Evaluation Report

The Southwest Center for Microsystems Education

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Annual Evaluation Report
For The Southwest Center for Microsystems Education

This evaluation report covers the period September 1, 2009, to May 1, 2010.

This evaluation report is divided into the following sections:

- SCME Mission and Goals
- "Model Kits" Workshop Evaluation
- "Innovator's Wanted" Workshop Evaluation
- "LIGA" Workshop Evaluation
- "Pressure Sensor" Workshop Evaluations
- Fall Semester 2009 Survey of Workshop Participants

SCME Mission and Goals

SCME Mission Statement:

> "The Southwest Center for Microsystems Education will serve as a sustainable resource center that identifies Microsystems technologist competencies, creates and disseminates educational materials and models, and provides professional development activities to develop a skilled microsystems workforce that can support research and development and manufacturing environments."

SCME Goals:

- Increase educational capacity to produce technologists skilled in assisting microsystems research, design, and commercialization activities.

- Increase the general public's awareness of the microsystems industry.

SCME's main strategy to develop a skilled microsystems workforce has been to equip secondary and post-secondary teachers and instructors in MEMS applications and fabrication. SCME's impact is then amplified through the classes that they teach.

A variety of faculty-enhancement workshops have been sponsored by SCME. These workshops include "Model Kits" Workshops where participants can sample the model kits that SCME has developed, "Innovators Wanted" Workshops where participants design and build models of MEMS devices, "Pressure Sensor" Workshops that provide cleanroom experiences through the manufacture of a MEMS device, and a new "LIGA" Workshop that teaches principles of high-aspect ratio processes for MEMS applications.

The following sections will summarize the workshop evaluations for SCME-sponsored workshop offered since September 1, 2009.

"Model Kits" Workshop Evaluation – "Mini Micro Conference"

The one-day Model Kits Workshop was held on January 9, 2010, at the Manufacturing Training and Technology Center at the University of New Mexico in Albuquerque, NM, and hosted by the Southwest Center for Microsystems Education (SCME). The workshop goal was to increase the awareness of MEMS applications and fabrication among educators in New Mexico and to showcase model kits that can be used in classrooms around the state.

Twenty-three educators participated in the workshop. All educators were from the State of New Mexico. Twelve participants teach at the K-8 education level, eight at the high school level, one at the community college level, and one from New Mexico MESA, Inc.

Evaluation Results

Workshop evaluation consisted of two-surveys: (1) Pre-workshop survey, and (2) Post-workshop survey. Questions focused on Level 1 and Level 2 Kirkpatrick evaluation methods.[1] Each participant was asked to list two outcomes they expected from the workshop. Outcomes related to professional development were cited seventeen times. Outcomes related to curriculum development and instructional improvements were cited seventeen times. Outcomes related to careers were cited five times.

On a ten-point scale with "10" representing "Achieved my Workshop Outcomes" and "1" representing "Did Not Achieve My Workshop Outcomes," the distribution of participant responses are shown in Figure 1. All but six (17 of 23 participants or 74%) of the participants rated their achievement of attaining their outcomes with a rating of 8 or higher, and three of the six participants rated their achievement of outcomes as a "6" or "7". Only three of 23 participants (13%) gave a rating of "5" or less. Reasons given for low ratings included a lack of information to know which afternoon workshop to choose, the length of the workshop (full-day instead of half-day), and topics they were already familiar with or had incorporated in their class already, e.g. cantilever. But, for the most part, participants found the workshop informative and beneficial in meeting their expectations for the workshop.

[1] Level 1: Reaction. To what degree participants react favorably to the learning event. Level 2: Learning – To what degree participants acquire the intended knowledge, skills, attitudes based on their participation in the learning event. (From *Training on Trial* by Jim D. Kirkpatrick and Wendy Kayser Kirkpatrick, American Management Association, 2010.)

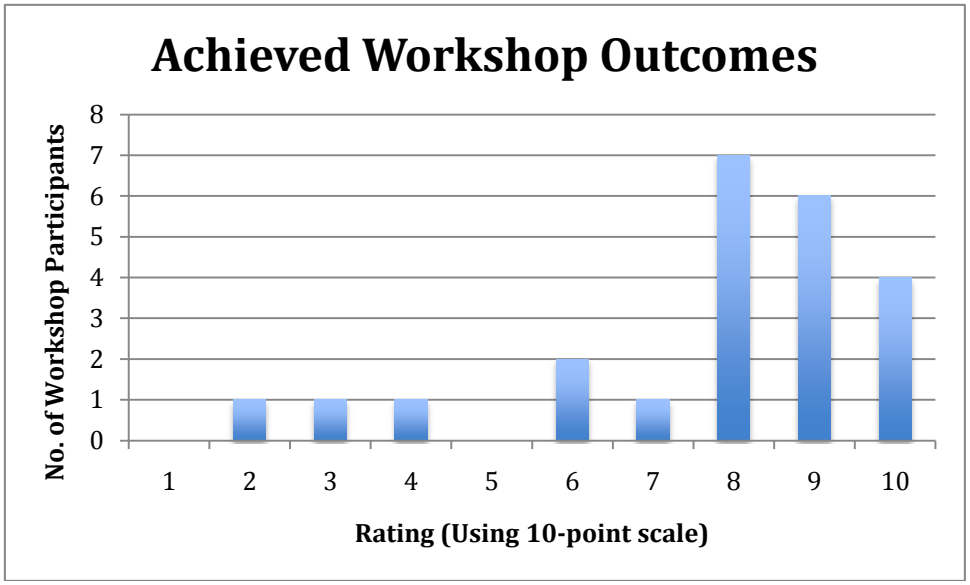

Figure 1. Graph of participant ratings that indicate whether they achieved their workshop outcomes. Ten point scale: "10" represents "Met Workshop Objectives" to "1" represents "Did Not Meet Workshop Objectives."

Seventeen out of 23 workshop participants liked the workshop format. Six workshop participants elected not to say whether they liked or disliked the workshop format.

Workshop participants were asked to self-assess their knowledge of MEMS applications and fabrication methods at the beginning and at the end of the workshop. Their responses are plotted in the table shown in Figure 2. A ten-point scale was used with "10" indicating an high-level of understanding and a "1" indicating a low-level or novice-level of understanding. Their pre-workshop level is plotted on the horizontal axis and their post-workshop level is plotted on the vertical axis. All data points are above a diagonal running from the lower left corner of the table to the upper right corner indicating that all participants felt that the workshop had increased their level of understanding of MEMS applications and fabrication.

Vertical Scale: Post-Workshop Level of Understanding of MEMS

10		1								
9										
8	3	1	1	1	1		1			
7			1							
6	3		1							
5	1		1	1						
4	2									
3		1								
2	2									
1										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Pre-Workshop Level of Understanding of MEMS

Figure 2. A scatter plot of the participant self-assessment rating of the pre-workshop and post-workshop levels of understanding of MEMS applications and fabrication. The bold numbers in the last row of the table are their pre-workshop ratings and the vertical numbers in the left-most column are their post-workshop ratings. The numbers in the remaining cells are the number of participants with each Pre-/Post-workshop rating.

Workshop participants were asked to identify which model kits they intend to use in their class(es) during 2010. The following table identifies the number of workshop participants that intend to incorporate each model kit into their class(es). The data presented in Table 1 can be used by SCME to plan the production of each model kit. Over half the workshop participants intend to use each kit in their classes except for Bulk Etch and Lift-Off. The Cantilever Model Kit was the most selected kit (selected by 87% of the workshop participants).

Table 1. The number of workshop participants indicating that they intend to incorporate a specific model kit into their class(es).

Model Kit	Number of Workshop Participants
Cantilever	20
Rainbow Wafer	14
Pressure Sensor	15
Crystallography	17
Bulk Etch	9
Lift-Off	9
MEMS Film	12
Wheatstone Bridge	13

All of the teachers attending the workshop planned to use at least one model kit in one of their classes during the 2010 calendar year. A follow-up survey will be sent to each workshop participant at the end of Spring semester and Fall semester to determine actual classroom usage. Phone calls will be made to non-respondents in an effort to improve our response rate.

Workshop participants were asked, "How could this workshop be improved?" Their suggestions are summarized in the following list:

- Less lecture, more hands-on
- Include guiding questions, visuals, and formulae for hands-on activities.
- Video of teaching it (the model kit) in a 8^{th} – 12^{th} grade setting.
- Encourage participants to bring a fellow teacher in a complementary discipline.
- Donuts!
- Half-day rather than full-day (only one response).
- Break up into two workshops.
- More demonstrations and videos.

Workshop participants were asked, "What can SCME do to help you incorporate these model kits into the class(es) that you teach?" The responses are summarized in the following list:

- Help with acquiring materials for the activities.
- Relationship to basic standards.
- Outline to use for lesson plans and benchmarks.
- Meet with other school professionals for MEMS examples to use in physics and math.
- Make classroom presentations.
- Mentoring/tutoring for individual teachers.
- More workshops.
- More class sets.
- Shorter, more focused workshops on specific model kits.
- Talk to our school administration.
- Invite students for workshops.

"Innovators Wanted" Workshop Evaluation

The one-day Innovators Wanted Workshop was held on January 9, 2010, at the Manufacturing Training and Technology Center at the University of New Mexico in Albuquerque, MN, and hosted by The Southwest Center for Microsystems Education (SCME). The workshop goal was to provide a hands-on, problem-oriented faculty development activity that depicted the manufacturing process in creating a MEMS device. This session was held in parallel to the Mini Micro Conference and served as a capstone experience for participants from a four-day intensive, cleanroom pressure sensor workshop.

Ten educators participated in the workshop. Of the ten educators, two were from secondary institutions, five from two-year institutions, three from four-year institutions. Five of the ten participants were from New Mexico, two from North Dakota, and one each from Massachusetts, Maryland, and Florida. Eight of the participants were male and two were female.

James Hyder and David Hata from the SCME staff evaluated the workshop by direct observation. David Hata is SCME's External Evaluator and James Hyder is SCME's Synergy Innovation Coach and industry liaison.

All participants cited "professional development" as their reason for attending the workshop. Seven also cited curriculum development as a reason for attending. Five of the participants currently teach MEMS topics in their classes. Topics taught by these five participants include nano-materials, imaging, MEMS devices, MEMS manufacturing processes, MEMS applications, MEMS history, and pressure sensors.

<u>Evaluation Results</u>

On a ten-point scale with 10 indicating "Met Objectives" and 1 indicating "Did Not Meet Objectives", nine out of ten participants gave a rating of "7" or higher. Therefore, the workshop was successful in meeting participant expectations and producing the outcomes that participants identified at the beginning of the workshop.

As for workshop format, eight of nine participants liked the project-oriented format. Some of the participant comments related to the project-oriented format include:

> *"This helped me to 'cement' how we created pressure sensors. There was a great deal of application and synthesis. Presenting made it better."*
>
> *"Yes, allowed for real problem-solving and a chance to gain a student perspective on building MEMS."*

"Project was an effective way of bringing all of the pressure sensor learning's together. It was a good application of the knowledge/ comprehension of the pressure sensor workshop."

"Really think through the whole process."

It gave us a chance for brainstorming on a new device. It helped review and model the whole pressure sensor → reinforcement."

"Tons of experience (hands-on) following regular engineering design steps, displaying our theoretical knowledge of MEMS in a 'real life' project!! Great experience!!"

Workshop participants were asked to self-assess their knowledge of MEMS applications and fabrication methods at the beginning and at the end of the workshop. Their responses are plotted in the table shown in Figure 3. A ten-point scale was used with "10" indicating a high-level of understanding and a "1" indicating a low-level, or novice-level, of understanding. Their pre-workshop level is plotted on the horizontal axis and their post-workshop level is plotted on the vertical axis. All data points above a diagonal running from the lower left corner of the table to the upper right corner indicate that participants felt that the workshop increased their level of understanding of MEMS applications and fabrication methods.

Vertical Scale: Post-Workshop Level of Understanding

10										1
9					1				1	
8			1				1	1		
7										
6				1						
5					1					
4										
3										
2		1								
1										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Pre-Workshop Level of Understanding

Figure 3. A scatter plot of the participant self-assessment rating of their pre-workshop and post-workshop levels of understanding of MEMS applications and fabrication methods. The bold numbers in the last row of the table are the pre-workshop ratings and the bold numbers in the left-most column are the post-workshop ratings. One participant did not provide a pre-workshop level of understanding resulting in only nine data points

Finally, participants were asked how this workshop could be improved. Their suggestions include:

- Maybe, let us do a PowerPoint.
- More information on MEMS components and more time to analyze their applications.
- More detail on the structure of MEMS devices.
- Additional information about different materials used in the process.
- Having the agenda ahead of time.
- More time for design. What about two days for the workshop?
- More challenging practical applications.

"LIGA" Workshop Evaluation

The one-day LIGA Workshop was held on April 17, 2010, at the Manufacturing Training and Technology Center at the University of New Mexico. The purpose of the workshop was to pilot the workshop with a small group of educators and to test the LIGA learning module. Five participants, three educators and two non-educators, attended the workshop.

Evaluation Results

On a ten-point scale with "10" indicating "Expert" and "1" representing "Novice," the participants rated their pre-workshop understanding of LIGA from a "5" to an "8". Their post-workshop assessment of their understanding of LIGA included four "9s" and one "10". The scatter plot shown in Figure 4 graphs the pre-workshop and post-workshop assessment values for each participant.

Vertical Scale: Post-Workshop Level of Understanding

10					1					
9			1		2			1		
8										
7										
6										
5										
4										
3										
2										
1										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Pre-Workshop Level of Understanding

Figure 4. A scatter plot of the participant self-assessment rating of their pre-workshop and post-workshop levels of understanding of LIGA. The bold numbers in the last row of the table are the pre-workshop ratings and the bold numbers in the left-most column are the post-workshop ratings.

On a seven-point scale with "7" indicating "Very Useful" and a "1" indicating "Not Useful", the five participants scored all parts of the workshop with a rating of "5", "6", or "7". The parts of the workshop rated include: Overview of LIGA, Creating Copper Acetate, Creating a Photo Mask, Expose and Develop, Electroplating, Cleanroom Tour, and LIGA vs LIGA Simulation. In addition, all three educators indicated that they planned to incorporate workshop material into the classes that they teach during either Spring semester 2010, Fall semester 2010, and/or Spring semester 2011.

Suggestions for improving the LIGA Workshop included:

- Really enjoyed "testing" the SCO. Going over and testing the steps makes for excellent learning.
- M. J. (Mary Jane Willis) did an amazing job capturing numerous suggestions that I know will be helpful in updating the material.
- Run it concurrently with MEMS micromachining processes.
- Provide "blogging" to teachers so they can share experiences as they perform this activity.
- All instructors worked hard to fine tune procedures for each step. They experimented with times, distances, and light sources. Great improvements by all instructors.

A final comment by one of the workshop participants:

> *"Training 'hands-on' for teachers gives us a much better understanding. This allows us to troubleshoot (learning modules) prior to use with our students. Sources of inexpensive materials makes it more likely to be used in the classroom."*
>
> Carla Burns, Ruidoso High School

"Pressure Sensor" Workshop Evaluations

Three one-week "Pressure Sensor" Workshops were held since September 1, 2009. One was held in October, 2009; the second in November, 2009; and the third in January, 2010. The first and third Pressure Sensor Workshops were for faculty, but the second workshop was for students from Northwest Vista College's Nanoscience program. All pressure sensor workshops were held at the Manufacturing Training and Technology Center at the University of New Mexico.

October, 2009, Pressure Sensor Workshop Evaluation

Five faculty members participated in a five-day "Pressure Sensor" Workshop, October 13-17, 2009. Of the five faculty members, two were from community colleges and three were from four-year colleges and universities. Two participants were from Pennsylvania and one each from Ohio, Virginia, and Wisconsin.

Survey data was not collected during and following this workshop because the workshop presenters did not hand out the survey forms during and at the conclusion of the workshop. Instead, workshop participants were asked for their overall evaluation of the workshop after the workshop. The following are quotes from their e-mail responses:

> "What an excellent workshop! Your material is fantastic! Keep up the great work everyone! Thank you for the opportunity!"
>
> Amy Brunner, Penn State University

> "This has been my new favorite workshop! – a combination of great people and strong content. Thanks!"
>
> Kurt Carlson, Chippewa Valley Technical College

> "I've been to quite a few workshops, but none has been as informative, enjoyable, and hospitable. I cannot wait to attend another workshop hosted by you all. Wonderful, wonderful, wonderful!"
>
> Beverly Clark III, Danville Community College

November, 2009, Pressure Sensor Workshop Evaluation

Six students and their instructor from Northwest Vista College in San Antonio, TX, participate in this workshop. Their pre-workshop, self-assessment of their knowledge of MEMS applications and manufacturing process was higher than expected and mostly likely indicates a significant amount of preparation for the workshop. Figure 5 shows a scatter plot of the pre-workshop and post-workshop knowledge levels.

Vertical Scale: Post-Workshop Level of Understanding

10						1				
9								1	1	
8							1			
7				1	1		1			
6										
5										
4										
3										
2										
1										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Pre-Workshop Level of Understanding

Figure 5. A scatter plot of the participant self-assessment rating of their pre-workshop and post-workshop levels of understanding of MEMS applications and manufacturing processes. The bold numbers in the last row of the table are the pre-workshop ratings and the bold numbers in the left-most column are the post-workshop ratings.

Using a seven-point scale with "7" representing "Very Useful" and "1" representing "Not Useful", the students rated six major workshop activities. The rating averages are all 6.0 or higher except for the "Art Wafer" project that scored a 5.8.

Activity	Average Rating
Safety Tour	6.5
Art Wafer Project	5.8
Backside Pattern & Alignment	6.2
Lift-Off and Gold Deposition	6.7
KOH Etch	6.5

Probe Station 6.0

The following quote from a report written by one of the students who participated in the workshop sums up the workshop.

> *"Throughout this semester, I have been trying my hardest to develop an interest in nanotechnology. When I first decided to change my major, from engineering to nanotechnology, I didn't know what to expect. . . . . However, as I learned more about nanotechnology, and what it could offer me, the more intrigued I became. The cleanroom workshop for MEMS only solidified my position. The purpose of this workshop was to educate its participants on MEMS (Micro-Electrical-Mechanical Systems) and the entire cleanroom process. This experience is one that I will never forget for the rest of m life."*
>
> Zachary Overton, November 10, 2009
> Student, Northwest Vista College

<u>January, 2010, "Pressure Sensor" Workshop Evaluation</u>

Nine faculty members attended the one-week "Pressure Sensor" Workshop held on January 5-8, 2010. The participants included six community college faculty and three professors from four-year colleges and universities. Four participants were from New Mexico, two from North Dakota, and one each from Maryland, Massachusetts, and Florida.

The workshop enhanced their level of understanding of MEMS applications and manufacturing processes. Figure 6 shows a scatter plot of their pre-workshop and post-workshop levels of understanding of MEMS applications and manufacturing processes.

Vertical Scale: Post-Workshop Level of Understanding

10										
9			1	1				1	1	
8		1				1				
7	1		1							
6		1								
5										
4										
3										
2										
1										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Pre-Workshop Level of Understanding

Figure 6. A scatter plot of the participant self-assessment rating of their pre-workshop and post-workshop levels of understanding of MEMS applications and manufacturing processes. The bold numbers in the last row of the table are the pre-workshop ratings and the bold numbers in the left-most column are the post-workshop ratings.

All of the faculty members attending the workshop plan to incorporate workshop material into the classes that they teach. Six will do so during Spring semester 2010, five during Fall semester 2010, and three during Spring semester 2011. Note: Some instructors will use the material during multiple semesters.

Fall Semester 2009 Survey of Workshop Participants

One hundred thirty four of 292 past SCME workshop participants are surveyed during Fall semester 2009. The 134 survey recipients represent active users and potential users of SCME materials. The remaining 158 "inactive" past workshop participants include those faculty that have since retired, left teaching, serve in a non-instructional capacity, or attended SCME workshops more than two years ago and have not reported any classroom MEMS instruction.

Thirty-seven workshop participants responded to the Fall semester 2009 survey, a return rate of only 27.6%. To gather more data on SCME workshop impact on classroom MEMS instruction, non-respondents to our Spring and Fall semester surveys will be interviewed by telephone to determine why they haven't used MEMS workshop material and to find out what barriers they face in integrating MEMS instruction into the classes they teach. SCME staff will conduct these phone interviews.

Seventeen indicated that they had used material from SCME workshops that they had attended. Nine of the respondents who used MEMS workshop material were from community colleges. They reported that their MEMS instruction impacted a total of 255 students and the total number of student-hours of instruction was 1,605.

Seven of the respondents who used MEMS workshop material taught at the secondary school level. They reported that their MEMS instruction impacted a total of 359 students and the total number of student-hours of instruction was 2,271.

One professor from a four-year university used MEMS workshop material. His instruction impacted fourteen students and produced 42 student-hours of instruction.

To summarize SCME's "broader impact" since its inception in 2004, 1,714 two-year college students have received 14,870 student-hours of MEMS instruction, and 1,978 students at the secondary level have received 18,977 student-hours of MEMS instruction. Combining the impact at the secondary and post-secondary levels, 3,692 students have received 33,847 student-hours of MEMS instruction. This is external to the students impacted by Central New Mexico Community College's program.

Survey of "Model Kits" Workshop Participants

Workshop participants from the "Model Kits" Workshop held at the 2009 HI-TEC Conference in July of 2009 were surveyed at the end of Fall semester 2009 to determine if they have used the model kit(s) that they received at the end of the workshop. Thirty-four of thirty-nine workshop participants returned the survey.

Of the 34 survey respondents who returned the survey, sixteen respondents indicated that they had used the model kit during Fall semester 2009. In addition, eight of the respondents who did not use the model kit during Fall semester 2009 indicated that they plan to do so during the Spring semester of 2010 along with 12 of the 16 respondents who indicated that they would use the kit(s) during both semesters. Of the 24 respondents using, or planning to use, the model kit, ten were from two-year colleges, thirteen from secondary schools, and one was from a four-year university. The percent of utilization for 2009-2010 academic year is predicted to be 71%.

The addition of model kits to the resources that SCME can provide to teachers is significant. Previous surveys have told us that classroom teachers needed more MEMS instructional resources. The high percent of utilization of the kits indicates that SCME is meeting their need for instructional resources, reducing barriers to MEMS classroom instruction, and we expect a higher number of students to be impacted by MEMS instruction in the future.

Summary

SCME continues to make progress in meeting its goal of increasing educational capacity to produce technologists skilled in assisting microsystems research, design, and commercialization through its faculty enhancement activities. Through a combination of Model Kits, Innovators Wanted, Pressure Sensor, and other workshops and activities, the number of students impacted and the total number of student-hours of instruction continues to increase. In fact, now that distribution of learning modules and model kits is gaining traction, we expect the numbers to increase at a significantly greater rate during the 2010-11 academic year.