Global Science

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Building a Global Culture of Science—The Vietnam Experience

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Dedicated to Professor Phan Thanh Binh

Abstract: *We detail the lessons learned, challenges, achievements, and outlook in building a chemistry research center in Vietnam. Through the principles of "global science", we provide specific insight into the process behind establishing an internationally-competitive research program—a model that is scalable and adaptable to countries beyond Vietnam. Furthermore, we highlight the prospects for success in advancing global science education, research capacity building, and mentorship.*

"Nature will reveal itself if we only look," said the Wizard of Menlo Park, Thomas Alva Edison. "But nothing will work by itself—you have to make the damn thing work." It is in this spirit that we approach building a culture of "global science" through discovery.[1,2] Global science is founded upon the principle of extending the mentoring relationship, a cherished practice of research-strong institutions, to all emerging scholars regardless of their geographic location, country of origin, race, gender, or religion. Another operating principle of global science is that people can learn from one another and that distribution of knowledge benefits everyone. Indeed, this inevitably breaks down barriers that separate people and helps in building a culture of science to address challenges facing humanity.[3–5] Through our experiences in building partnerships between our home institution and institutions abroad,[1] we have identified eight principles that ensure the success of any given global science program (Figure 1):

1) Inclusivity: the ability to provide research opportunities to emerging scholars is predicated on these opportunities being open and accessible to all.
2) Mutual understanding: global science work must embody a joint vision and common goal with partnering institutions.
3) Accessibility: mentors are readily accessible through a mixture of on-the-ground visits and weekly video conference meetings to ensure that the research agenda is progressing.
4) Working from a position of strength: both partnering institutions' strengths, whether they lie in science, mentorship, navigating cultural norms and institutional policies, or fundraising, must be utilized and built on.
5) Solid infrastructure: infrastructure must be put in place to enable impactful, internationally competitive research to be carried out.
6) Sustainability: mutual benefit is paramount and a sustainability plan that is developed at the outset ensures that this occurs.
7) Funding: reliable long-term funding must be established.
8) Institutional and intergovernmental support: international efforts are inevitably stymied without support from our own institutions and governments.[1]

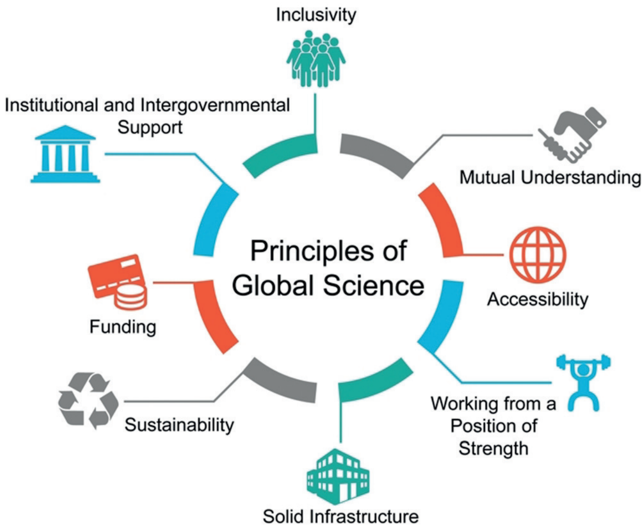

Figure 1. We have found that success in building a global science program is dependent on the degree in which each of these eight principles are properly addressed and implemented.

In this contribution, we provide a detailed account of our role as founders and mentors, the lessons we learned, the challenges we faced, and the prospects for further success in advancing scientific education, research-capacity building, and research mentorship in the context of our joint partner-

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The Challenge in Brief

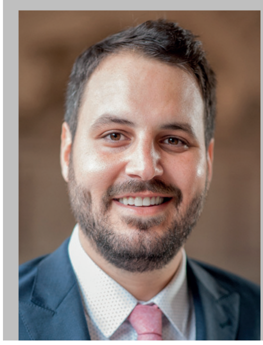
One might be hard-pressed to find a country that is more resilient than Vietnam. Since Doi Moi (economic reform) in 1986, the country has experienced a developmental explosion that has resulted in one of the fastest-growing economies in Asia. In fact, this country of 93 million has seen its gross domestic product (GDP) increase by 3303% between 1990 and 2016, making Vietnam's GDP growth rate the second fastest in the world behind only China over this period.[6] With all of this economic opportunity coming to Vietnam, how will the ordinary Vietnamese citizen respond and take advantage of the new era that Vietnam appears to be headed toward, if not already entered? Conventional wisdom points to higher education as being a key driving force in upward mobility. However, Vietnam, like many developing countries, has traditionally experienced the phenomenon of "brain drain", in which the brightest emerging scholars are exported to study in research-strong countries with the expectation that they will return and contribute to the scientific development of their home country.

The lure of a greater degree of economic opportunities that further improve their lives and the lives of their families often prevents them from returning.

The brain drain problem in Vietnam is further exacerbated by a higher education system that lacks a structure for fostering intellectual freedom, financial resources (only 0.6%, or USD $628 million, of Vietnam's 2014 national budget was spent on science and technology research),[7] and practical education curricula to equip emerging scholars with the necessary tools to innovate and contribute to their society.[8] The magnitude of this problem is highlighted by the fact that an estimated 63000 Vietnamese emerging scholars were studying abroad in 2016 (accounting for 10% of all international enrollments)—a number that increased by 680% since 1999.[7,9] To create "brain circulation" in Vietnam, it is critical that capacity building is given a high priority.

Although Vietnam has more than 350 public universities and more than 80 private higher-education institutions, which, when combined, serve more than 2 million students nationwide, there was not a single Vietnamese university ranked in the top 1000 universities worldwide until 2018.[10,11] This is likely due to the fact that the majority of these universities are dedicated to teaching as opposed to providing opportunities for their faculty to carry out academic research. Academic research remains mostly confined to Vietnam's two largest universities, Vietnam National University—Ho Chi Minh (VNU-HCM) and VNU—Hanoi. Over the period of 2001–2015, in excess of 18000 scientific publications were produced by Vietnamese research institutions, which represented about 0.2% of the world scientific output (this number is notably small when considering Vietnam's population is around 1.2% of the world's total population).[12] Publication in the chemical sciences ranked below other fields with respect to percent output (9.6%), but did have the second highest rate of growth (22.6%) between 2001–2015.[12] In this context, 77% of Vietnam's scientific output involved international collaboration (most notably with the United States and Japan).[12] International scientific collaboration is championed as a fundamental mechanism for improving quality of research as well as the impact that research has on addressing critical challenges.[13,14] The challenges faced by Vietnam are similar to other developing countries in that there is insufficient funding for advanced research and, therefore, scientific research lacks the robust infrastructure needed to grow research and innovation.

Omar M. Yaghi was born in Amman, Jordan and educated in the United States. He currently holds the James and Neeltje Tretter Chair Professorship in Chemistry at the University of California, Berkeley and is the Founding Director of the Berkeley Global Science Institute. He is known for pioneering reticular chemistry and, more recently, a global mentoring model that is being implemented in research centers around the world.



Kyle E. Cordova was born in the United States and mentored by Prof. Omar M. Yaghi at the University of California, Los Angeles. He is currently the Associate Director at the Berkeley Global Science Institute. His work primarily focuses on building research capacity in developing countries through the mentoring model. He is actively engaged in mentoring research groups in Vietnam, Malaysia, Saudi Arabia, Mexico, and United Arab Emirates.

Sowing the Seeds of Research

In 2009, the then President of VNU-HCM, Professor Phan Thanh Binh, initially approached O.M.Y. (K.E.C. joined this effort shortly thereafter) with a simple proposal: To establish a center of research excellence in Vietnam that fosters the growth of emerging scientists and affords them with the opportunity to conduct innovative basic research under the mentorship of top international researchers. Our general objective was to demonstrate that the success of such a research center would serve as a world-class model in Vietnam for how to approach and solve scientific challenges that have far-reaching, global implications. To ensure the long-term sustainability of this center, we proposed our "global science" model, in which the time-honored mentoring tradition would be extended to Vietnamese scholars that took part. The premise of implementing this approach was that, over time, these Vietnamese scholars will be equipped with scientific innovation and excellence, ethics, new knowledge, and know-how, which then could be imparted on the next generation of scientists. Therefore, a cyclic and sustainable model is achieved with the mentored emerging scholars growing to become mentors for the next generation.

It is important to note that in the case of Vietnam, a key factor for establishing and maintaining the initial connections with VNU-HCM was a Vietnamese–American former graduate student in Yaghi's research laboratory, who acted as a liaison and proved invaluable in navigating cultural differences and expectations from both sides, all the while helping to create the foundation for the research program. With the connections in place, we began to make use of the well-established infrastructure and administrative support that our then institution, University of California, Los Angeles (UCLA), had to offer. We mobilized a team of UCLA scientists and administrators and travelled to VNU-HCM in 2009 to discuss the program development in more detail. Over the course of the discussions, the skeletal framework of the program quickly grew in scope and size. What started as an initial plan to simply develop a research program, quickly blossomed into the desire to develop a chemistry graduate program and a research center whose structure, curriculum, and execution were unique in Vietnam.

Upon signing partnership agreements, we created the Center for Molecular and NanoArchitectures (MANAR), which consisted of two parts: 1) A research center that would carry out world-class research and offer world-class capabilities (infrastructure, environment) and 2) a chemistry doctoral program that educated researchers and positioned them to be future science leaders at both VNU-HCM and throughout Vietnam (Figure 2). As a part of our agreement, the US side would use its expertise to build Vietnam's scientific and technological portfolio whereas the Vietnam side would streamline the development process in order to make it culturally and scientifically relevant (Figure 2). A critical component for ensuring initial success was to work side-by-side with our Vietnamese colleagues to obtain buy-in from the Vietnamese government, most notably the Ministries of Science and Technology (MoST) and Education and Training (MoET). Furthermore, we engaged the U.S. Department of State, Science and Technology Cooperation Office as well and, as a result of our efforts, our plan was prioritized within the broader Vietnam and U.S. Science and Technology Collaboration Agreement. This accomplishment led to widespread support, calls-to-action, and seed investment funds for developing the free-standing research center. It should be made clear that at the core of all of this was the joint plan that we created collaboratively. It was the scientists, emerging scholars, and mid-level administrators together who initiated and worked out the details of establishing the center and graduate program. This collaborative effort resulted in a cohesive plan, which was presented and argued to the university administrators and government ministers. The fact that we had a shared vision, strong commitments from both sides, support put in place to bridge the two sides, and a viable scientific plan ensured institutional and intergovernmental support.

Funding—Always an Issue, Never a Problem

In principle, any research topic can be pursued depending on the country's and institution's priorities. For MANAR, we jointly designed a research program based on the discovery and fundamental development of new nanomaterials for clean energy and environmental applications.[15] This research

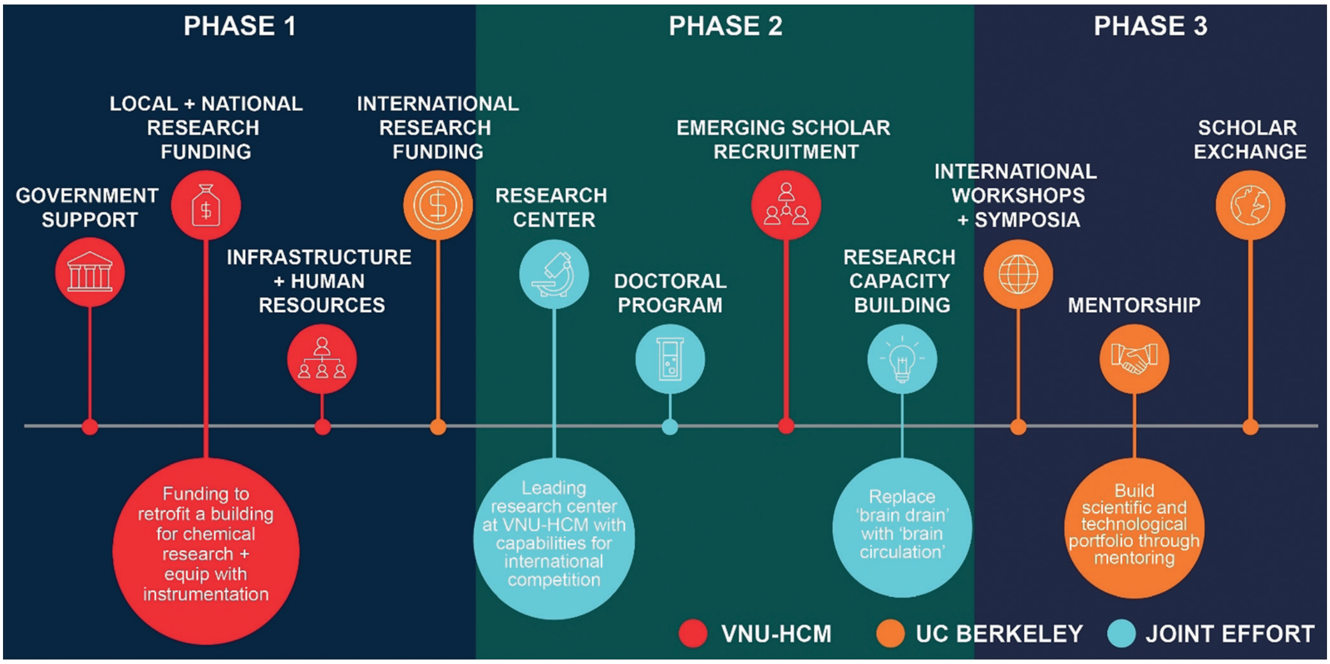


Figure 2. Through a partnership with Vietnam National University—Ho Chi Minh (VNU-HCM), we were able to effectively establish, build up, develop, and sustain a center of research excellence and a doctoral program in Vietnam. Both sides of the partnership contributed to this joint effort in their own way. The mechanism with which this partnership progressed is adaptable to countries beyond Vietnam.

program was crafted with Vietnam's research challenges in mind; Vietnam's scientific impact and specialization in chemical research is one of the weakest in the world.[7] To realize this program, we sought funding for three phases of development (Figure 2). The first phase was to equip an already established laboratory at the University of Technology in VNU-HCM with basic essential instrumentation. This initial phase would afford us the opportunity to begin collaborating and recruiting early career professors and emerging scholars to join the program and to initiate research immediately prior to finishing and inaugurating the stand-alone research center. The second phase of funding, which occurred concurrently with the first phase, was to retrofit a building for wet chemistry and materials science research and to purchase the more advanced state-of-the-art instrumentation that were required (Figure 3). The third and final stage was focused on garnering research grants from national and institutional funding schemes.

After this initial funding period, we continued to jointly pursue national and institutional grants to fund the research; however, we also turned our focus beyond Vietnam to international funding agencies. This was an important strategic decision as the program continued to grow at a rate that was unsustainable solely by the Vietnamese government and VNU-HCM. An important distinction about the global science model is that the partnering organization receives credibility and prestige behind their funding proposals—a distinction that greatly increases the likelihood of receiving such funding. We found a valuable partner in the U.S. Office of Naval Research Global with other opportunities existing through the World Bank.[16,17]

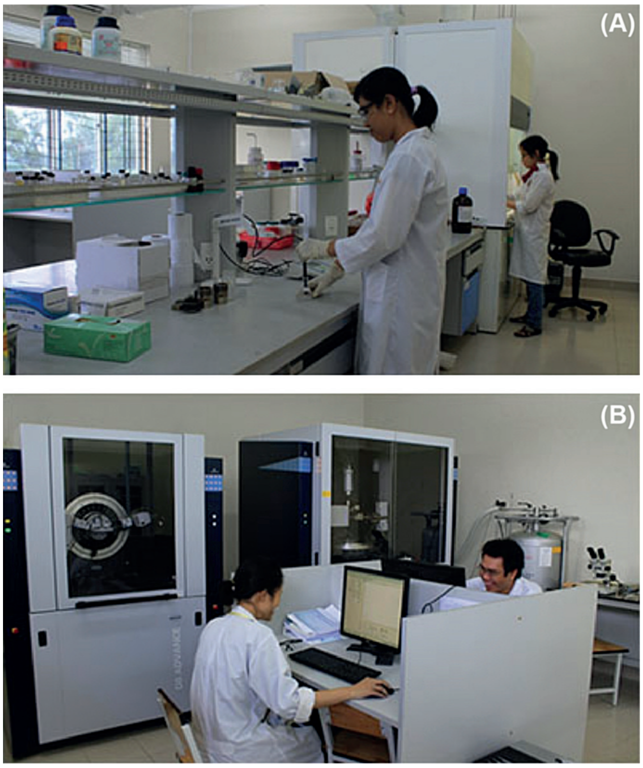


Figure 3. A) A typical wet chemistry laboratory at MANAR. Each Ph.D. student was provided with their own fume hood, a luxury in Vietnam, as well as common laboratory supplies and consumables. The laboratory met international safety standards; B) MANAR housed the first single crystal X-ray diffractometer and second powder X-ray diffractometer in Vietnam. An important policy was that there were no technicians hired to operate these instruments. This allowed emerging scholars to become experts in operating, making measurements, training other scholars, maintaining, and repairing the instruments housed at the center.

A Solid Infrastructure for Research Success

In order to achieve impactful results, a solid infrastructure had to be put in place to support the ambitious research programs. As mentioned previously, phase 2 of the funding scheme was focused on retrofitting a building for laboratory activities. Once the building—originally planned as a high school—was identified, we began working with VNU-HCM officials to devise the laboratory layouts and space allocation. We arrived at constructing five research laboratories (>1400 m^2 in total), each equipped with two fume hoods, a luxury for researchers in Vietnam, and ample bench space to carry out chemical synthesis. Significant efforts were also placed on ensuring that laboratory safety measures were integrated within the construction plans, including safety showers, eye washes, proper storage spaces for hazardous and/or flammable chemicals, and dedicated spaces for chemical waste in each laboratory. Such measures are almost non-existent in other Vietnamese laboratories and were often difficult negotiating points due to the added costs of including them. We also dedicated three separate spaces to equipment, specifically, two materials characterization rooms and an X-ray diffraction room (Figure 3). Following approval and construction for the better part of a year, the research center was inaugurated in 2011 with an incoming class of 9 Ph.D. emerging scholars. Two instalments of funding, one during the construction phase and the other in 2014, were used to purchase instrumentation, part of which we were able to secure the first single-crystal X-ray diffractometer in all of Vietnam (Figure 3B).

From our experience, the research program played a critical role in building infrastructure and research capacity at VNU-HCM. The technical specifications of the designed laboratories suited research carried out not only in our program, but also for other fields of chemistry and materials science. This was done deliberately to create a space where collaboration with surrounding research groups would flourish. Additionally, the instrumentation that was required was diverse in scope and was judiciously chosen to fill the scientific needs of VNU-HCM and Vietnam. MANAR's instrument facilities functioned as a "user facility" where outside scientists sent samples to be analyzed. The capacity that MANAR took on lent itself useful for allowing the center to serve as a vital component of the scientific ecosystem that VNU-HCM sought to instill.

Although developing laboratory space is nothing out of the ordinary for chemists, the experience in Vietnam proved challenging. The reasons for this often centered on competing outside interests and opinions, lack of financial planning, and different standards for what should be the basic components in a world-class chemistry laboratory. As expected, early-career faculty demanded (rightfully so) a lot of attention during the planning process as they wanted to ensure that MANAR would cater to their research interests as well. This was an area in which compromise was met with steadfastness towards upholding the highest possible standards of practicing science and safety.

Merit-Based Inclusivity

A critical issue for our participation as partners was that recruited emerging scholars were selected based solely on merit. This means that those who were offered research positions were among the brightest with respect to their scholastic achievements and their demonstrated potential for carrying out independent research. The emerging scholars came from universities within VNU-HCM and other highly regarded universities throughout Vietnam (Can Tho University and University of Science and Technology, Hanoi). The primary educational backgrounds of MANAR researchers were in chemistry (65%), chemical engineering (25%), and physics (10%). As we had considerable input in deciding who would join, we ensured a fair gender balance among the incoming emerging scholars. Indeed, we are proud to report that there was an equal number of male and female scientists from different ethnic backgrounds researching at any given moment at MANAR.

Another critical issue for achieving an inclusive environment was related to removing economic barriers. When crafting the program our intention was to ensure that joining the program would not place any financial stress. Although the country is experiencing rapid economic growth, Vietnam remains a relatively poor country with a per capita GDP of USD $2186.[6] To remove economic barriers, we worked with VNU-HCM to put in place a system of “financial aid”, in which all MANAR researchers received a stipend that covered tuition and personal finances. Additionally, all costs relating to research, including chemical expenses and instrumentation support were to be covered by grants secured by MANAR administrators and research directors. This “financial aid” system was not without controversy as, at the time, no program or research center offered such benefits for their graduate students. A typical Ph.D. student in Vietnam is expected to pay for classes, fees for outside instrument use, and even chemicals that they need for their project. Often times this requires students to take on additional jobs to pay for their graduate education. Although the “financial aid” was overwhelmingly successful at enabling the emerging scholars to focus all of their efforts towards science, we found that the greatest point of contention consistently surrounded paying the students their stipends regularly.

Mentor Accessibility

Accessibility was the single most important aspect of this partnership. At the outset, we ensured that MANAR was equipped with a video conferencing system. Researchers participated in weekly meetings with our group in order to be engaged through scientific presentations and regular updates on their research. These weekly group meetings also included researchers from similar centers in Japan, South Korea, and Saudi Arabia. Furthermore, ensuring accessibility allowed for an additional weekly intra-center group meeting with a mentor in order to receive direct advice and strategic planning of the next steps for their project to reach its full potential. The intra-center group meeting was a time in which MANAR emerging scholars were able to present their data and research progress. The meetings and presentations were treated as formal, which allowed the MANAR emerging scholars to hone their technical skills, learn proper presentation techniques, and strengthen their communication skills. Furthermore, it was a time where idea generation happened with scientific discussions often becoming hotly debated. It was our observation that when given the chance, the emerging scholars appreciated the voices that were given to them during these meetings, which led to substantial growth in both their scientific and communication skills.

Accessibility also played a critical role when the time came for manuscript preparation. Typically, our strategy for this would first center on the collection of the necessary data to form the supporting information of an article yet to be published. This taught the emerging scholars how to logically order their experiments and provided a frame of reference for writing the manuscript. After the supporting information was completed, the emerging scholars were responsible for preparing the first manuscript draft. Once finished, and after a lot of “pushing”, the mentor would provide comments for further improvement. This process would play out over countless drafts (including additional countless scientific figure iterations), at which point the emerging scholar had improved the manuscript as best as they could. “Paper readings” were then scheduled with the mentor. The paper reading process was a time in which the mentor and MANAR emerging scholar discuss (or debate!) word-by-word the merits of the work, highlight flaws and/or weak points, and place the research in a larger context. There was no compromise on the rigor nor quality of the work and its presentation. Both of us were intimately engaged from start to finish with the process of paper preparation, reading, and finalization.

The other aspect of accessibility that contributed to the growth and success of MANAR was through scholar exchanges. Not only were mentors visiting MANAR, but MANAR scholars were visiting the US as well as other global science nodes. Once the center was established and research progress was made, we identified the first emerging scholar to visit our global science node at the Korea Advanced Institute of Science and Technology (KAIST) in 2013. While there, the scholar learned the fundamentals of photocatalysis, which translated into real results that were published upon the emerging scholar’s return to MANAR.[18] We also have had multiple emerging scholars visit UC Berkeley for 6–12 month periods, which has resulted in first author publications for each of them in high-impact journals.[19–21] In order to help minimize the burden on resources that comes with a visiting scholar, we worked with colleagues at other institutions to raise funds for scholar exchanges. One such example came from the Instituto de Ciencia de Materiales de Madrid (ICMM), now a global science node, who partnered with MANAR to obtain funding from the Consejo Superior de Investigaciones Científicas Program for Scientific Cooperation with Developing Countries.[22] Through this trilateral partnership, MANAR scholars visited ICMM for three-month periods to collaborate on joint research projects, gain experience in crystallography, and even publish joint work together.[23]

Fostering Intellectual Growth

We found that the growth of the Vietnamese scholars took place in five distinct stages (Figure 4). By passing through each stage, the emerging scholars grew as scientists and the success they achieved was due in large part to the experience gained in preceding stages. Each emerging scholar entered the first stage upon joining MANAR, in which their research experience was relatively minimal (this is also true of any place of research throughout the world). This first stage can be characterized as a time for research project ideation with the prospects for success being connected to a robust feedback loop being established with the mentor. Specifically, the emerging scholar would research ideas, propose research projects, receive feedback from the mentor, refine their proposal, and then commit to carrying out the project via experimentation. It is important to note here that the mentor's role is delicate in that their opinion may overly influence the research direction in which the emerging scholar wants to proceed toward. Research is not a linear activity, rather, it is chaotic. Thus, it was important that the mentor provided sufficient space for the emerging scholar to explore on their own, to create their own research path by never prejudging an experiment, and to learn to get past their preconceived notions about what research life is like.

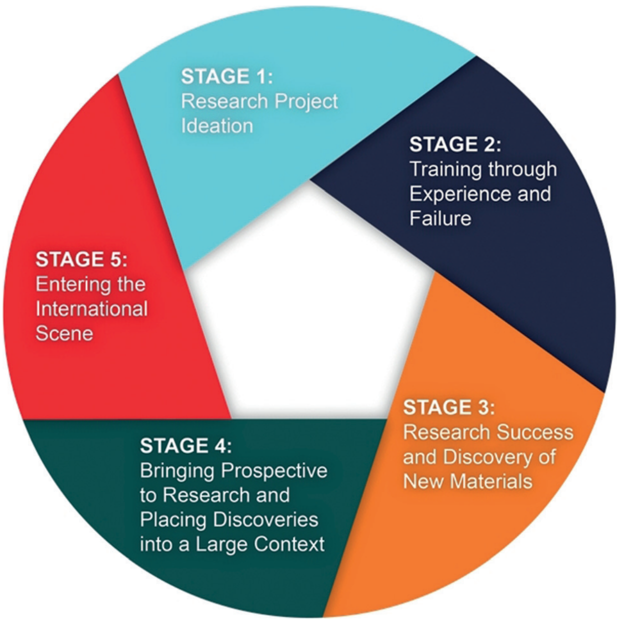


Figure 4. Through our experience serving as mentors at MANAR, we found that the intellectual growth of the emerging scholars occurred through five distinct stages. The first stage was characterized by research ideation and was supported by the establishment of a robust feedback loop with the mentor. The second and third stages were periods of scientific growth, in which the emerging scholars learned from failures in the laboratory that eventually led to the achievement of success through discovery. The fourth stage was situated on the emerging scholars being able to frame their research discovery within a larger context. The fifth and final stage witnessed the emerging scholar publishing their work and reflecting on their accomplishments through this process.

The second and third stages can be characterized as a period of training through repetitive failures leading to research success through discovery. Specifically, the second stage was a period of their development, in which independent exploration was encouraged. More often than not, the emerging scholars would get started by reproducing reported procedures that afforded them with the opportunity to hone their skills and lay a foundation for their understanding of their chosen research topic. Instrument-specific trainings, through organized workshops, supplemented their development during this stage; however, it was our observation that their own experiences, struggles, and failures with experiments and instrument usage were the primary driving force behind their eventual success. After confidence was built, they then focused their attention to carrying out their own research projects with mentorship occurring as needed. It is noted that this second stage had the highest "activation barrier" and, as such, required the most time for the emerging scholars to progress through (2–3 years). By learning to push through failure, the emerging scholars eventually advanced to the third stage, which is characterized by research success. In this stage, the emerging scholars begin to see the fruits of their labor (materials discovery) and their enthusiasm and outlook began to dramatically increase. Their development shifted from exploration to learning how to maintain a critical perspective on the data they were acquiring in order to ensure that analysis and characterization was rigorous, correct, and thorough. Throughout the first three stages, the emerging scholars were mentored on how to keep an open mindset toward what they were observing in the laboratory—again, a critical point here was that mentorship taught them to never prejudge an experiment. It was often the case that the emerging scholars were discovering interesting phenomena that were distinctly different than what their original research project was focused towards. A considerable part of the mentorship process was to provide feedback on maintaining a wide perspective, which was opposite to the "tunnel vision" that they tended to prefer.

The fourth stage of intellectual growth focused on providing perspective and placing their discovery into a larger scientific context. This stage was punctuated by the question, "What is your finding good for in the larger context of science?" Discussion of this question was then singularly important. The fourth stage also was a time for framing the discovery and subsequently communicating the results in an article (as detailed above), choosing and targeting the right journal, and, for the first time in their scientific lives, responding to comments and criticisms via peer-reviewed referee reports. The fifth and final stage of their progression was a time characterized by having their work published, which made it open to be viewed and analyzed by the international scientific community. Through these stages, the scholars realized that they had learned to formulate what was at the time a fundamental question and basic science research idea and translate that into practical applications that have real world meaning.

Accomplishments

To say that MANAR is a success would be an understatement. This global science experiment has had an immediate and lasting impact on the scientific landscape in Vietnam. This is evidenced not only by the infrastructure developed, but also in the effectiveness of the research mentoring program. Over the past 6 years, we have educated/trained 15 Ph.D., 10 M.Sc., and 20 B.Sc. scholars in how to carry out internationally competitive and impactful scientific research in materials science and chemistry. It is important to note that all of these emerging scholars were trained on how to use the instruments housed in MANAR themselves—from simple operating procedures to data analysis to maintenance and repairing (Figure 3B). In this way, we avoided the common system employed in Vietnam of using technicians, thus, granting the emerging scholars with the opportunity to become experts in their own right. Additionally, we guided them through elevating their soft skills, including critical thinking, developing research methodology, scientific professionalism (ethics), and effective communication of results. This has led to more than 30 scientific publications with several appearing in the *Journal of the American Chemical Society* and *Angewandte Chemie International Edition*, which represent some of the most prestigious publications ever achieved by Vietnamese scientists carrying out chemical research at a Vietnamese institution (Figure 5).[19–21] In these 30 publications, MANAR scholars have reported the synthesis of more than 25 new materials discovered at MANAR (with many more unpublished) for use in applications ranging from selective CO_2 capture, proton-exchange membrane fuel cells, heterogeneous catalysis, adsorption-driven heat pumps, photocatalytic chemical transformations, and gas detection (Figure 5).[19–21] Interest from local chemical and technology industries is gaining traction and researchers from around the world are now using the materials developed at MANAR as the basis for their own research programs.

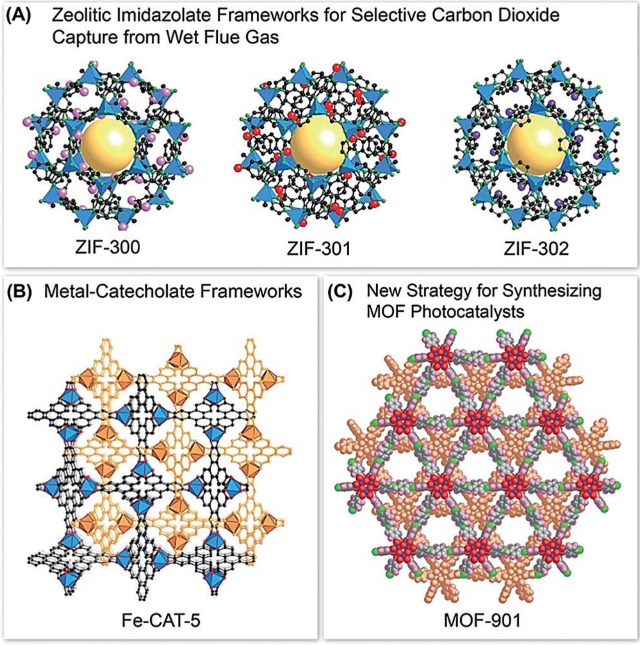


Figure 5. Representative research highlights from MANAR. MANAR researchers discovered more than 25 new materials, of which several were considerable achievements for a wide variety of applications: A) hydrophobic zeolitic imidazolate frameworks capable of selectively capturing carbon dioxide in the presence of water;[19] B) a series of metal–catecholate frameworks exhibiting ultrahigh proton conductivity for proton exchange membrane fuel cells;[20] and C) a new strategy for synthesizing metal–organic frameworks by utilizing the chemistry of covalent organic frameworks.[21]

Challenges Faced, Lessons Learned

The substantial accomplishments and overall success of MANAR did not come without overcoming obstacles. Continuous financial and accounting issues were the most prominent challenges. We experienced that, at times, the financial aid was used as a tool to pressure scholars to carry out extracurricular obligations or paperwork (Vietnam has a lot of paperwork!) at the behest of administration—duties that were originally agreed to not be passed on to the scholars. Furthermore, we often found ourselves overhauling administrative structures and mechanisms put in place that hindered progress of the scholars. In terms of the Ph.D. program, changing administrative tides greatly influenced the progress of the Ph.D. scholars toward their degree with former agreements and systems put in place being nullified upon the involvement of new academic leaders. With respect to the research program, Vietnam does not have a robust system in place for local vendors. With this comes long waits (as is true in much of the developing world) for chemicals and instruments, laboratory supplies, and repairs of instruments. Furthermore, if MANAR did not have an instrument within its facility, then it was likely that the scholars would need to ship samples abroad for analysis, which significantly delayed their research progress. Frequent power outages and a research facility that was open to all elements of Mother Nature led to instrument failure and regular flooding during monsoon seasons.

Finally, the goal for MANAR was always to mentor the next scientific leaders in Vietnam, who would then serve as mentors to the next generation. A major challenge faced while going through this process was resistance at the notion of placing newly minted Ph.D. scholars, those who went through our mentoring process and were deemed the most capable, in leadership positions. This was directly a result of maintaining control and consolidating power by established scientists, which ran counter to the original, established working arrangement.

Outlook for Global Science in Vietnam

Through the Vietnam experiment, we were able to realize a mutually shared dream of bringing innovation in the chemical sciences to Vietnam and to prove to the world that the model of global science is successful in building research capacity. Knowledge transfer and development through mentorship occurred with profound results. MANAR is an inspiration for what can happen when scientists from research-strong countries aspire to extend the mentoring relationship to a global stage. In an ever-increasing, interconnected world, global science offers the practical benefits of helping train researchers in far off, distant countries on how to think critically and solve problems that may be applied to local challenges before these challenges become global. Our experience in building research capacity at VNU-HCM has provided opportunities for Vietnamese emerging scholars to achieve impactful results while remaining in their home country, thus, encouraging “brain circulation” as opposed to “brain drain”.

The level of productivity, achievements, and, now, researcher expertise has led to MANAR becoming a formidable node in a quickly growing network of global science centers.[24] With that, we have recently begun to witness MANAR scholars engage with the global science network through collaborations, trainings, and scholar exchanges (notably, in the absence of our participation; Figure 6). Indeed, they are publishing high-impact discoveries independently and continuing to innovate by developing new materials that were previously unseen. Scholars who want international educational opportunities are also pursuing them through this network and they will most certainly arrive at their new destination with a skillset that will ensure their success. Nevertheless, the momentum at which MANAR is progressing is inspiring and we can now conclusively state that global science—the practice of extending our experiences and knowledge to all people—is and will continue to be a success.[25]

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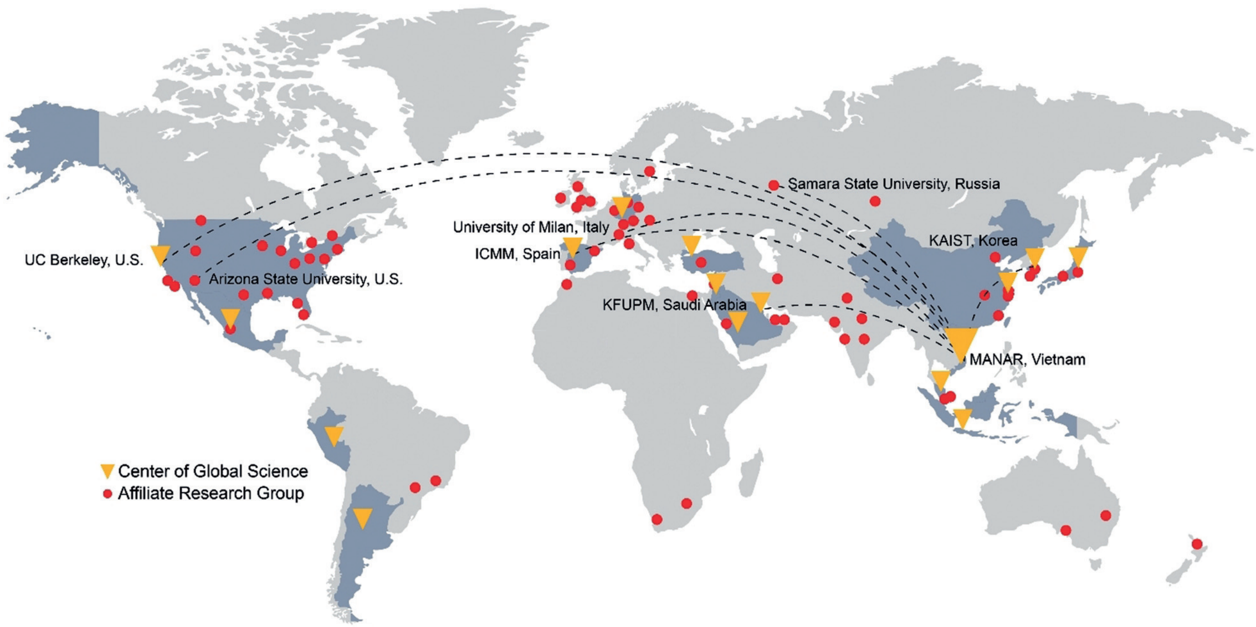

Figure 6. MANAR has now become a formidable node in a quickly growing global science network. Through collaborations, trainings, and/or scholar exchanges, MANAR researchers are engaging with the global scientific community. Inverted triangles are Centers of Global Science and red dots are affiliated research groups, which plug into the global science network.

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Conflict of interest

The authors declare no conflict of interest.

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