Trends in Cognitive Sciences

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Scientific Life

Neuromatch Academy: Teaching Computational Neuroscience with Global Accessibility

Neuromatch Academy (NMA)
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Neuromatch Academy (NMA) designed and ran a fully online 3-week Computational Neuroscience Summer School for 1757 students with 191 teaching assistants (TAs) working in virtual inverted (or flipped) classrooms and on small group projects. Fourteen languages, active community management, and low cost allowed for an unprecedented level of inclusivity and universal accessibility.

NMA

Traditionally, summer schools have been instrumental in teaching computational skills, with training in useful methods and unique networking opportunities. Summer school attendance, to most participants, is a career-defining event. However, most scientists never get this opportunity for financial, geographic, or other reasons.

We created NMA with the goal of making computational neuroscience (and neural data science) summer schools inclusive and globally accessible. Like its legacy predecessors, NMA consisted of lectures, tutorials, question-and-answer sessions, and networking opportunities. The course was conducted online, in parallel over three major time zones. We ran prerecorded lectures with code-based tutorials in 185 groups (pods), with each group led by a TA. Supervised by 277 volunteer academic mentors, students also worked on group projects to obtain hands-on experience with real data or theoretical projects.

NMA also recreated the career mentorship of traditional summer schools by providing professional development (PD) sessions offering practical scientific applications (e.g., scientific writing, open science practices) and career panels featuring scientists from industry and academia. We achieved increased inclusivity worldwide and across economic and language barriers through: (i) NMA's large size, which allowed us to group students with the same mother tongue; and (ii) generous funding from our academic and industry partners, which allowed us to offer the course at a low, fully waivable fee to all students.

To help others develop similar programs, we discuss various facets of NMA, including our curriculum, managing a large force of volunteer organizers, efforts to make NMA open and accessible, and lessons we learned.

Curriculum

NMA's 3-week curriculum introduced traditional and emerging tools in computational neuroscience, examining their complementarity and what they can tell us about the brain. We taught approaches to modeling, how to select and use algorithms and methods, and how to interpret the results [1,2]. The curriculum covered basic to advanced data analysis, as well as modeling and statistical approaches for biologically realistic behavioral models (Figure 1A).

To ensure coherence, each day had a leader who outlined that day's coverage, prerequisites, and target learning outcomes. To ensure a consistent rhythm, we delivered content in a fixed daily structure that shifted slightly within each major time zone to accommodate various live events (Figure 1B; within time zone shifts not shown). After a prerecorded 'intro' lecture to frame the day's main questions, students explored techniques through hands-on tutorials followed by a prerecorded 'outro' lecture showing how the ideas could be extended or applied. We enforced consistency across lectures by providing slide

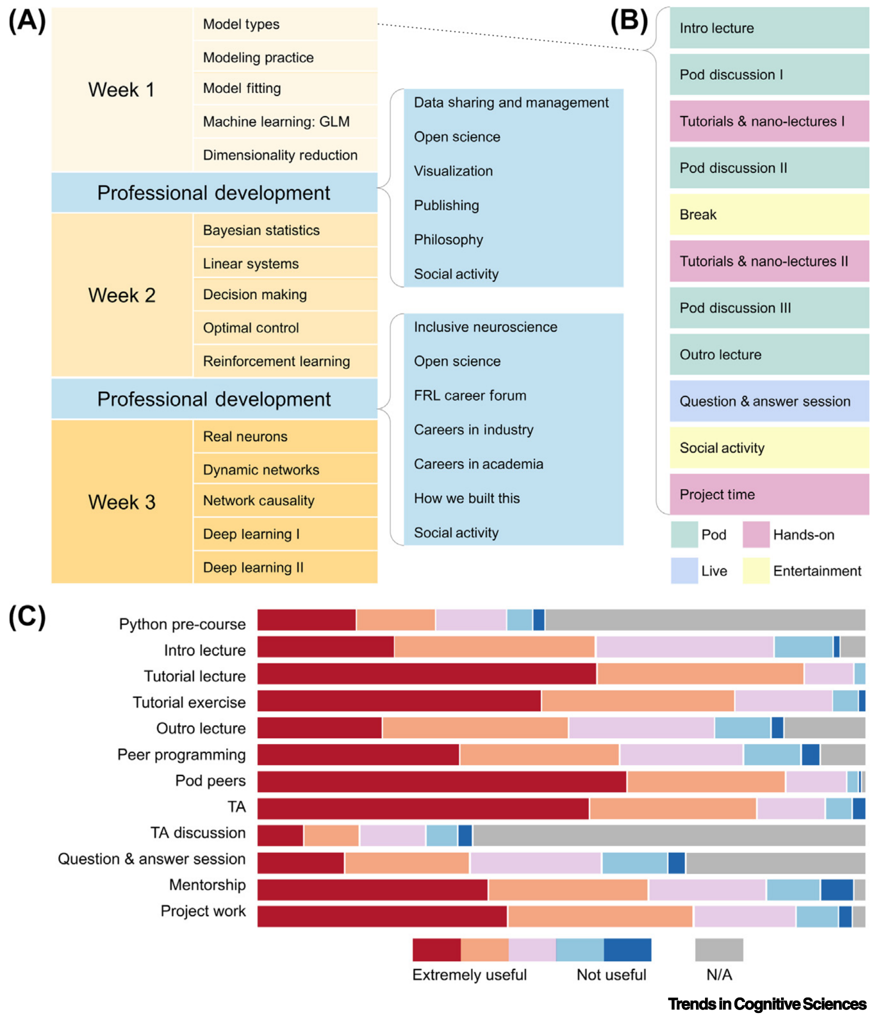

Figure 1. Curriculum, Day-Schedule, and Student Evaluation. The 3-week curriculum of Neuromatch Academy (NMA) introduced traditional and emerging computational neuroscience tools (A; orange). On the weekends there were several live sessions that focused on professional development (A; blue). Each day consisted of the same schedule as indicated by the broken line. (B) An example day schedule. The ordering of the daily schedule shifted slightly (e.g., shift of social activities or project time) within a time zone to accommodate the live question and answer session in that time zone. (C) Student ratings in end-of-school survey. Extremely useful (leftmost) to not useful is shown from red to blue, with nonapplicable (N/A) in gray (rightmost). Pod peers, teaching assistants (TAs), and tutorial materials scored high on students' perceived usefulness. Abbreviations: FRL, Facebook Reality Labs; GLM, generalized linear model.

templates, recommended software for recording, and preferred math notations. Each day culminated in a live question-and-answer session with leading experts on the day's topics. Lecturers were selected based on their pedagogical skills and scientific knowledge, with careful consideration of racial and gender diversity [1]. A dedicated team of faculty and volunteers was essential to ensure all deliverables (slides, recordings, tutorial code, etc.) were finished on time.

Students also participated in projects, in groups of three to five students, to practice applying their new skills. NMA curated several datasets to choose from, and faculty mentors and TAs provided groups with structured brainstorming, clear expectations, and guidance. An example project question provided was: which patterns of facial movements are captured in brain activity from the primary visual cortex? At the end of NMA, groups gave short talks about their accomplishments; some presented at subsequent Neuromatch Conference 3.0[x] [3].

Tutorial Format

Our inverted classroom [4,5] and peer-programming philosophy [6] produced a curriculum consisting of short hands-on code-based tutorials interspersed with explanatory videos. We used Google Colaboratory[i], a free, browser-based online Python programming environment, which allows code editing and sharing in a standard web browser. In our tutorials, students never had to produce more than a few lines of code, which gave them time to engage with other interactive elements – including widgets with sliders or buttons to change embedded figures in real time – allowing exploration of the techniques to build stronger intuitions of models' behavior.

Tutorial quality was improved by: (i) an experienced group of code editors, who standardized code across tutorials; (ii) a practice day, where one day's materials were tested across the different time zones; and (iii) a dress rehearsal, where TAs vetted all course materials by going through the entire curriculum and providing feedback about the timetable, tutorials, and recordings. These trial runs were fundamental to the NMA curriculum, and future iterations of NMA will be more polished given feedback from the inaugural event.

Community Building

We worked actively to build community and camaraderie among students. Students were matched into 185 small pods (modal n = 9), each led by a TA based on time-zone preferences, preferred language, experience, and interests (interests were measured through dataset preferences for group project work). The pod structure created intimate groups to facilitate student-centered learning using peer programming [6]. Other extracurricular activities featured PD (Figure 1A in blue), virtual social hours, yoga classes, and karaoke sessions. We also ran algorithmic introductions of students interested in similar topics (neuromatching [3]) to facilitate networking. The pod matching was successful in creating tight bonds among students and TAs (Figure 1B), but the virtual social events were less well attended by students and rarely attended by NMA faculty or volunteer organizers; future iterations of NMA will focus on how to best create successful, integrated social experiences outside the virtual classroom.

About 150 researchers (excluding TAs and project mentors) spanning the ranks of academia from different countries came together as NMA volunteers. Organizers and volunteers communicated using Slack[ii], which has become a mainstream communication tool in science [7]. We used Airtable[iii] to develop a volunteer database of skills and availability, which made task assignment much easier.

Assessing NMA's Success

Beyond creating a worldwide summer school in 3 months, we surpassed several standard metrics. Relative to massive open online courses, NMA had higher retention (86.7% versus 5–10%) [8–10], measured as the percentage of students who attended >50% of classes. Ninety-four percent of students who responded to the end-of-school survey said they would recommend the experience to a fellow student; they attributed the school's success to a wide range of factors (Figure 1C), but often commented they felt like they belonged. Every day, as well as at the end of the school, we polled students and TAs to understand the effectiveness of our teaching, learning, and community, with very high rates of survey completion (>90% participation for the final survey). We are thus in a great position to make future programs like NMA better (Box 1).

Building a Diverse and Inclusive School

NMA prioritized diversity and inclusion in many ways. This included: (i) offering language pods so TAs and students could communicate in their mother tongues (i.e., despite NMA's language of instruction being English, we had language pods in Arabic, Farsi, French, German, Greek, Hebrew, Hindi, Italian, Mandarin, Portuguese, Russian, Spanish, and Turkish); (ii) adjusting the $100 registration fee to reflect national median-wage differences; (iii) offering fee waivers; (iv) offering curated closed captions under prerecorded materials in English, Spanish, and Mandarin; and (v) encouraging people to share their pronouns whenever possible. Through the Neurostars forum[iv] from the International Neuroinformatics Coordinating Facility[v] (INCF) we created virtual classrooms to communicate with students and support them. These virtual spaces also created online communities for students, TAs, and mentors. We evaluated and maintained the learning atmosphere through Zoom visits to pods by NMA faculty, by monitoring students' daily reflections about interactions with peers and TAs, and by having a code of conduct[vi] in place with a rapid-response team to address anonymous reports of violations. We made specific efforts to include students from countries across geopolitical borders, including successfully applying for a last-minute license from the US Office of Foreign Assets Control allowing us to include Iranian resident students and TAs [11]. US sanctions (and those of many other countries) typically prohibit inclusion of Iranian residents (and those from other sanctioned countries) in schools like ours, so we encourage organizers of similar programs to apply for exemptions as early as possible.

All materials were published under a CC-BY license on YouTube[vii] and GitHub[viii]. We used various methods to realize our ideal of open and global access to NMA content, such as mirroring content to Bilibili for accessibility in China since YouTube is blocked. Our materials are also available as courses through the INCF TrainingSpace[vi]. As materials were all openly available online, students could also participate as so-called Observers (~5000 registered) to work through NMA at their own pace. We believe that through these innovations NMA has paved the way for collaborative, coordinated development of teaching materials for inverted-classroom formats, thereby dramatically decreasing duplicated effort and allowing university faculty to focus more on impactful one-on-one mentorship.

Box 1. Lessonsfor Others and the Future

Do you want to run an NMA-like program? Here are some lessons we learned and will implement in the future:

(i) Tackle economic barriers. NMA prioritized accessibility through low, waivable registration fees, but some potential students were still excluded due to employment or childcare. Work to circumvent these barriers.
(ii) Plan for comprehensive feedback. NMA iteratively improved our curriculum through feedback, but our cycle was rushed and missed some key details. Prioritize proper evaluation.
(iii) Do not underestimate personnel and time requirements. NMA grew quickly, necessitating swift onboarding of many volunteers. Organize your workforce early and recognize that recording and editing content will take more manpower and time than you anticipate.
(iv) Be aware of geopolitical constraints. Beyond political sanctions, streaming or other services are also blocked in some countries. Investigate which services work where.
(v) Prioritize administrative and organizational support. NMA implemented task management in Slack, Google Drive and Quire[ix]. This was inefficient and taxing. Use a proper task management system, and do not assume that financial or administrative clean-up can be completed later.
(vi) Assign credit appropriately. Volunteers are the lifeblood of NMA. Ensure your workforce receives due credit through manuscript authorship, public-facing personnel lists, and social media. You cannot do this without them.

Concluding Remarks

To many of us, NMA was an eye-opening experience that highlighted the importance of dedicated faculty and volunteers. Our cooperative efforts produced a better learning experience than we ever imagined. We believe this combination of strong community building, inverted-classroom teaching, and a discipline-based coding curriculum promises major improvements for the future of higher education.

Acknowledgments

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Resources

[i]https://colab.research.google.com/

[ii]https://slack.com/

[iii]https://airtable.com/

[iv]https://neurostars.org/

[v]https://training.incf.org/

[vi]www.neuromatchacademy.org/code-of-conduct

[vii]www.youtube.com/channel/UC4LoD4yNBuLKQwDOV6t-KPw

[viii]https://github.com/NeuromatchAcademy

[ix]https://quire.io/

[x]https://neuromatch.io/

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