Mind the gap!

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Recently, I have returned from this year's μTAS conference which was held on the stunningly beautiful island of Jeju, off the south coast of Korea. Almost 1000 people from the scientific community found their way to this conference, slightly less than in the last two years, but given the current state of the global economy and its consequences on travel budgets, this can count as a great success and without a doubt can be attributed to the fact that μTAS is clearly seen as the most important scientific gathering in the field, despite the large number of other meetings either solely dedicated to lab-on-a-chip topics or with a significant number of sessions reserved for contributions from this field. With 667 oral and poster presentations, the full spectrum of the current state-of-the-art research in lab-on-a-chip technologies and applications could be reviewed. But was it really the full spectrum? An issue which has worried me for the last couple of years has been the representation from the industrial side of the field. Of course, one could argue that μTAS is and has always been a more academically oriented conference and that rapid progress in academic research, which generates exciting scientific results, is not matched by the results from the world of industrial R&D. So the stringent scientific quality level to be included in the conference, safeguarded by a fastidious peer-review process, is not achieved by industrial contributions. Furthermore, an often heard argument is that many companies would not publish their research due to reasons of confidentiality or simply because the academic community is not their product target audience. One set of figures however lets me believe that we are facing more of a systematic gap that, in my opinion, is continuously widening and, if the community as a whole does not pay attention to it, could eventually lead to a dichotomy which could prove disastrous for the future development of the lab-on-a-chip field, both for academia as well as industry. The worrisome figures are that at the μTAS 1998 conference in Banff, 27 of the 122 contributions had an industrial author or co-author, which is 22%. At this year's conference 51 (of which 6 came from various divisions of Philips) of the 667 contributions had an industrial author or co-author, which is only 7.7% (all manually counted, so I may have missed one or two contributions, but not so many that it would change the overall picture). How can this development be explained in the context of the community mantra that the economic potential of microfluidics is huge and that the commercialization of the field is progressing well? I see a growing gap between research activities in the academic community on the one hand and commercialization efforts in industry on the other, a point which is fortunately also raised by others.[1] One could dismiss this observation simply by either accepting it as an inherent dynamic development in a maturing technology field or more fatalistically as a given schism observed in many modern scientific disciplines. I would however argue that both parts of the lab-on-a-chip community, academic as well as industrial, have an equal responsibility to work towards bridging this gap. Both parts of the community are probably more strongly linked than most of us are likely to acknowledge at first glance. The academic community has been doing extremely well in terms of public funding in this field over at least the last 10 years, the number of academic groups worldwide working in microfluidics has grown to several hundred (my personal estimate; it would be an interesting but sedulity-requiring piece of work to actually compile a list—ref. 2 lists 118 university groups and 269 companies, in my opinion too small a number on the academic side). Several problems that the academic community has to face in the not-too-distant future as a consequence of this strong growth are actually strongly associated with the success of commercialization efforts in industry. A very obvious example is the state of public funding. Having been a reviewer for national and international (EU) research proposals for many years, I regularly read in the (required) section on exploitation that whatever work is proposed, the economic potential is huge. I (still) tend to agree with this statement which is also supported by a plethora of market studies (see *e.g. ref.* 3–5). But upon closer inspection, I see comparatively little overlap of the work presented in the proposal, at the various scientific conferences or in the relevant journals with the described industrial applications. There is no question that it is not the task of an academic group to develop a microfluidics-based product, but the width of the gap between the academic results presented and the steps necessary to embark on a real industrial product development process worries me enormously. And the question remains, how long can the current high level of funding be sustained when the road towards commercialization remains as long and winding as it is now? Funding agencies have an intrinsic interest in some "return on investment", due to political pressures, paid for by tax-paying corporations (and employees), this is even more significant now in these times of skyrocketing public debt. Despite the fact that most program managers have a sound understanding of the underlying technologies, the timescales involved and the risks and obstacles inherent in any R&D process, in the long term they need to show their respective institutions that the taxpayer's money was well spent. This usually means more than a high number of scientific publications and a long list of graduates. This brings me directly to a second issue which is generated by the rapid growth in the numbers of the academic groups working

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on microfluidics. What happens to all their graduates? Even if the problem might not be that acute today due to the fact that a PhD requires several years to complete, it is however foreseeable that within a certain time period the number of graduates will rise in the same fashion as the number of groups within academic institutions. But where will all those students go after their graduation? If there is no "microfluidics industry" growing at least at the same rate in the same time-scale, graduates and post-graduates who have spent considerable effort and time in the lab-on-a-chip domain will have to move to different fields (not everyone can embark on an academic career), probably wondering if it was a smart move to devote their time to this field. Of course all these people will hopefully have a sound underlying education in chemistry, biology, engineering or physics, but, nonetheless, their chosen career path was specializing in microfluidics. I consider it an act of fairness with respect to the students to give them assignments for bachelor, master or PhD theses which enable them to relate to problems they may face in their future professional career which for more than 50% of them will likely be in an industrial environment. Again, I do not wish or expect universities to streamline their education to industrial needs, but a somewhat higher degree of consciousness of what these graduates might face once they leave university would certainly be desirable. Otherwise, job interviews can become quite frustrating experiences for both sides, speaking from experience. In this context I would like to highlight two examples which hopefully indicate the direction in which I would like to see some awareness. The first point is the discussion about the predominant use of PDMS as a material for microfluidic devices in academia. I do not want to recall all the arguments which have been brought forward in this discussion and rather point out a relevant article discussing the relevant issues.[6] The only point I would like to stress again is the obvious difference in usage-intensity of this material in academia *vs.* industry. So much excellent work is done in academia in devices made out of this material, while very few commercial devices use it (mentioning of course Fluidigm's devices which make explicit use of the elastomeric properties of PDMS). As much of the performance and many of the properties of a microfluidic device are determined by surface effects (*e.g.*, zeta potential, specific and unspecific molecular binding, surface roughness, contact angle, coatings *etc.*), it is clear that the choice of material critically influences all aspects of a microfluidic device. It is my fear that much of the excellent academic work will lead to dead-ends, simply because many of the results obtained with PDMS-based devices cannot easily be transferred to devices made in other materials. If one thinks about commercialization, one has to take into account manufacturability issues and scaling factors,[7] points in which PDMS does not fare too well. So at one point in the development phase, one hits a "phase transition", *e.g.*, going from prototypes to volume manufacturing. If this phase transition involves a change in material type (*e.g.*, from elastomeric polymer to glass or thermoplastic polymer), it essentially means that most or even all the results and protocols obtained with the prototypes cannot be used for further development. They may possibly still make a nice paper in *Lab on a Chip*, but that is the end-of-the-line. What often leaves me irritated is the fact that in job interviews, I often meet fresh graduates who are completely blind to the fact that there are materials other than PDMS available for the manufacture of microfluidic devicesand they do not understand the need for alternatives.

The second point is an observation which comes from looking at published experiments with an industrialist's set of eyes. In many papers, repeat experiments (*e.g.* multiple injections in CE) are shown, leading to certain statistical data on reproducibility and stability of the experiment. What I have almost never seen is a series of experiments which display chip-to-chip performance variability. This is of critical importance for any kind of product development. How much do devices made with one of the many prototyping methods differ from one chip to another, even if the manufacturing protocol is the same? What influences do my back-end processes (*e.g.*, bonding, dynamic coating) or the actual experimental protocol have on the chip-to-chip reproducibility of the results? If I, at some point in the future want to have a product, it has to work within defined specifications practically every time I use it. How do I know how robust my experimental protocol or set-up is, if I am not measuring this chip-to-chip variation? I would very much like to see more data on this issue in academic papers. Unfortunately, I cannot dismiss my suspicion that the majority of published work relates to one-chip experiments.

Most of the above mentioned issues were addressing the academic side of the microfluidics community. What on the other hand can the industrial part of this community contribute to potentially closing the gap? One simple point, of course, is more active participation in the community dialogue, in symposia and conferences, not just on a promotional basis but on a scientific one. Clearly, many activities will remain under the radar for reasons of competition and confidentiality, this is not surprising given the significant amounts of money invested in founders of microfluidic companies. But I think the industrial players have to take a more active role in shaping the discussion on where the field as a whole should move to and give academic partners better feedback about applicability and possible user expectations. A tool which I find increasingly useful for this kind of dialogue is the facility to give pre-conference short courses on topics which are more industry-oriented such as those dealing with manufacturing methods for microfluidics or commercial applications of microfluidics. These can significantly raise the awareness of students about issues which are relevant in microfluidics from an industry perspective in an environment which still feels familiar to them.

I am still rallying for an industry-led session at one of the next μTAS conferences. I think both parts of the lab-on-a-chip community are in need of more direct dialogue. The industry will need a continuous stream of ideas and concepts developed by academia in order to develop and fill the product development pipeline to eventually fulfill the promised economic potentials of our technology. I am not going as far as A. E. Kamholz did in his 2004 *Lab on a Chip* paper,[8] stating "All relevant participants, including universities, companies, venture capitalists, and publishers all need to emphasize that the final goal in microfluidics research is product development." Nonetheless, a little thought and concerted action in this direction would be beneficial for all stakeholders in the community, both in the short, medium and longer term.

All opinions are those of the author and do not reflect the views of *Lab on a Chip* or the Royal Society of Chemistry.

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