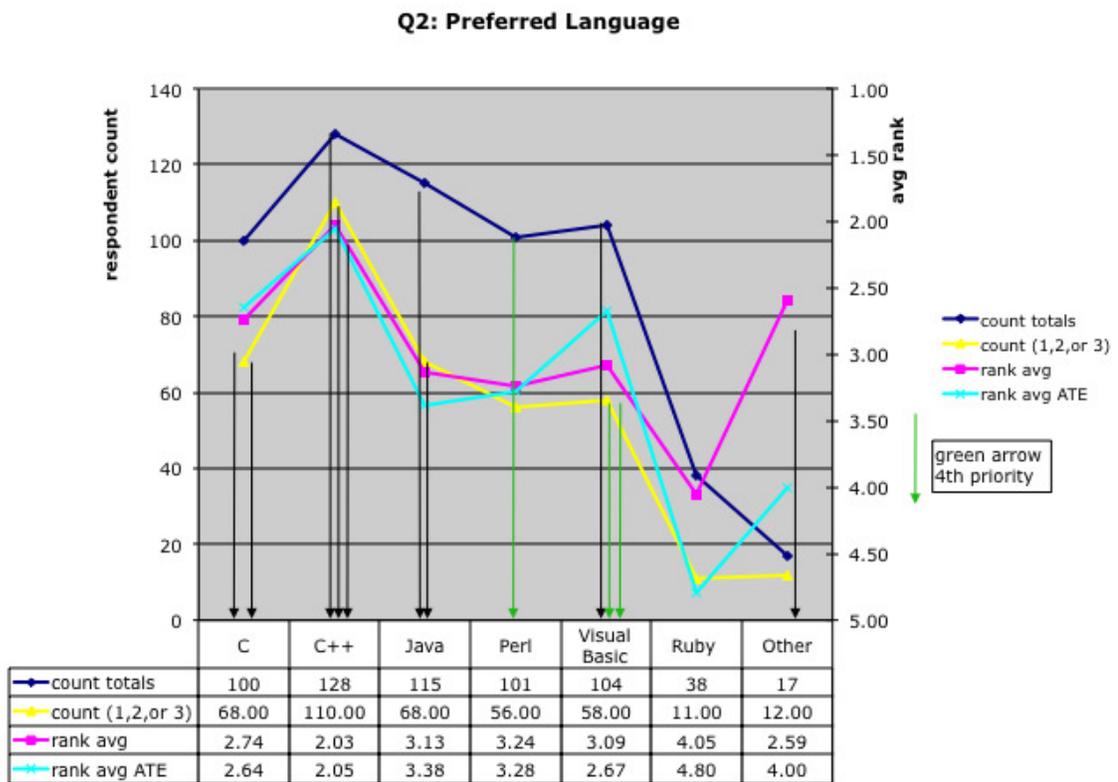


Figure 3: Results of question #2, Preferred language.

Question 3:

**If you had a choice of what devices you would like your new hires to have already tested, would they include: (Select and rank the top 10)**

- \_\_\_ Resistors
- \_\_\_ Capacitors
- 5 Operational amplifiers
- \_\_\_ Counters
- \_\_\_ Voltage regulators
- \_\_\_ FETs
- \_\_\_ Digital to analog converters
- 4 Analog to digital converters
- 2 Microprocessors and/or general logic
- 3 RF components
- 1 Mixed-signal devices
- \_\_\_ Other

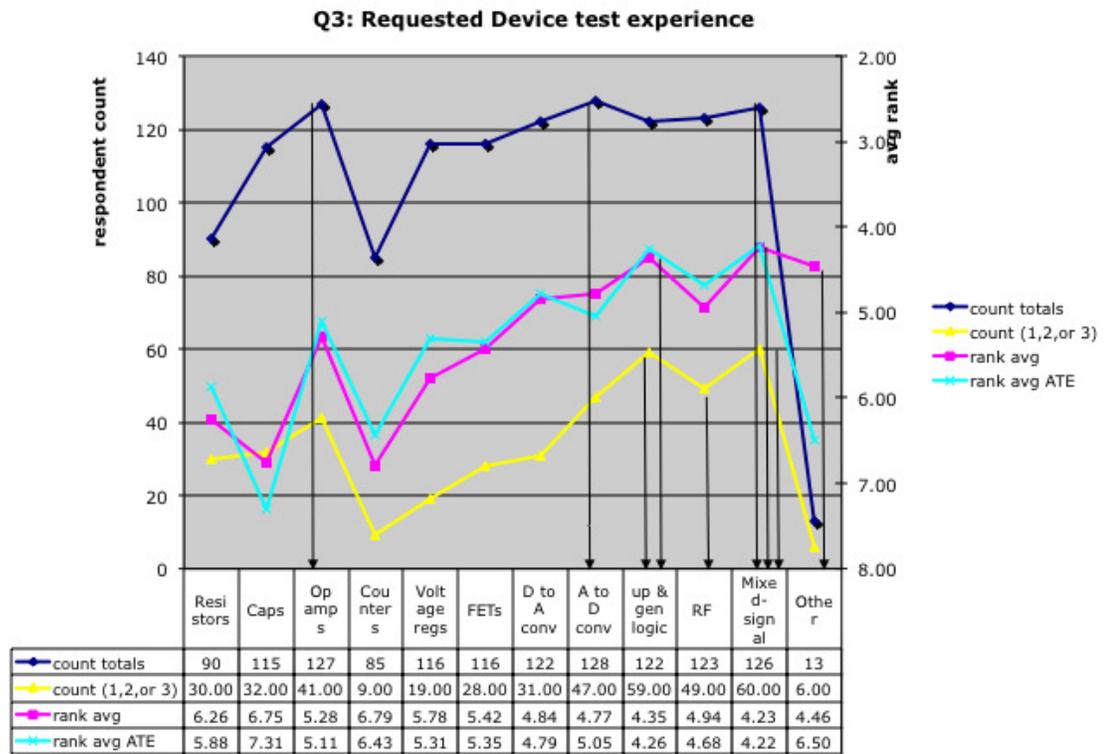


Figure 4: Results of question #3, Requested Device test Experience.

Question 4:

**If you had a choice of concepts you would want college new hires to already be familiar with – what would they be: (Select and rank the top 10)**

- |  |  |
|--|--|
| <input type="checkbox"/> Kelvin connections                            | <input type="checkbox"/> BIST techniques                       |
| <input type="checkbox"/> Coherent sampling                             | <input type="checkbox"/> Test safety                           |
| <input type="checkbox"/> FFT   | <b>4_Test program development process</b>                      |
| <input type="checkbox"/> RF interconnections                           | <input type="checkbox"/> Test time reduction                   |
| <b>2_Analog measurement</b>  | <input type="checkbox"/> Adaptive test                         |
| <b>3_Instrumentation ranges and accuracies.</b>                        | <input type="checkbox"/> The economics and logistics of test   |
| <input type="checkbox"/> Mechanical measurement concept and tolerances | <input type="checkbox"/> Quality assurance (AQL)               |
| <input type="checkbox"/> High speed interconnection                    | <b>6_Statistical process control (SPC)</b>                     |
| <input type="checkbox"/> High current interconnection                  | <input type="checkbox"/> Mechanical measurement and tolerances |
| <input type="checkbox"/> Low current interconnection                   | <b>5_Project management</b>                                    |
| <input type="checkbox"/> Logic Scan testing                            | <b>1_Problem solving techniques</b>                            |
| <input type="checkbox"/> Memory Test Algorithms                        | <input type="checkbox"/> Other                                 |

**Q4: Test Concepts**

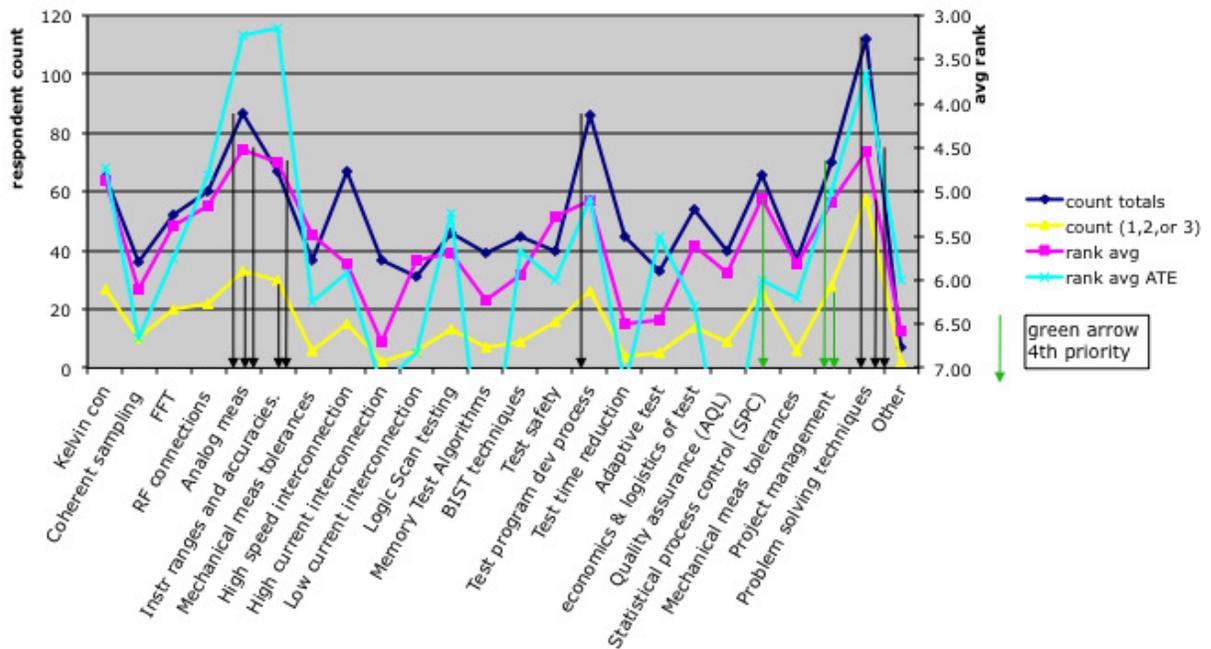


Figure 5: results of question #4, Test Concepts.

Question 5:

**What other skills would you consider useful? (Select and rank the top 5)**

- 4 \*Specific Data analysis tool use
- 1 Basic understanding production test – probe/final
- 2 General understanding of device packaging
- \*Specific Semiconductor Device physics
- \*Specific Data management tools
- 3 General Networking and automation
- General Clean room environment
- Other

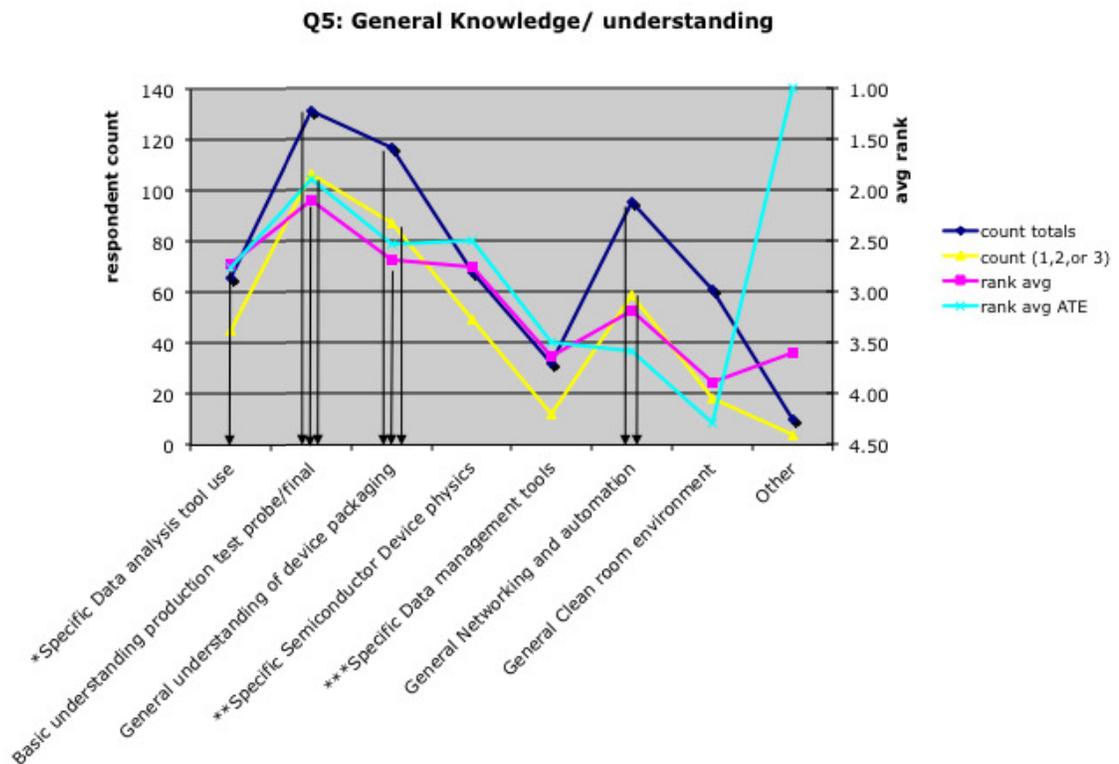


Figure 6: Results of question #5, General Knowledge and Understanding

### Industry Academia Roundtable Review

Texas A&M wanted to create a meeting or forum for a different kind of technical exchange between Industry and Academia. The outcome was a conference and gathering in May of 2010 in College Station on the campus of Texas A&M University by a select group of Test professionals from both Industry and Academia. The IAR Mission Statement seems a bit altruistic, but is listed below:

“Creating Industry and Academic cooperation, involvement, collaboration, and understanding on a continuous basis”

The key word in the statement is “understanding”. It had become clear that Industry and Academia were sometimes using the same words with different meanings. The best description and overall purpose of the conference was to address the type of questions listed in the IAR Standing Agenda and Challenge Questions:

- ALL: What engineer types (DFT, Product, & Test) can best be produced on the undergraduate level and which require graduate level education?
- ACADEMICS: What is the difference between EE and ET Departments, goals, etc?
- INDUSTRY: What are your challenges in the next 2 to 5 years which the Universities should know about?
- ACADEMICS: Which, if any, existing University courses could be adapted to meet needs not covered elsewhere?
- INDUSTRY: What are the key areas of new technology/process/equipment/tools or techniques for which education is needed?
- ACADEMICS: What University classes simply do not exist to provide a theoretical background in these areas of new technology/process/equipment/tools or techniques?
- INDUSTRY: How can the Universities gain expertise if they don't already have it?
- ACADEMICS: Which Universities are currently best equipped to produce which type of engineer and why? (Test, Product, and Design)

**SPEAKOUT SESSION:** Each participant was invited to prepare and present a short 5min presentation on one or more of the topics above, or any other visionary topic that is expected to be an Industry challenge in the next 2-5 years.

It would seem easy to focus exclusively on the major gaps that exist between Industry and Academia. Because of the concern that the conference could be overwhelmed with a negative tone of only listing deficiencies, the first conference was organized with select companies, universities, and professionals that could bring the most energy and positive support to the needed solution space. The exit feedback forms of those attending attest to the fact that the topics were balanced, and that they had accomplished an overall productive outcome at addressing the agenda. The all day conference was extended with an invitation to a casual group dinner. More evidence into the extent of positive collaboration was that 85% of the audience continued the communication process well into the dinner activities.

### **Approved Industry Survey Analysis**

A perfect topic match for the intent of the Roundtable was to challenge the audience with the detailed review of the survey. Consequently the same audience was the first benefactor of the results of the survey on Test Engineering skills requested of new hires. Once again, the process was to spend quality time to review the wording of each survey question. Then debate the raw results of the poll and to come to an understanding of what the Industry consensus was voicing in their votes.

## **IAR Validated Summaries of Survey Results (by specific question)**

### **Q1: General test tool knowledge of new hire:**

Specific tester language training was not a top priority, however useful. The key priority identified was for hands on skills in debug of technical issues in a lab bench environment (Oscilloscopes, frequency analyzers, etc...). The IAR review committee debated the survey results as it pertained to knowledge and acquired skill in use of Automated test Equipment (ATE), and considered use of the ATE as an extension of the lab bench environment. The IAR review made it clear that the aptitude of students in these areas translated to skills usable and favored in the work environment. The subsequent skills of CAD design, and in particular PC board layout were not without relatively high interest and marks, but the top response was for new hires to enter the work force with basic Bench-top Test and practical debug skills.

### **Q2: Preferred language:**

The survey confirmed that the most highly used language within the Semiconductor Test industry is still C or C++ based. We assumed this was within a UNIX environment, but we had no statistical means to prove this statement. The specific tester language of the current Teradyne Mixed Signal test platform (FLEX/microFLEX) was selected in third place (Visual Basic with VBT extensions). The committee was somewhat surprised that the scripting language of PERL received only half as many top three votes as the C++ response. We had assumed that PERL would be treated hand in hand with either program automation or post tester result data manipulation. The respondents also treated the JAVA response with similar low relevance, fourth out of six options. We assume this is possibly in deference to the predominance of the C and C++ languages (assumed to be within the UNIX domain). However it could be a low level vote for JAVA used in Software testing and WEB site testing techniques. Though it was not one of the given answers to the survey question, the respondents did write-in several references to National Instrument's LABVIEW as a language skill of new hires. For this chart the visual dropdown arrows were enhanced to include the top four selections from each of the four analysis methods. This weighting helped to illuminate the industry interest in VBT over JAVA.

### **Q3: Requested Device Test Experience, Repertoire:**

In general the survey responses point to the industry preference to have students already trained and experienced with testing complex products. Mixed Signal devices cause an extra level of complication and challenge. The summary chart for question #3 (Figure 4) reveals that having only tested a resistor or counter is not enough. The industry is looking for experience with the most complicated devices possible. The response with the term microprocessor and general logic had a much larger top 3 response than the question that listed a simple counter. The selection of a general Mixed Signal device had twice as many votes as the selection of any individual device (Voltage regulators, op amps, and DAC/ADC's). With the combined volume of votes for all of the Mixed Signal responses, the committee believes a true highest priority from the Industry is knowledge and skill in Mixed Signal device Test. Memory test was logged heavily in the write-in portion of the responses.

#### **Q4: Test Concepts:**

The responses of this question continue with the strong theme of an Industry need and want for Analog and Mixed Signal skill in the work place. Analog measurement and instrumentation ranges and accuracies were selected as a strong second and third place response. It may have extra merit that the top selection for this question was the last selection in the written list. The respondents banked one of their top 3 votes for the last item in the list, which was “problem solving techniques”. One selection that did attract more response than the Texas A&M staff had predicted was “Project Management”. Project Management was actually the fourth priority of selection from both the total count and top-3 count methods of data analysis.

#### **Q5: General Knowledge and Understanding:**

The summary of question five had industry feedback that was not completely expected. The responses for basic understanding of production test and general networking and automation were expected to be the Industry top selections, however we were interested to see that general understanding of device packaging took a strong second place within the feedback. From a pure Test Engineering perspective we were surprised at this outcome, but as we looked back over the industry respondents from the CAST population, we had extensive representation from executives and upper management, and they must be telling it like they see it! Semiconductor Device packaging is a complex issue in the market place. Specific data analysis and data management tools were not a strong selection of the polling community. The IAR committee assumed this was because every company has their own software product or method for this aspect of their business. Hiring for this specific skill or training is apparently not necessary.

#### **Overall Conclusion**

Academic programs need to be relevant to provide students with an education that prepares them not just to think, but also to live and work in the real world. Academia cannot invent relevancy in isolation. Industry is needed to provide the closing of a feedback loop to Academia just as Academia is needed to provide the education which industry can build upon in their new hires. It cannot be done without key people in both Industry and Academia sitting down to understand the complex systems in which each side must work. When Texas A&M started out to determine the relevancy of their curriculum, an entire process had to be created. Industry had to assist in gathering data and also in validating the data that was collected. Academia could do neither in isolation. Now with validated data, Academia is faced with how to inject these new concepts and ideas, if needed, into existing curriculum or generating new courses to fill the identified voids.

A Center of Excellence from the perspective of either the Academic or Industrial side has to be an intuition where this feedback loop exists as a series of continuous processes. At Texas A&M we have created the relationship with SEMI’s Collaboration of Automated Semiconductor Test (CAST) to ensure the validity of our questions and to gain breadth of our audience. We have invited major industry and academic players to come together in a new kind of discussion, the Industry Academia Roundtable (IAR). We then asked the IAR as a

group to discuss and validate the Test Engineering Skills survey, the survey analysis, and the summary of results. With the validated results, the Texas A&M staff will subsequently review our curriculum and complete a knowledge and task analysis. This analysis will provide a clear picture of what we are teaching and what areas are not being adequately covered. We have already introduced many minor knowledges (lectures) and tasks (labs) into existing curriculum, and are working on introducing more major changes. It is an understatement to report that these major changes will still need to evolve through the required University procedures. Details of this curriculum evolution are planned in a follow on paper.

## **Biography**

TOM MUNNS is a veteran of microprocessor debug and development having worked at Motorola/Freescale on 3 generations of products namely 68k CISC, 88k RISC, and PowerPC families. Has held positions in Product Engineering, Design, and most recently Test Engineering. Tom has a BS and Masters in EE from Texas A&M University, and is currently consulting with the TI Mixed Signal and Freescale Digital test Labs at Texas A&M.

Dr RAINER FINK Ph.D. in biomedical engineering from Texas A&M University. After finishing his Ph.D., he joined the Department of Engineering Technology at Texas A&M University. Currently he is serving as the Director of the Texas Instruments Mixed-Signal Test Laboratory at Texas A&M.

ELLEN ONDERKO came to Academia to be the Project Manager of Semiconductor Test Continuing Education at Texas A&M from 15 years in the ATE industry in Silicon Valley. She was a field applications training engineer at both LTX and Teradyne Inc. Prior to that, she was a government certified Instructional Systems Designer and a contractor instructor in the Air Force Satellite Control Network (AFSCN).