Teacher Perceptions of Using Robots to Teach Neuroscience in Secondary School

Claudio C. S. de Freitas[a], Camden Hanzlick-Burton[b], Miroslav Nestorovic[b], Jennifer DeBoer[a], Gregory J. Gage[b], Christopher A. Harris[b1]

[a] School of Engineering Education, Purdue University, USA
[b] Backyard Brains, Inc., Ann Arbor, MI, United States
[1] Correspondence: christopher@backyardbrains.com, 308 1/2 S State St Suite 35, Ann Arbor, MI 48104, (855) 438-7745

Abstract

A study based on a survey questionnaire was conducted with 91 teachers across multiple high schools in the United States to understand their perceptions about the usefulness of using neurorobots to teach neuroscience. In this paper, neurorobot refers to a combination of robotics, active learning, and neuroscience. To situate teachers with an example of how robots can be used to teach neuroscience, we describe an educational tool called the SpikerBot. Our preliminary results indicate that there is an opportunity for neuroscience-oriented robots in secondary education, provided sufficient on-boarding and training videos.

Keywords: neuroscience, neurorobots, neurorobotics, computational neuroscience, education technology, active learning, secondary school, high school, teachers

Introduction

Understanding the brain is a profound and fascinating challenge, captivating the scientific community and the public alike. The lack of effective treatment for most brain disorders makes training the next generation of neuroscientists, engineers and physicians a key concern. Developing the ability to work effectively with neural networks for artificial intelligence (AI) applications is also increasingly important to students [1], [2]. To introduce brains and neural networks in early education, it is important to adopt multidisciplinary pedagogies and technology tools, such as robot-based pedagogy [3], [4].

Robotics has been shown to be a highly motivating and effective framework for teaching STEM in schools [5]–[7], including to underrepresented students [8]–[10]. Additionally, robots have been considered a key educational technology to teach various fundamental skills in STEM education, such as spatial ability, computational thinking, and programming. Consequently, robotics has become popular in schools. Among the most popular educational robots, LEGO robotics [11], [12], and Arduino-based kits [13] have been extensively used to teach robotics. A systematic review of 315 research articles that used LEGO robotics in educational settings concluded that teamwork and problem-solving are the key educational contributions of LEGO robotics in K12 [14].

Teachers also benefit from robots in the classroom. Recent studies highlight the ability of robots to assist teachers when they face difficulties on specific tasks in the classroom [15]–[17]. Similarly, robots play an effective role to scaffold multiple disciplines with a positive impact on achievement scores, science concepts, and attitudes [18]–[20].

While the literature shows a wide range of applications and benefits of robotics in the classroom, there is little research describing how to use robots to teach neuroscience. To address this need, we have developed a camera-equipped brain-based robot that students control with an app (Figure 1). The app allows students to design neural networks and observe their effect on the robot's behavior in real-time. We have shown that participation in a 1-week neuroscience module based around our robots improved high school students' conceptual understanding of neuroscience and their self-conception as neuroscientists [21]. However, for robots to succeed in neuroscience education, it is necessary to establish a dialogue across multiple stakeholders to understand their perceptions and needs. To begin this process, we conducted a survey of high school teachers across multiple states in the United States, to understand teachers' perceptions about using robots to teach neuroscience in school.

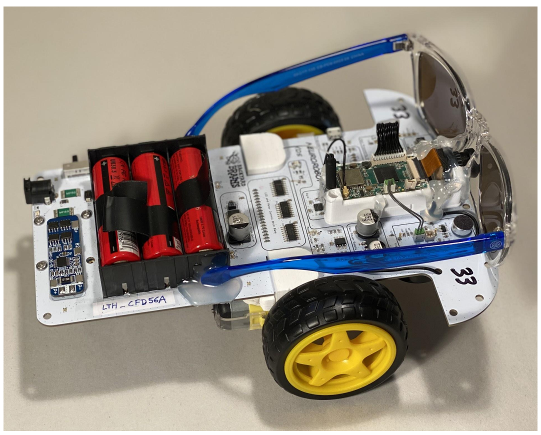


Figure 1. The SpikerBot - a neurorobot for education

Methods

We designed a survey to explore US high school teachers' perceptions of the idea of using robots to teach neuroscience (Appendix 1). The goal of the survey was to address the following questions:

- Can teachers add neuroscience activities, given the limited space for neuroscience in the Next Generation Science Standards (NGSS)?
- Are teachers interested in using robots to teach neuroscience?
- What supports do teachers feel they would need to teach neuroscience with robots?
- What technology availability and budget considerations need to be addressed?

To facilitate quantitative analysis, all questions were multiple-choice. We also collected demographic information for statistical purposes. The survey development process is described in Figure 2.

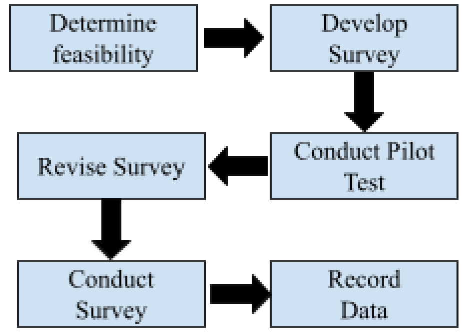


Figure 2. Survey design process

The survey was disseminated using Qualtrics to a pool of 500 K12 teachers within our network. Most of these teachers had provided their email at one of Backyard Brains' science or education conference booths. All participants were included in a lottery to distribute 10 neuroscience research kits (value: $200 each).

Results

We received 91 responses to our survey. Participants taught a variety of STEM subjects including biology (19.2%), anatomy and physiology (11.4%), general science (9.2%), computer science (8.5%), and engineering (7.1%). To facilitate this, most teachers stated that they used hands-on activities daily (17.0%) or a couple of times per week (47.5%), and had Chromebooks (36.3%) or PC/Mac computers (21.8%) available for students taking their courses. Most participating teachers stated that their courses align to the NGSS (50%) or State Science Standards (22.4%).

On the important question "Given the limited space reserved for neuroscience in state-standards, if you wanted to add neuroscience activities to your classroom, could you do it?" 80.0% of teachers stated they could add neuroscience activities. Of these, 54.5% felt that neuroscience was well supported by their state standards, while 43.2%% said they could justify it even if not in state standards.

We then asked respondents to watch a 2-minute video about the SpikerBot [22], showing how students use the robot in class. After watching the video, 84.6% of teachers stated that they would be interested in using the robot to teach neuroscience. Moreover, 84.3% said that learning to use the SpikerBot (ex. by participating in a workshop) would count towards required professional development hours.

On average, teachers felt that a new robot-based neuroscience curriculum should consist of 5-6 lessons, with 90% of teachers preferring 10 lessons or fewer. Nearly all teachers said they would require at least some training to feel comfortable with the robots. When asked which professional development resources would best prepare them for teaching, most wanted teacher training videos (20.3%) or live virtual training workshops (19.6%). Finally, 80.6% of teachers stated that they would need to apply for private donations or a grant to afford a $2500 set of 10 robots for their classroom.

Discussion

Taken together, these results indicate that there is space in US secondary education for a neuroscience-oriented robot. Teachers feel they can add neuroscience activities to their teaching, even though neuroscience is a new discipline that has yet to be fully integrated in state standards. Moreover, teachers like the idea of teaching neuroscience with robots, and feel that learning to use a robot such as the SpikerBot would count towards professional development hours they are required to obtain.

The survey also identifies two challenges. First, it shows that at the price point of typical "smart robots" such as LEGO Mindstorms, only a small number of teachers (14.0%) would be able to use department/school funds. To ensure broad adoption of neuroscience-oriented robots, it is therefore necessary to reduce the hardware cost of the robot, while also providing teachers with support to write grants.

Second, enabling teachers to teach neuroscience with robots will require production of a variety of onboarding, training and support materials.

Although the survey shows promising results, this study has a couple of limitations. First, the survey participants are familiar with Backyard Brains, and may have used other neuroscience classroom products. They are therefore subject to biases. Second, the internal consistency of the survey was not assessed and the sample size is relatively small.

Although the survey was used to understand teachers' perceptions using the SpikerBot, there is a huge opportunity to take our findings and translate them to other neurorobots in the market. Thus, it is recommended that to fully satisfy some minimum requirements as a neurorobot in secondary education, robots designed to teach neuroscience should meet at least three requirements: 1) being cost-effective, 2), compatible with multiple hardware and software, and 3) supporting teachers with pedagogical and training material to reduce the learning curve to adopt and use the tool. In the future, we expect to increase our sample size and increase the research rigor throughout the survey development process. We also identified opportunities to engage with multiple stakeholders in order to understand their perceptions about the value of neuroscience and potential space to include neuroscience as a discipline in secondary education.

Overall, the positive impact of active learning and robotics is well known in STEM education, but if educators who teach neuroscience-related topics are too disconnected from the underlying principles of active learning and robotics in the classroom, they can inadvertently mitigate and remove important elements of neurorobots in the classroom. Thus, we argue that the successful delivery of neurorobots in the classrooms has a direct correlation not only with learning objectives and teaching styles, but also a meaningful application of robots in the classroom and a supportive environment that recognizes the value of neuroscience at schools.

Acknowledgments

GJG is a co-founder and co-owner of Backyard Brains, Inc., a company that manufactures and sells

neurorobots. CHB, MN, and CAH are employed by Backyard Brains, Inc.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Research reported in this publication was supported by a Small Business Innovation Research grant #1R43NS108850 from the National Institute of Neurological Disorders and Stroke of the National Institutes of Health. CAH and GJG are Principal Investigators on this grant.

References

[1] H. Bakhshi, J. Downing, M. A. Osborne, and P. Schneider, “The future of skills: Employment in 2030,” Pearson and Nesta, London, 2017.

[2] OECD, “Future of Education and Skills 2030: OECD Learning Compass 2030,” OECD, 2019. Accessed: Mar. 30, 2021. [Online]. Available: http://www.oecd.org/education/2030-project/teaching-and-learning/learning/learning-compass-2030/OECD_Learning_Compass_2030_Concept_Note_Series.pdf.

[3] K.-Y. Chin, Z.-W. Hong, and Y.-L. Chen, “Impact of Using an Educational Robot-Based Learning System on Students’ Motivation in Elementary Education,” *IEEE Trans. Learn. Technol.*, vol. 7, no. 4, pp. 333–345, Oct. 2014, doi: 10.1109/TLT.2014.2346756.

[4] P. Nonnon, “Robot-based Pedagogy,” *J. Artif. Intell. Educ.*, vol. 2, no. 1, pp. 15–21, 1990.

[5] B. S. Barker, G. Nugent, N. Grandgenett, and V. I. Adamchuk, Eds., *Robots in K-12 Education: A New Technology for Learning*. IGI Global, 2012.

[6] M. E. Karim, S. Lemaignan, and F. Mondada, “A review: Can robots reshape K-12 STEM education?,” in *2015 IEEE International Workshop on Advanced Robotics and its Social Impacts (ARSO)*, Lyon, Jun. 2015, pp. 1–8, doi: 10.1109/ARSO.2015.7428217.

[7] F. B. V. Benitti, “Exploring the educational potential of robotics in schools: A systematic review,” *Comput. Educ.*, vol. 58, no. 3, pp. 978–988, Apr. 2012, doi: 10.1016/j.compedu.2011.10.006.

[8] S. Ludi, “Educational robotics and broadening participation in STEM for underrepresented student groups,” in *Robots in K-12 Education: A New Technology for Learning*, Pennsylvania: IGI Global: Barker Bradley, 2012, pp. 343–361.

[9] J. Rosen, F. Stillwell, and M. Usselman, “Promoting diversity and public school success in robotics competitions,” in *Robots in K-12 education: A New Technology for Learning*, Pennsylvania: IGI Global: Barker Bradley, 2012, pp. 326–342.

[10] T. T. Yuen, L. D. Ek, and A. Scheutze, “Increasing participation from underrepresented minorities in STEM through robotics clubs,” in *Proceedings of 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, Bali, Indonesia, Aug. 2013, pp. 24–28, doi: 10.1109/TALE.2013.6654392.

[11] E. Danahy, E. Wang, J. Brockman, A. Carberry, B. Shapiro, and C. B. Rogers, “LEGO-based Robotics in Higher Education: 15 Years of Student Creativity,” *Int. J. Adv. Robot. Syst.*, vol. 11, no. 2, p. 27, Feb. 2014, doi: 10.5772/58249.

[12] R. Grandi, R. Falconi, and C. Melchiorri, “Robotic Competitions: Teaching Robotics and Real-Time Programming with LEGO Mindstorms,” *IFAC Proc. Vol.*, vol. 47, no. 3, pp. 10598–10603, 2014, doi: 10.3182/20140824-6-ZA-1003.00222.

[13] J.-D. Warren, J. Adams, and H. Molle, “Arduino for Robotics,” in *Arduino Robotics*, Berkeley, CA: Apress, 2011, pp. 51–82.

[14] I. M. L. Souza, W. L. Andrade, L. M. R. Sampaio, and A. L. S. O. Araujo, “A Systematic Review on the use of LEGO ® Robotics in Education,” in *2018 IEEE Frontiers in Education Conference (FIE)*, San Jose, CA, USA, Oct. 2018, pp. 1–9, doi: 10.1109/FIE.2018.8658751.

[15] J. S. Kay, J. G. Moss, S. Engelman, and T. McKlin, “Sneaking in through the back door: introducing k-12 teachers to robot programming,” in *Proceedings of the 45th ACM technical symposium on Computer science education - SIGCSE ’14*, Atlanta, Georgia, USA, 2014, pp. 499–504, doi: 10.1145/2538862.2538972.

[16] C.-F. Shih, C.-W. Chang, and G.-D. Chen, “Robot as a Storytelling Partner in the English Classroom - Preliminary Discussion,” in *Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007)*, Nigata, Japan, Jul. 2007, pp. 678–682, doi: 10.1109/ICALT.2007.219.

[17] D. Conti, C. Cirasa, S. Di Nuovo, and A. Di Nuovo, “‘Robot, tell me a tale!’: A social robot as tool for teachers in kindergarten,” *Interact. Stud. Soc. Behav. Commun. Biol. Artif. Syst.*, vol. 21, no. 2, pp. 220–242, May 2020, doi: 10.1075/is.18024.con.

[18] K. Jaipal-Jamani and C. Angeli, “Effect of Robotics on Elementary Preservice Teachers’ Self-Efficacy, Science Learning, and Computational Thinking,” *J. Sci. Educ. Technol.*, vol. 26, no. 2, pp. 175–192, Apr. 2017, doi: 10.1007/s10956-016-9663-z.

[19] E. Z. F. Liu, C. H. Lin, and C. S. Chang, “Student Satisfaction and Self-Efficacy in a Cooperative Robotics Course,” *Soc. Behav. Personal. Int. J.*, vol. 38, no. 8, pp. 1135–1146, Sep. 2010, doi: 10.2224/sbp.2010.38.8.1135.

[20] G. Chen, J. Shen, L. Barth-Cohen, S. Jiang, X. Huang, and M. Eltoukhy, “Assessing elementary students’ computational thinking in everyday reasoning and robotics programming,” *Comput. Educ.*, vol. 109, pp. 162–175, Jun. 2017, doi: 10.1016/j.compedu.2017.03.001.

[21] C. A. Harris *et al.*, “Neurorobotics Workshop for High School Students Promotes Competence and Confidence in Computational Neuroscience,” *Front. Neurorobotics*, vol. 14, p. 6, Feb. 2020, doi: 10.3389/fnbot.2020.00006.

[22]Vertebot (2021) Introducing SpikerBots. Available at: https://www.youtube.com/watch?v=gNkJ2hmodlw

Appendix

Appendix 1. Survey questions

Q1. What is the name of the school(s) where you teach? Please, specify:

Q2. What is your school's zip code(s)? Please, specify:

Q3. What grades do you teach? (select all that apply)

- K-5
- 6-8
- 9
- 10
- 11
- 12
- College

Q4. What courses do you teach? (select all that apply)

- Biology
- Psychology
- Neuroscience
- Engineering
- Bioengineering
- Computer Science
- Anatomy and Physiology
- General Science
- Robotics
- Artificial Intelligence
- Chemistry
- Physics
- Math (Algebra, Trig, Calculus, etc.)
- Other

Q5. What standards do your courses align to? (select all that apply)

- Next Generation Science Standards
- State Science Standards (Non-NGSS, e.g., TEKS in Texas)
- HAPS (Anatomy & Physiology)
- College Board Framework (AP Courses)
- International Baccalaureate (IB)
- I don't know
- Other

Q6. Do you current use hands-on activities in your classes?

- Yes, Daily
- Yes, A couple of times per week
- Yes, A couple of times per month
- Yes, but rarely (< once a month)
- No

Q7. Given the limited space for neuroscience in standards-based curricula, if you wanted to add neuroscience activities to your classroom, could you do it?

- Yes, I feel that neuroscience activities do meet our state standards.
- Yes, I have independence on classroom activities, I can justify adding neuroscience even if not in our state standards.
- Yes, I have time after our state standards exam to introduce new activities.
- No, I cannot add activities unless they directly relate to our state standards.
- Other

Q8. Which of the following technologies are available to students taking your courses? (select all that apply)

- Apple iOS smartphones
- Apple iPad tablets
- Android smartphones
- Android tablets
- PC/Mac laptops
- PC/Mac desktop computers
- Chromebook laptops
- Chromebook tablets
- Students bring their own device
- Other

Q9. Would you be interested in using SpikerBots to teach?

- Yes
- Maybe yes, but I don't think this is sufficiently aligned with our standards
- No, I don't think this is sufficiently aligned with our standards
- No, this looks too complicated / I don't have time to learn this
- Other

Q10. Which types of instructional materials do you feel would most benefit students who are new to the SpikerBot neuroscience curriculum? (select up to 3 answers)

- Textbook
- Student worksheets (online & printable)
- Video library of demonstrations of laboratory exercises (ex- YouTube channel)
- STEM career connections (profession profiles, interviews with experts, networking opportunities, etc)

- Problem-based challenges and games (e.g. FIRST Robotics, FTC)
- Online platform to share brain designs

Q11. How long do you think the SpikerBot-based curriculum should be (assuming each lesson is 60 minutes)?

- 1-2 lessons
- 3-4 lessons
- 5-6 lessons
- 7-8 lessons
- 9-10 lessons
- 11-15 lessons
- 16-20 lessons
- 21-25 lessons
- 25+ lessons

Q12. If a classroom set of SpikerBots costs $2500 (about 10 robots for 30 students), how would you go about acquiring these funds? (select all that apply)

- I can use my department/school funds
- I would need additional private donations (ex. DonorsChoose)
- I would need to apply for a grant
- I would need to recruit other teachers
- Other, please specify.

Q13. What kind of professional development resources do you think would be most beneficial to teachers adopting SpikerBots for the first time? (select up to 3 answers)

- In person, half-day training workshop (post-COVID)
- In person, whole day training workshop (post-COVID)
- Live virtual training workshops
- Pre-recorded videos (ex- YouTube channel)
- In-class demonstrations by Backyard Brains
- Online teacher forum
- Online support by Backyard Brains
- Other.

Q14. Would learning to use the SpikerBot (ex. by participating in a workshop) count towards professional development hours/credits that are required by your school to collect?

- Yes
- No (explain why not).

Q15. How do you currently describe your gender?

- Female

- Male
- Self-identity
- I prefer not to answer

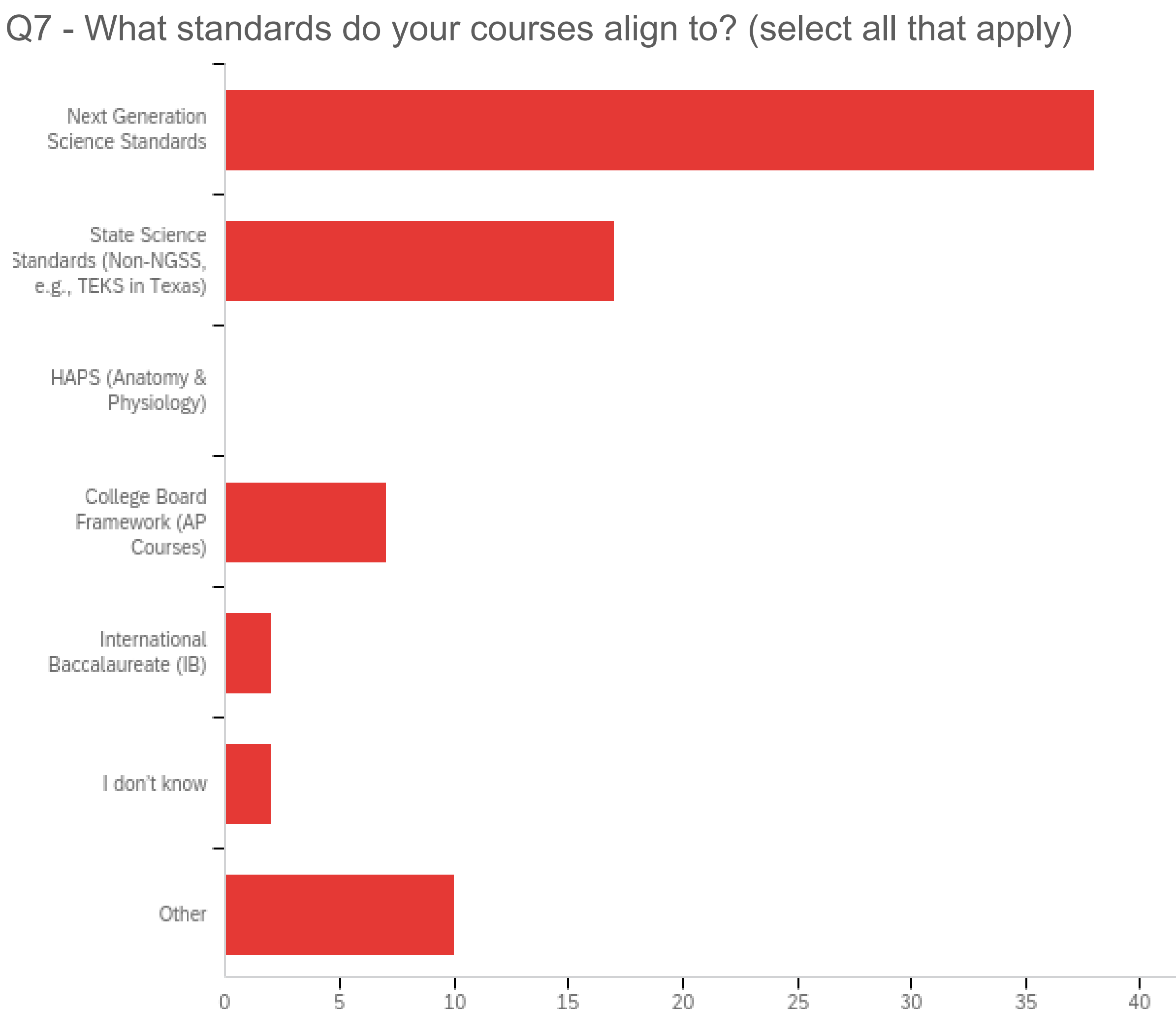
Q16. How do you currently describe your race/ethnicity? (mark all options that correspond)

- American Indian or Alaska Native
- Asian
- Black or African American
- Hispanic or Latino
- Native Hawaiian or Other Pacific Islander
- White
- I prefer not to answer

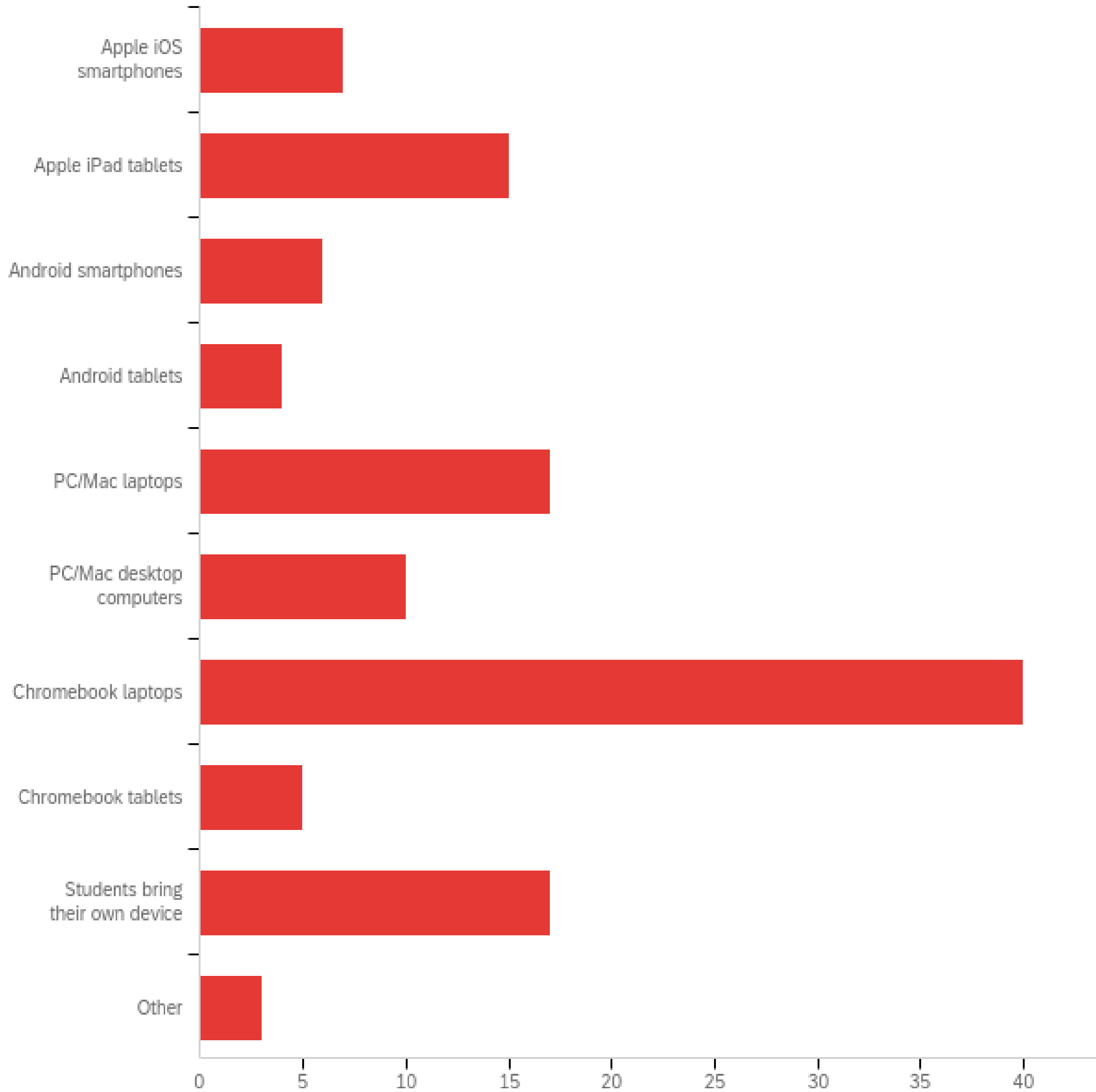
Q17. How long have you been teaching?

- 1-5 years
- 6-10 years
- 11-16 years
- 16-20 years
- 21+ years

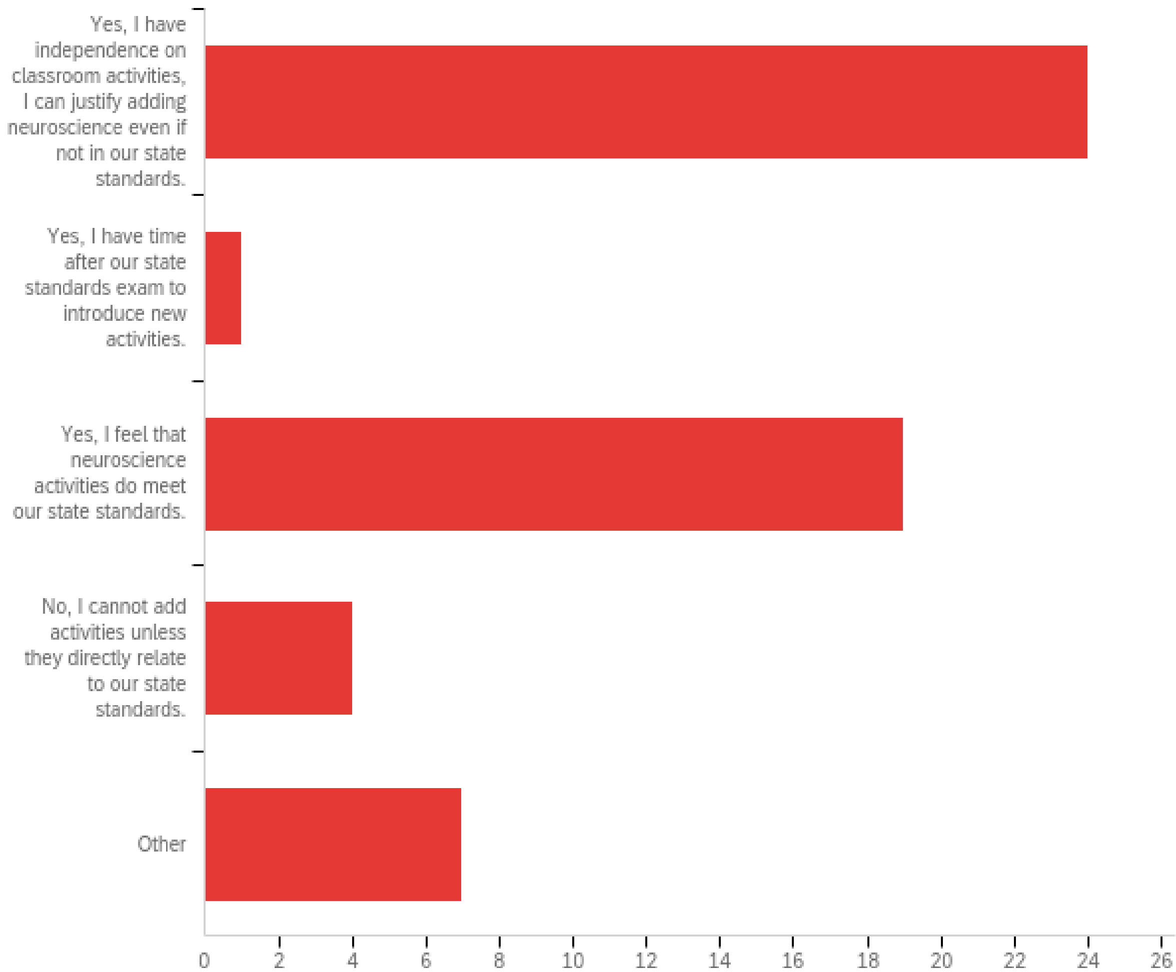
Appendix 2. Plots of data from the survey



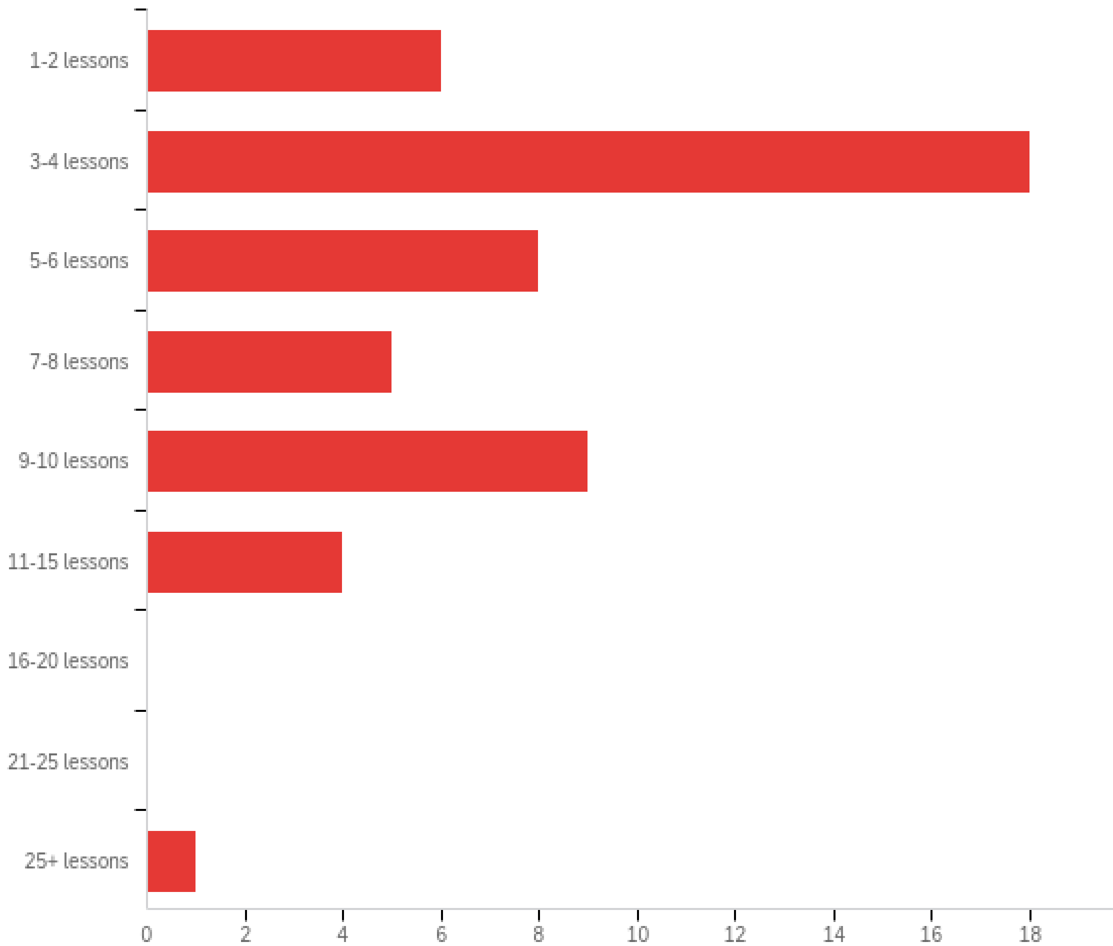
Q9 - Which of the following technologies are available to students taking your courses? (select all that apply)



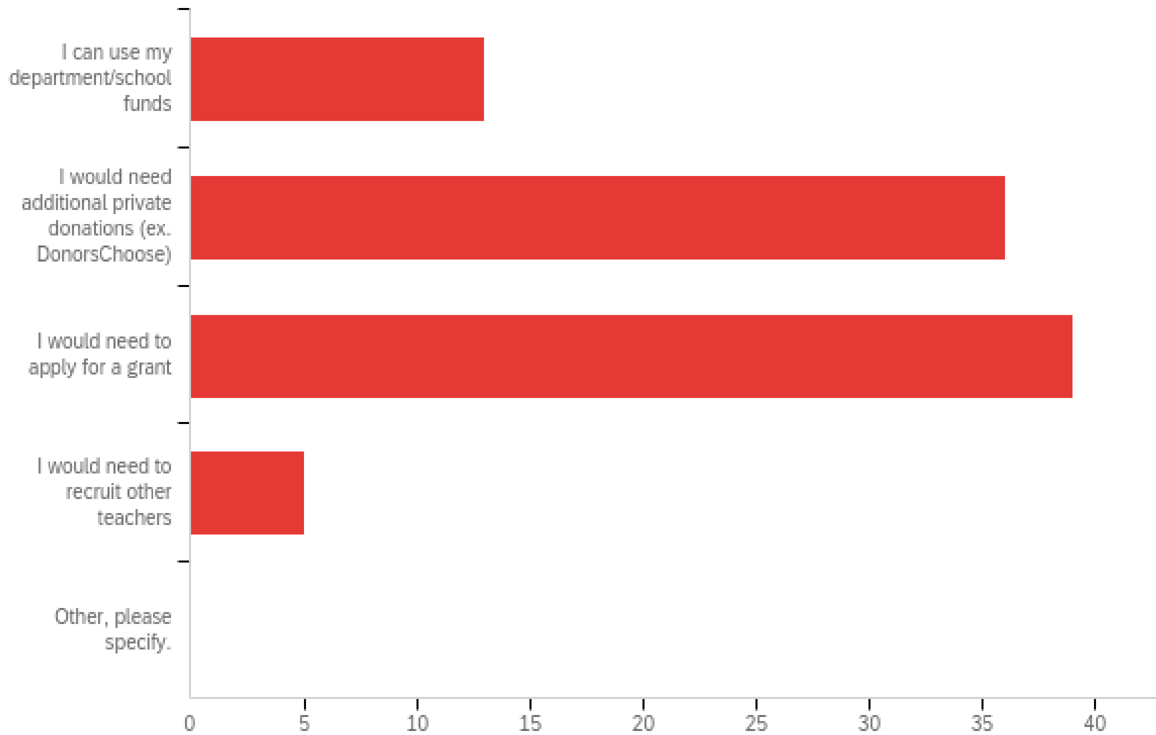
Q13 - Given the limited space for neuroscience in standards-based curricula, if you wanted to add neuroscience activities to your classroom, could you do it?



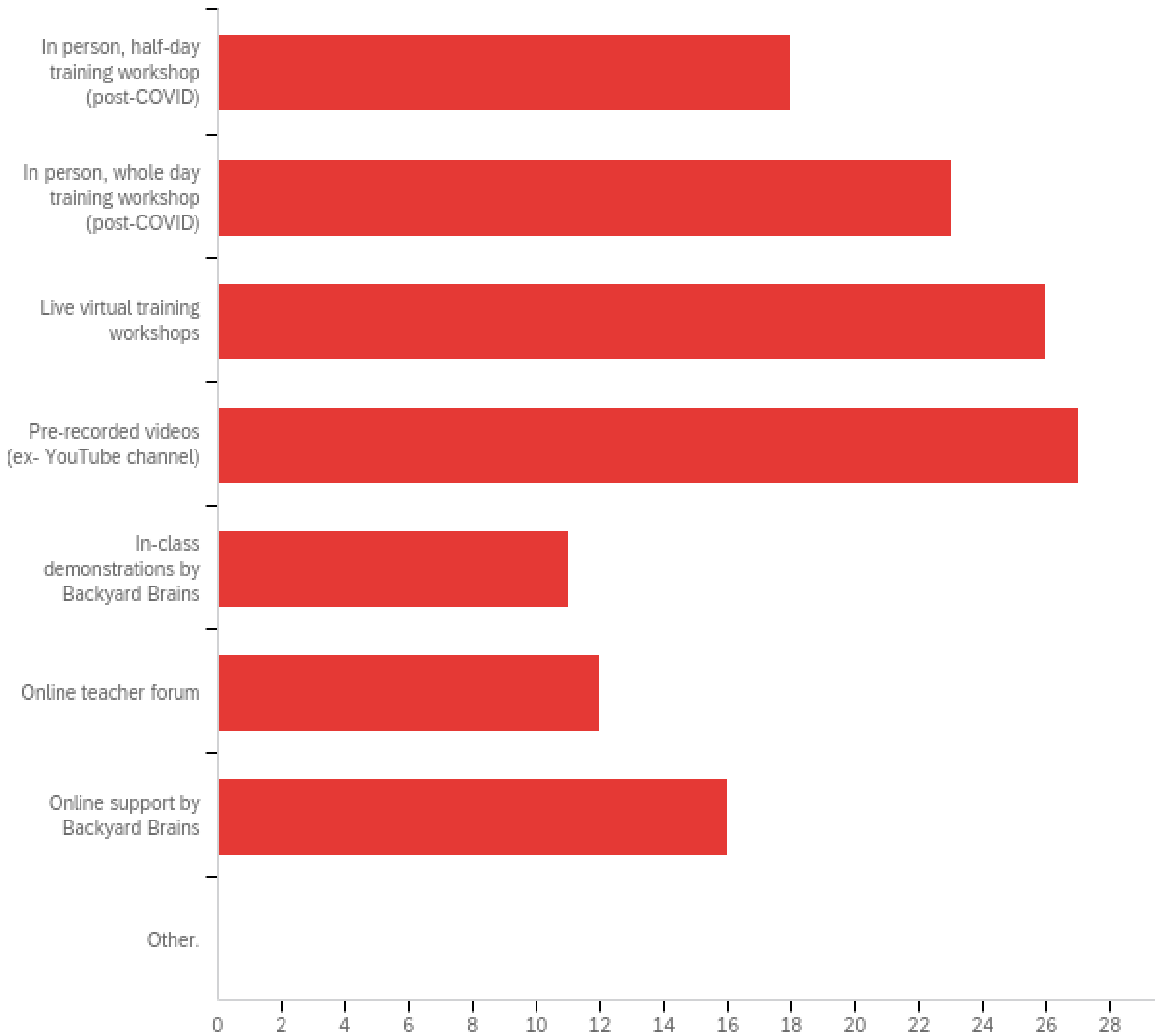
Q15 - How long do you think the SpikerBot-based curriculum should be (assuming each lesson is 60 minutes)?



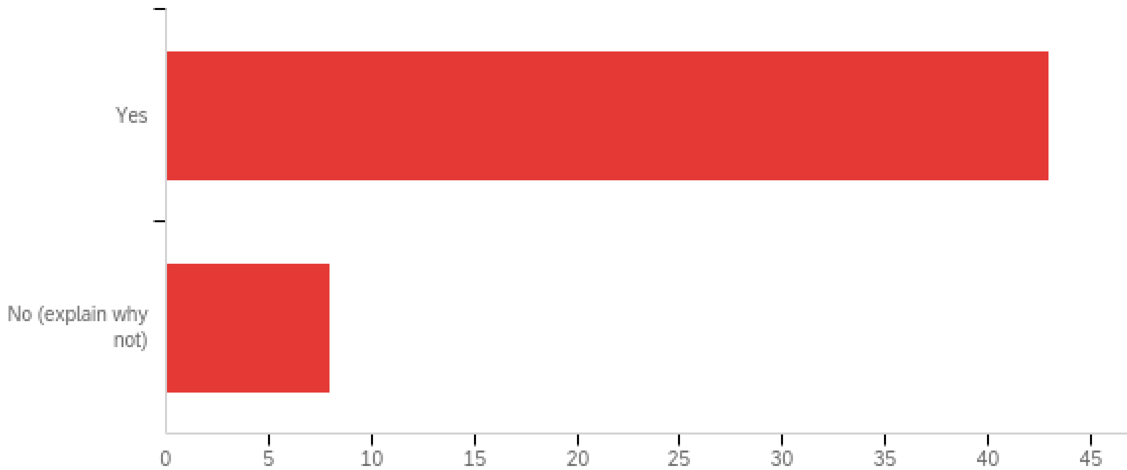
Q16 - If a classroom set of SpikerBots costs $2500 (about 10 robots for 30 students), how would you go about acquiring these funds? (select all that apply)



Q17 - What kind of professional development resources do you think would be most beneficial to teachers adopting SpikerBots for the first time? (select up to 3 answers)



Q18 - Would learning to use the SpikerBot (ex. by participating in a workshop) count towards professional development hours/credits that are required by your school to collect?



Q21 - Would you be interested in using SpikerBots to teach?