

## Nobody Reads a Preface!

Either you have been teased by the odd headline, or perhaps you are curious about the genesis of this work. For some readers, the preface is the part of the book to be skipped. But I still believe it is my best opportunity to develop a bond with you and leave a lasting impression about the rest of the book. By the end, if you continue reading, I think you will know my approach and whether this book is a good match for your teaching or learning style.

For fifteen years, I had organized voluntary after-school activities for high school students with the main goal of stimulating and sustaining their interest in science, technology, engineering, and mathematics (**STEM**). Over time, we had implemented ambitious projects, created sophisticated computer programs, and developed electronic devices like a Morse-to-text converter that we could directly connect to our short-wave amateur radio LX9CC. After leaving school, most of the attendees had started a degree in engineering, and a few had joined renowned companies. I felt that our work had been successful in many ways. However, participation began to decline and finally completely died. I was left puzzled, wondering why the students were no longer attracted by the formerly well-received workshops.

Was the new situation related to my personal teaching approach toward the students? Had I changed? During this time, I had been appointed director of a boarding institution, a position that brought with it a range of new responsibilities. However, in order to remain grounded in teaching, I had decided to continue with the workshops, and for several years, there was no appreciable change in the participation levels. Had the students changed? Of course they had! They always have! Colleagues described them as poorly motivated and undisciplined, more attracted by the social interactions of their peer group than by the cognitive demands of school. While I knew that such complaints had been lodged against young people since the days of my own youth, was I missing something else? Or had the students' fascination with science and technology significantly suffered?

Then, in 1999, I stumbled on the July edition of the German scientific journal *Bild der Wissenschaft*. Devouring the article “Klötzchen mit Köpfchen (Smart Bricks)” by B. Müller, V. Steger, and H. Hautop, I knew I had found something important. In this remarkable article, the authors presented the new LEGO® Robotics Invention System™. In fact, they described a truly innovative concept—far more than just another box of LEGO® pieces. Almost one year earlier, the LEGO Company had publicly announced the introduction of a novel product line strangely called **Mindstorms**®. I suddenly realized that this new approach would help me reinvigorate our workshops. I never could have imagined the extraordinary adventure that would follow.

I thought back on my own educational journey. My most enduring memory was the night of the 21st of July, 1969. I was sitting in front of the TV, watching what to me was the most exciting event in history. As a 10-year old boy, I was electrified when, at 2:56 UTC, the astronaut touched the soil of the moon. “*Sats ow smo steb fomae...*” –What is he saying? I had no clue! ... Later, I learned that Armstrong had spoken the inspiring sentence: “That’s one small step for [a] man, one giant leap for mankind!” Growing up with a fascination and attraction to science and technology, my friends and I all wanted to become astronauts. Our games revolved around the Star Trek adventures through the Universe on board the Starship Enterprise. At home, we played with *Philips Electronic Engineer* sets, and sometimes we couldn’t believe that we were becoming masters of the electron.

Two years later, we went off to high school 30 km away from our hometown. We were eager to finally meet those professors about whom we had heard so much. (Note that in French-cultured Luxembourg, secondary teachers are called professors.) However, we were quickly disappointed to find ourselves being taught by competent but unspectacular people who just rattled out their lessons. Then we met and fell under the influence of Professor Jean Mootz. Mootz was a phenomenon, officially a chemistry teacher, but also a fervent radio amateur and a talented electronics technician. Besides his chemistry lab, he had installed a complete electronics laboratory under the roof of the *Lycée Classique Diekirch*. This laboratory rapidly became the center of gravity for our small group of enthusiasts.

Almost every school break, and (certainly) each Wednesday after school, we met with Professor Mootz. What made these sessions so exciting was the fact that we could play around with electronics: make tests, solder small devices, and start bigger projects, although only part of what we learned was included in the curriculum. Nothing was planned; every project emerged from the group. During these after-school activities, Professor Mootz never lectured, but he patiently answered all our questions. “What happens if I apply 40 V to this 16-V electrolytic capacitor?” —“Try it!” he said. We fetched the DC-source and two wires with alligator clips and attached them to the capacitor. Then we switched on the power supply... and boom! The capacitor had gone. “Do you understand now? Then clean up the mess!”

Then came the day when Professor Mootz brought an HP® (HP-35) calculator to the laboratory. It was one of the very first electronic calculators available in Luxembourg. We were thrilled to be among the first to play with it, feeling like pioneers. The programmable HP-65 followed the scientific calculator. Interestingly, the user guide called this seminal device *a personal computer*. We were exposed to computer programming. And that’s when a second remarkable teacher entered our lives, Professor Francis Massen, a splendid physicist and computer specialist. With him, we continued to enjoy the workings of the programmable calculators. We attended his optional BASIC programming courses, which were a novelty in Luxembourg. Now we could play around with a real computer for every free minute. More and more we became specialists—even trying undocumented things, widely known today as hacking.

These after-school activities were the most important events in our high school lives, keeping us in constant excitement about what the next school day would bring. The added benefit was that our grades consequently improved. For instance, when the math teacher first introduced trigonometry, we already knew the rudimentary concepts because we had observed sine waves on Professor Mootz’s oscilloscope and had come to understand Lissajou graphs. It certainly was unusual that 16-year old students had already programmed the digital Fourier transform on a computer before officially having started learning calculus. We had become highly motivated and curious students, because over the years, we had learned by playing with problems.

It is not surprising that years later, as an educator, I started applying my teachers’ prolific methods in similar after-school workshops. These activities mostly centered on electronics and computer programming. Over time, it seemed that, as more technology filled our daily lives, the students became less curious about the secrets behind the technology. The electronic circuitry we were previously able to homebrew in our workshops was now terribly complex. And now *everybody* could assemble a motherboard, hard disk, CD-drive, and sound

card and could successfully run a desktop computer. No special skills were required any longer, no soldering iron was needed, and no transistor and processor-programming knowledge was necessary. And in any case, if the motherboard didn't work anymore, it was thrown away, since nothing was worth repairing. This lethal combination was probably the most important reason for the declining attendance at the workshops.

By contrast, and right from the start, LEGO Mindstorms projects became a runaway success in our after-school activities. Certainly, it was because the stuff was exotic and new! Perhaps it was also because the LEGO kits invited adolescents to play with a material that was paradoxically both familiar and new and offered increasing levels of difficulty that corresponded to their actual interests. Again, they could create objects that they were able to understand. The analog and digital electronics involved in the LEGO Robotics Invention System had been kept at such a reachable level that students (and notably, adults of my generation) were immediately encouraged to start conceiving, building, and programming spectacular robots. Somehow, I personally felt linked back to my youth workshops with Professor Mootz. The enthusiasm for the LEGO robotics projects that arose from the very first experiments has been kept vivid for a decade among both students and educators, and nothing indicates that it will decline in the coming years.

When the LEGO Company announced its slogan “**Build and program robots to do what you want!**”, the Mindstorms engineers knew that this was the most exciting challenge they could ever send to their customers. However, they could hardly imagine that the educational world would embrace this challenge and adapt it as a tool for teaching content from the widespread branches of science and technology. The experiences our students have enjoyed in problem solving with LEGO robotics have touched on everything from computer science to neuroscience, and they have faced challenges from the mechanical to the behavioral and beyond. The problems students tackle are largely ones that they are excited about solving. This is how it should be with the pursuit of new knowledge.

This book, *Eureka: Problem Solving with LEGO® Robotics*, is an invitation to the reader to start his or her very personal adventure in solving scientific problems related to the creation of real robots. It exposes many of the extraordinary projects that our students have realized in the local robotics club during the last twelve years. However, the idea is *not* to present a textbook that may serve for simple copy-and-pasting. On the contrary, the goal is to initiate the reader into the art of tackling problems for which there are no plug-and-play solutions. Although this book contains a bonanza of detailed information about most relevant topics of robot design, the specifically developed solutions are not necessarily transferrable point-by-point to problems that the reader may encounter with his or her own robotic project. However, this book will certainly provide directions, give hints and clues, and help sustain the boldness and confidence needed to face difficult problems.

The contents of this book are put together in ways to help the reader learn and think. The interdisciplinary nature of robotics is the major reason for the blended presentation. Our audience is anyone who wishes to tackle demanding challenges from science and technology and who wants to be challenged by LEGO robotics. It contains a multitude of ideas about the extensive field of robotics, demonstrating the possibilities that LEGO offers and exploiting LabVIEW™ for these activities. Overall, this book is about problem solving, seeing interrelationships and connections, and integrating one's knowledge. The first part develops a non-exhaustive list of problem-solver methods. The presentation is based on authentic stories of famous personages from science and technology. In parallel, the chapters show how young

students have solved their actual robot problems, while deploying methods that are very similar to the ones applied by their inspiring examples. The second part of this book changes the viewpoint by inviting the reader to create robots that solve problems on their own, such as autonomous obstacle avoidance, pursuit of a predefined direction, or foraging on particularly difficult terrain. To this end, a collection of thought-provoking open-ended projects are included to inspire readers to become enthusiastic problem-solvers.

There are many ways to navigate through this book. You may classically read it page by page or jump from challenge to challenge. Perhaps you want to browse through the work and halt at attractive or intriguing pictures. For sure, you will not want to miss the selected historical examples. However you experience this book, we hope that you will discover its fundamental message and challenge: Have fun while solving problems, think about changing your perspective, be prepared to improvise, and never give up! If during your study, you meet facts and details that seem beyond your scope for the moment, just skip them and continue with the next paragraph. During your creative journey in robotics, there is a chance that you will stumble upon a particular problem that might bring you back to the section that you skipped earlier. Note that the only prerequisites for the reading of this book are a basic knowledge of the LabVIEW for LEGO Mindstorms® software that you will acquire easily by following the excellent tutorial and examples that are part of the software package ... and the motivation to venture into unexplored terrain.

This book is the result of lengthy cooperation with many dedicated people, whom I earnestly want to thank for their help and support. First of all, I must mention Jean Mootz and Francis Massen, who long ago initiated me into the secrets of solving problems in electronics. Then, of course, my inspiring students and collaborators –especially Laurent Kneip, Juri Chomé, Ben Birkel, Scharel Clemens, Luc Theisen, Thierry Conter, Erik Heinen, Laurent Hettinger, Stéphan Gravé, Eric Moszcynski, Philippe Jacob, and many others without whom I never would have learned so much; certainly, nothing increases personal knowledge more than teaching and instructing brilliant minds. My deepest gratitude goes to Chris Rogers for being the initiator of this book project; Tom Robbins and Erik Luther for their confidence and assistance; and Catherine Peacock, who patiently and thoroughly polished my non-idiomatic formulations. Special thanks to Ray Hsu and Hunter Smith from National Instruments for their helping hands and to the book’s reviewers, whose comments and advice improved the final product. Finally, I owe a debt of gratitude to the numerous people who contributed ideas, contraptions, and pictures: Paul-Nicolas Baumann, Daniele Benedettelli, J. P. Brown, Mike Davey, Brian Davis, Mario Ferrari, Michael Gasperi, Roy Harmen, George W. Hart, Philippe (Philo) Hurbain, Remco Leine, Krystian Majewski, Andy Milluzzi, Frank de Nijs, Philippe Reist, Eric Wang, and Barbara Webb. I’m quite certain that this book hides a few errors. Of course, none of these persons is to blame—only myself. I am anxious to learn of any errors so that they may be fixed in future printings. Please send these to [info@ntspress.com](mailto:info@ntspress.com).

May this book contribute to the extension of your robotics portfolio and to the strengthening of your problem-solving capacities!

Claude Baumann