Alan V. Oppenheim

One Plus One Could Equal Three (and Other Favorite Clichés)

In this column, I summarize my personal approach to and view of research in an academic setting, somewhat as a continuation of my article published in the *IEEE Signal Processing Magazine* in 1992 titled "A Personal View of Education." Throughout my career, I have enjoyed and derived tremendous satisfaction from the symbiotic relationship between teaching, mentoring, and research in an academic setting. Among the many unique aspects of research in such an environment is the fact that it includes significant involvement from and with students and the opportunity to work with students who are bright, creative, motivated, well matched to the personal style of the advisor, coachable, and fun to work with. In this role, I have found myself often citing various clichés, metaphors, and phrases to my students and colleagues as a way of making specific points as we move together through a research adventure. It's my hope that the reader will find these at the least entertaining and perhaps even interesting and useful.

GOALS AND DELIVERABLES

Research in an academic setting often has goals and constraints that differ significantly from those in other environments such as industrial or government research laboratories. The primary mission of an educational institution is education and mentoring, and in my view, key deliverables include well-educated students. Correspondingly, a significant portion of the research staff consists of students who are in various stages of learning how to do research. In a research-oriented university, the intimate relationship between research and teaching contributes strongly to the overall educational mission. Of course, research in an academic setting also plays an important role in the financial structure of the institution, the career development of the faculty, the resume building process for graduate students, and the goals of the research sponsors. When the system is working well, all of the stakeholders (students, faculty, institution, sponsors) mutually benefit in an incredible win-win situation.

The approach to research to which I have gravitated over the years and the one most comfortable for me when working with research students is perhaps best characterized as "finding solutions in search of problems." Put differently, appropriately or not, I tend to personally become more excited about chasing ideas than about attempting to solve specific problems. For some students and colleagues, this approach is very appealing. Others tend to prefer an approach focused more on specific open problems in a field or with clearer initial objectives. Whatever the research philosophy is, it is essential that the chemistry and style of the research team be well matched and in synch.

However each of us personally approaches research, at a research university we have the common goals of helping students learn how to choose research directions; how to creatively focus, pursue, and modify those directions; and of course, how to complete the work. In my opinion, it is important to encourage and guide them to be bold, creative, adventurous, and to go beyond what they thought they might be capable of. Toward these goals, I tend to refer to similar clichés or metaphors, summarized below, as my students and I move through the process of choosing and focusing the direction and completing the work.

EDITOR'S INTRODUCTION

This is the last article in the sequence of "Leadership Reflections" articles, which I initiated more than three years ago and have edited ever since. It has been a great honor and privilege to edit this column. I am thankful to the authors for accepting my invitations, sharing their thoughts with our community, and making this column series so successful and useful. The authors have come from diverse backgrounds and careers, including academia, research, industry, and government. They described interesting perspectives of leadership experience and gave invaluable advice on becoming successful. They presented both different viewpoints and common underlying ideas. Overall, we've had a unique glimpse into the work and paths of well-known leaders. It was interesting to find out that some of the articles became popular in very different Societies (also outside the IEEE), indicating that the ideas are fundamental and significant.

It gives me a special pleasure and honor to introduce the author of this article, Prof. Alan V. Oppenheim, who is well recognized as a founding father of the field of signal processing. He has had a distinguished leadership career in education and research, in which he has made truly significant contributions. He has taught and advised generations of students who then became leaders in their own right. He is well known to us from the original textbook that introduced us to signal processing and made many of us choose it to develop our careers. I invite you to read his article, enjoy it, and become inspired again.

—Arye Nehorai
"Leadership Reflections"
Column Editor

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IN THE BEGINNING

In carrying out academic research, the first phase, naturally, is choosing a direction. I often describe this as the "one plus one could equal three" phase, suggesting that unconventional thinking and discussion can often lead to surprising, new results. One of my former doctoral students, Yonina Eldar, captured this in the following playful lyric in the style of Dr. Seuss:

> One plus one adds up to two if that's all you think it can do. But one plus one could equal three or anything else you'd like it to be.

In this spirit, I personally place a lot of emphasis in the early phase of working with research students on our being adventurous in our thinking and on exploring ideas outside of conventional directions. I particularly avoid beginning with a list of current open problems or extensions of recent work and focus instead on intriguing directions. Of course, eventually, the thinking and the direction need to become appropriately focused, but often an initial opportunity for very uninhibited thinking can open up some intriguing, surprising, and interesting new directions. In this phase, I'm often also reminded of a comment that was made to me by an architect while I was attempting to preserve a particular flowering tree that was (in his view) negatively affecting the overall design. He commented that "a flower in the wrong place is a weed" and the flip side that suggests that anything in the right setting and with appropriate nurturing is potentially a flower. It is an interesting and exciting challenge to be as open minded as possible about new ideas and directions to give them the opportunity to flower in an appropriate context.

THROUGH THE TUNNEL

In the famous words of Thomas Edison, "genius is 1% inspiration and 99% perspiration," or to quote another well-known cliché, "the devil is in the details." Clearly, a significant part of the research experience is making forward progress on the details. I've often heard it said that in the context of research, once it looks like a problem set in a course, the hard part is done." Getting the project focused into the form of well-articulated problems is a major part of the task. Nevertheless, there's generally still plenty that needs to be accomplished (and lots of perspiration to be expended) to carry the work to completion. During this phase of filling in the details and doing the problems in the problem set, there are (at least) two potential difficulties that I hope to guide a student in avoiding. One relates to the well-worn cliché, "don't confuse motion with progress." Lots of perspiration can be generated running around in circles. Likewise, doing lots of simulations or analysis without a purpose can be mentally exhausting but doesn't necessarily correlate with progress.

Of course, even in this more focused phase of the research, it's fun, energizing, and stimulating to continue to pop back into the "one plus one equals three" style of thinking, often enhanced by total immersion in totally unrelated activities (e.g., sports or meditation) that frees the mind and lets creativity naturally bubble to the surface. Put another way, as I often phrase it to my students, "When in doubt go skiing" (or more generally, periodically immerse yourself in any other intense diversion unrelated to research).

Among the goals of guiding students in a research setting is helping them understand that difficulties are surmountable and that there's eventually "light at the end of the tunnel." In this context, as I like to remind them metaphorically: "Don't forget your lucky socks." For me, this metaphor was inspired by a talk that I had heard about superstition, which, among other things, suggested that the most superstitious people are sailors, athletes, gamblers, and of course, students. Undoubtedly, all of us have our version of "lucky socks" or icons that give us the feeling of an undeniable edge against the odds and helps make things go our way when we wear or carry them. (When proctoring exams, I often find it interesting to try to spot some of the lucky icons that students might have on their desks.) In the context of gambling, I doubt that it works (unless the socks are appropriately enhanced electronically). In the context of research truly believing that a problem is solvable or that one plus one can equal three often tends to be self-fulfilling. Put another way, "the power of positive thinking" is awesome.

As a research project is maturing, there's always the reminder that "you can paint 90% of a room in 10% of the time." The walls are the easy part. The trim or edges can be deceptively long and tedious. Inevitably, with any project (research, installing a new dishwasher, planning a vacation) there are lots of details that get swept under the rug until the truly final phase; quite often it's cleaning up those fine points, details, and unresolved issues that can take longer than anticipated. It is also often in resolving these that some of the most surprising and creative ideas emerge.

INTO THE SUNSHINE

Of course, the point inevitably comes when the current phase of any project (such as the thesis, journal article, or book) has to be considered complete and finished. A critical and often time-consuming and difficult phase of completing a research project is writing it up in a form that is accessible to peers and colleagues. This also means a willingness to expose the work to the scrutiny, applause, and possible criticism of others, an anxiety that I and I know most or all of my colleagues have experienced at one time or another.

Many years ago, Bruce Musicus, a former MIT doctoral student put on the opening page of his doctoral thesis the memorable and often quoted (by me) sentence, "The only good thesis is a finished thesis." As another former MIT student, Dave Harris, said just after he graduated (again, now often quoted by me and others), "My room was never so clean as when I was writing my doctoral thesis." Other equivalent diversions from writing (at least for me and others that I know) include the instant gratification and sense of having accomplished at least something by dealing with e-mail.

A somewhat related sentiment is captured in a wonderful cartoon sent to me

by Ron Schafer as we were working on a revision of our text. In it, a writer is working in his basement study, surrounded by manuscript piles on his desk. His wife is standing at the top of the stairs, obviously having just asked him a question, to which his reply (in the caption) is "Finish it? Why would I want to finish it?"

SOME FINAL THOUGHTS

Approaching research from the perspective of "one plus one can equal three" has led to many interesting adventures over the years. Very typically, a conversation with a new doctoral student evolves along the lines of the following conversation that I had with another former student, Andy Singer, when he was just starting his doctoral program. Andy was (and is) extremely creative and adventurous, and when he asked me what he might work on I suggested "solitons," to which he replied, "what are those?" to which I replied, "I don't know, let's go find out." Similar conversations were characteristic of the early phase of a great many of our research adventures, such as those on fractals, chaos, signal processing inspired by quantum mechanics or biology, and new sampling strategies, just to name a few.

With research projects done in this style, the question is sometimes asked by colleagues or during job interviews for the graduating students, "what problem did you solve?" Of course quite often a natural by-product of the work may be the solution to some current or future problem or perhaps a useful device. However, in the context of research at a university, I personally don't see that as the primary goal. My usual reaction is that I'd much rather be asked whether the students involved have learned to think creatively and outside the box, have learned how to challenge themselves, and have gained the confidence to be bold and adventurous intellectually. Having been teaching and working with extraordinary students at a research university for over forty years, its been interesting and gratifying to see how this particular style of choosing research problems and guiding students has led to exciting adventures, useful results, and most importantly, a style that continues for the students throughout their careers.

In a conversation many years ago, Prof. Kenneth Steiglitz of Princeton University made a comment to me that became one of the guiding principles for me personally in shaping my research career. Ken was describing a particular problem that he was working on. When I asked him why he chose that problem, he said simply that it was fun to work on. He then quickly added, "Look, Al, the whole idea is to have fun."

AUTHOR

Alan V. Oppenheim (avo@mit.edu) received the S.B. and S.M. degrees in 1961 and the Sc.D. degree in 1964, all in electrical engineering, from the Massachusetts Institute of Technology (MIT).

He is also the recipient of an honorary doctorate from Tel Aviv University. In 1964, he joined the faculty at MIT, where he is currently Ford Professor of Engineering and a MacVicar Faculty Fellow. Since 1967, he has been affiliated with MIT Lincoln Laboratory and since 1977, with the Woods Hole Oceanographic Institution. His research interests are in the general area of signal processing and its applications. He is coauthor of the widely used textbooks Discrete-Time Signal Processing and Signals and Systems. He is also editor of several advanced books on signal processing.

He is a Fellow of the IEEE, a member of the National Academy of Engineering, and a member of Sigma Xi and Eta Kappa Nu. He has been a Guggenheim Fellow and a Sackler Fellow. He has received a number of awards for outstanding research and teaching, including the IEEE Education Medal, the IEEE Centennial Award, the IEEE Third Millennium Medal, the Society Award, the Technical Achievement Award, and the Senior Award of the IEEE Society on Acoustics, Speech, and Signal Processing. He has also received a number of awards at MIT for excellence in teaching, including the Bose Award and the Everett Moore Baker Award and was the 2005 recipient of the IEEE Signal Processing Education Award. SP

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The reports mentioned in this article, along with several additional studies detailing the growth of IEEE citations in patents, are available for download through the IEEE Web site at www.ieee.org/patentcitation, where you can also find in-depth looks at IEEE's impact on patents in five key areas of technology.

REFERENCES

[1] A. Breitzman, *IEEE and Patents: An Analysis of Patent Referencing to IEEE Papers, Conferences and Standards*, 2005.

[2] A. Breitzman, *IEEE and Patents: An Objective Analysis of the Effect of IEEE Publications on Subsequent Patented Technology*, 2003. SP