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Long-Term Learning Gains in Students Using Community Based Learning

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A significant promise of scientific research is that basic science discoveries lead to innovations that result in positive change for individuals and communities. Considering this, translational communication skills and motivation to engage the general population are critical measures to consider when educating future scientists. A community-based learning (CBL) teaching method has been shown to be effective in developing these skills when used in higher education humanities settings, as students are able to synthesize class information with real-life community problem solving. Despite this evidence, CBL approaches are not generally practiced in STEM classroom settings. To assess the efficacy of CBL within a STEM setting, 90 undergraduate seniors in a Developmental Neuroscience course at the University of Notre Dame from 2017-2019 completed pre/post surveys focusing on four areas: content knowledge, scientific literature literacy, effective communication of scientific literature to the general population, and degree of civic engagement. During the course, students participated in a CBL experience along with regular coursework but were not subject to high-stakes examinations. Ten of 90 alumni completed the same pre/post survey to assess long-term learning gains. Results indicated significant gains in content knowledge, literature literacy, and translational ability between pre-course and post-course conditions, with significant gains maintained over time in the alumni condition. These data make a valuable contribution to both the STEM and CBL literature by demonstrating the long-term efficacy of a CBL approach in a STEM course in the absence of high-stakes examinations, as well as demonstrate long-term learning gains associated with scientific communication skills and dispositions towards civic engagement.

Key words: community-based learning (CBL); developmental neuroscience; long-term learning gains; STEM education

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New approaches to education are constantly evolving to improve student learning. One approach occasionally used in higher education settings is the practice of community-based learning (CBL), a teaching style that emphasizes learning through community engagement. CBL utilizes strategies to connect students with community mentors, resulting in integration of classroom material with actionable community problems to enrich student learning and benefit community members (Melaville et al., 2006). By engaging in academic-based community service, civic education, and project-based learning opportunities, students challenge the extent of their knowledge and develop crucial problem solving, collaboration, and listening skills by directly applying course content to practical community problem solving.

Improving student learning is a fundamental goal of educators, and participation in community service work also contributes to well-rounded personal development as well as community healing. Previous research suggests interactive problem- solving reinforces learned concepts and results in better persistence of learning over extended time periods (Terenzini et al., 2001; Nagel et al., 2012). Implementing CBL in classrooms has the potential to positively enhance student content retention, literacy, and desire to participate in community service work (Terenzini et al., 2001; Melaville et al., 2006; Nagel et al., 2012). Research conducted at the University of Pennsylvania studied community-centered classrooms within neuroscience curriculum specifically, finding that student communication, critical thinking, and social awareness improved after just ten weeks of engagement with local high school students (Flanagan-Cato, 2019). Additionally, community engagement has been shown to positively impact individuals' self-confidence, self-esteem, social relationships, and physical and emotional health (Attree et al., 2011). By embracing CBL teaching in STEM classrooms, educators can enhance learning, boost community engagement, and enrich personal achievement and self-confidence for their students.

Another significant benefit to the application of CBL in classrooms is the ability to integrate active learning and application of content knowledge beyond a classroom setting. When compared to direct instruction, still used by the majority of STEM courses (Stains et al., 2018), active learning strategies, like those implicit to CBL and project-based learning, have been shown to increase agency, curiosity, retrieval, internal error correction, and flexibility of thought models (for review see Dubinsky and Hamid, 2024).

Instructors can harness the intrinsically active nature of CBL approaches, allowing for a much greater diversity of assessment strategies (i.e. moving towards communication accuracy, clarity, reliability). When community-centered project design becomes a central assessment strategy, instructors' assessment can become diversified. Knowledge of foundational course content may still be assessed through more traditional methods (e.g. standardized testing), but in effort to meet CBL needs, assessment may include the development and accuracy of science communication pieces. Feedback from community mentors allows for assessment of engagement with the community aspect of the course design. By including written reflections, peer-to-peer communication, and community-centered project design as assessment strategies, CBL approaches can significantly reduce or even eliminate the need for standardized testing as well as increase student engagement (Dubinsky and Hamid, 2024). Diversifying assessment strategies to include the explicit weighting of skill and attitude competencies not only communicates to students the value in learning beyond information recall, but can also offer practical assessment strategies that foster transformative integration (Baartman and De Brujin, 2011). When taken together, a CBL strategy can bring broad learning goals of disciplinary content, scientific communication, and civic engagement to life. By developing alignment across course activities, community engagement and assessment strategies, attitudes of curiosity and skills of communication accuracy are no longer implicitly assumed through classroom instruction, but explicitly developed throughout the engaged learning activities of the course.

Assessing how CBL teaching may impact college student learning is an important first step in implementing wider adoption. CBL has been shown to be successful in non-STEM courses such as humanities, social sciences, and the arts, but its use in STEM classrooms has been largely unexplored (McClure et al., 2024, Mooney and Edwards, 2001). Integrating CBL with STEM coursework, while challenging, has the potential to impact both students and communities in very positive ways. Integration of community engagement within neuroscience fosters the development of interpersonal skills between STEM students and non-STEM-trained populations (Stevens, 2011). Additionally, CBL gives student scientists the opportunity to share current scientific knowledge directly with the public, while also fostering civic engagement skills and attitudes of students (AAC&U VALUES Rubric, 2009), thereby taking an active role in re-building public trust in science through shared connection (Bringle and Hatcher, 2002; (Wandersman, 2003). Prioritizing civic engagement and trust in higher education is increasingly important, as trust in the scientific community has waned since the COVID-19 pandemic in 2020 (Kennedy and Tyson, 2023; Boyle, 2022). Exploring the effectiveness of CBL within higher education STEM classrooms offers a potentially powerful strategy into how to 'narrow the gap' that exists between professional scientists and public perception.

The Developmental Neuroscience course at the University of Notre Dame utilized CBL-style teaching to educate upper-level neuroscience students in early nervous system development, while promoting scientific literacy, encouraging civic engagement and community learning. As part of standard course assessment, students enrolled in the course were surveyed at the beginning and end of the course to evaluate pre-post learning gains over the semester-long period. To explore longer-term learning, alumni of the university who had previously taken the course were invited to complete the same course survey one to three years following graduation. The study authors hypothesize that a CBL course-design would yield learning gains both over the semester as well as learning that persisted after graduation. This study aims to assess the effectiveness of the CBL approach in a STEM setting and considers benefits and barriers to broader implementation of CBL strategies into university STEM classrooms across the nation.

METHODS

Participants

Survey respondents included students aged 19-22 enrolled in the Developmental Neuroscience course at the University of Notre Dame during fall semesters from 2017 to 2019. Students were required to complete the survey as a standard pre/post assignment in the course. One to three years following graduation, alumni of the University of Notre Dame who had previously taken the Developmental Neuroscience course were invited to take the same course survey a third time by email. In total, 90 students and 10 alumni responded (n=90). All respondents completed the described survey. Notre Dame's IRB determined the course-based and alumni survey methodology used were in alignment with program assessment procedures, and beyond the scope of human subject's research. Informed consent was not required.

Course Design

Students were enrolled in "Developmental Neuroscience" at the University of Notre Dame, an upper-level seminar course intended to teach developmental neuroscience and apply this knowledge to support general community capacity (Simmons et al., 2011) in the surrounding community during the semester. The course structure was carefully designed to promote learning in four areas: (1) developmental neuroscience content knowledge (knowledge competency), (2) ability to read scientific literature (skill competency), (3) ability to translate scientific jargon into non-scientific terms (skill competency), and (4) commitment to civic engagement with community members (attitudes competency). The collaborative tenants of community-based learning were reinforced throughout this structure, ensuring that attitudes related to content learning and engagement with the community were promoted and supported throughout. Assessment aligned such that grades were earned through class participation (lectures and active learning, journal clubs with peer review to discuss scientific literature); formative scientific communication "translation writing" assignments (accuracy of literature understanding, development of science communication skills); formative integration reflection writing (explicit interrogation of synthesis across course learning outcomes); and a summative community engagement capstone project.

The capstone project utilized community connections established through the Center for Social Concern at the University of Notre Dame and created opportunities for students to directly apply concepts rooted in developmental neuroscience to community problem solving. Groups of students connected with community partners, identified a community knowledge gap relevant to the field of developmental neuroscience, and collaborated with the community partner to develop an actionable community-engagement activity or intervention that provided knowledge or support. The overarching goal of the community partnerships was to "narrow the gap" between academic knowledge and practical, community practice. For example, students working with early childhood educators may communicate the effects of talking with one's baby on postnatal brain plasticity and pruning to parents. Another alignment could include working with a center for marginalized individuals to educate employees and volunteers of the impact of early life stressors on adult behavior. None of these collaborations are considered formal research projects, but lend to community prevention capacity by building the general community knowledge (Cohen & Swift, 1999; Flaspohler et al., 2008; Simmons et al., 2011) and skill base surrounding issues related to nervous system development.

Survey Design

Guided by the aforementioned course design, an instructor-designed student survey was created to assess the four overarching learning targets of the course. The survey consisted of 8 written-response questions to assess specific learning gains in content knowledge, scientific reading and writing skills, and civic engagement attitudes. A 22 question, five-point Likert scale tool was also used to assess student self-perceptions of the above categories. Written-response questions included:

1*) What are the repeating themes of nervous system development? For each, provide a definition and an explanation of this process "in action" at example stages of development. [knowledge competency]*

2) Chose one of the developmental themes from above, and describe how an individual's environment can influence nervous system development on the cellular/synaptic, circuit and behavioral level. Relate your answer to the appropriate critical period of development. [knowledge competency]

3) How well do you think you are able to communicate to someone of the importance of research conducted in the basic sciences? Why? [attitudes competency]

4) On a scale of 1-10, with 10 being the highest, how would you rate your ability to evaluate primary literature? E.g. your ability to identify the relevant background, knowledge gap/rationale, primary methodology, major results, interpretation and implications. Please explain your rationale. [skills competency]

5) [students were instructed to read a specific abstract] "For the abstract above, identify the background, knowledge gap/rationale, primary methodology, major results, interpretation and implications. [skills competency]

6) "Using lay terms, "translate" the above abstract to a young parent with no formal scientific education" [skills competency]

7) "Should science try to do "more" for the community than what it currently does? Why or why not?" [attitudes competency]

8) "In the context of scientific practice, does Catholic Social Tradition bear any relevance? Explain your thinking." [attitudes competency]

The Likert scale assessment complemented the written assessment by inviting students to self-assess their attitudes, behaviors and beliefs relevant to the expressed learning gains of the course. For example, Likert question 5 stated, "I am confident that when I talk about primary literature, the people I'm talking to understand what I'm saying" and instructed the student to choose between 1 (strongly disagree) and 5 (strongly agree). This question assessed a student's perceived ability to translate scientific literature for public benefit (learning target #3). Likert questions, written questions and scoring rubics can be found in the supplemental materials.

Survey responses were initially scored by the instructor during the term and rescored by an additional researcher who was blinded to condition. Written responses were scored using a rubric determined by the researchers prior to pre-survey collection. The Likert statements were scored from 1 (strongly disagree) - 5 (strongly agree), based on the selected response by the student. 3 of 22 questions were reverse scored. For point allocations and scoring criteria for written and Likert responses, see supplemental materials.

Scores from the pre- and post- written responses were analyzed for each of the four course targets (content, scientific literacy, translational ability, civic engagement), and changes in scores were used to perform data analysis. The data for written responses are standardized for comparison, presented as the percentage correct. Data from Likert surveys illustrating changes in student self-perceptions over the same period are graphed separately on a five-point scale.

Procedure and Analysis

Enrolled students completed the survey on paper at the beginning and end of the neuroscience course. Alumni were contacted via email and completed the survey electronically. All students completed the same survey. Written data was organized for qualitative themes and graphical data representation was conducted in Microsoft Excel. Statistical analysis was performed using VassarStats T-test and ANOVA statistical compilation platforms. For enrolled students, a two-tailed t-test was performed to compare pre- and post-survey results and allow for movement in any direction. For assessment of alumni, a 1x3 ANOVA (course x pre, post, alumni) was performed to compare pre-, post-, and alumni survey responses. An alpha value of 0.05 was utilized. Effect sizes were calculated using Cohen's d formula. Cohen's criteria for small, medium, and large effect sizes are 0.2, 0.5, and 0.8 or greater, respectively.

RESULTS

Data presented includes a total of 90 respondents who completed the pre/post survey as a part of standard course practice, with 10 alumni completing the survey for a third time.

Learning Gains for Enrolled Students

Paired t-test analysis of the course-based pre/post written responses (n=90) demonstrate significant improvement of correct answers in each of the four categories (p<.0001 for all). Effect size for Content Knowledge, Literature Literacy, Translational Ability, and Civic Engagement was ES = 4.75, 0.44, 0.71, and 0.50, respectively. A large effect size for Content Knowledge firmly supports the practical significance of the learning gains. Medium effect sizes were found for Literature Literacy, Translational Ability, and Civic Engagement, lending a moderate level of practical significance. Figure 1 shows the learning gains for all 90 students assessed as part of course-based practice. Significant increases were found in all categories (Content Knowledge, Literature Literacy, Translational Ability, and Civic Engagement).

Paired t-test analysis of course-based pre/post Likert responses (n=90) demonstrate significant changes in student self-perception across Content Knowledge, Literature Literacy, Translational Ability, and Civic Engagement (Figure 2; p<.01 for all). Effect size for Content Knowledge, Literature Literacy, Translational Ability, and Civic Engagement was ES = 2.61, 1.47, 1.22, and 0.64, respectively. Large effect sizes found for Content Knowledge, Literature Literacy, and Translational Ability firmly supports the practical significance of changes in self-perception. A medium effect size was found for Civic Engagement, lending a moderate level of practical significance.

Learning Gains including Alumni

Alumni responses (n=10) were compared to their pre-course and post-course surveys to provide insight into potential longer-term learning gains. A two-way 1x3 ANOVA (pre-, post- and alumni-) of course-based written responses showed significant differences in content knowledge (F(1,27)=45.71, p<.00001) with Tukey SD post hoc analysis identifying significant improvements in content knowledge that persisted over time (pre- vs alumni-, p=.00016). Significant changes in translational ability were identified (F(1,27)= 7.46, p<0.01), with Tukey SD post hoc analysis identifying increased translational skill that persisted over time (pre- vs alumni-, p<0.05). No significant changes were found for the literature literacy (F(1,27)=0.27, p=0.769) or civic engagement categories (F(1,27)=3.1, p=.061). Effect size (ES) is large for content knowledge and translational ability (ES=5.41 and 1.16, respectively). Effect size is medium for literature literacy and civic engagement (ES=0.53 and 0.55, respectively.) The effect sizes for these categories lend support to the practical significance of the statistical findings. Rubric-scored data evaluating longer-term learning gains for the four categories are depicted in Figure 3.

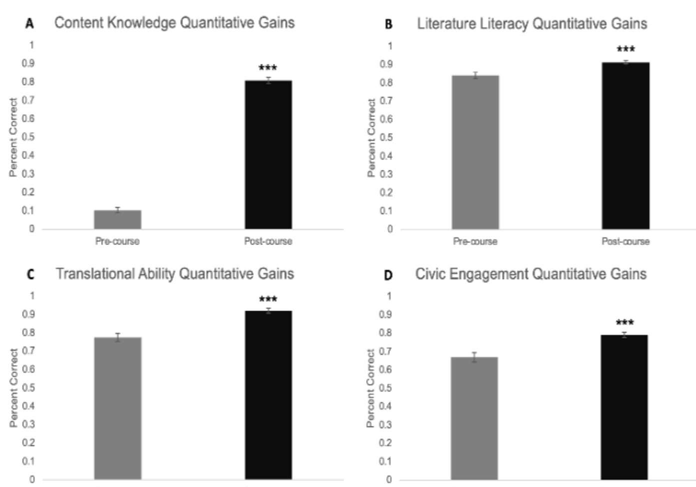

Figure 1. Quantitative learning gains across course-based pre/post written responses for enrolled students. Paired two-tailed t-test reveals significant increases between the pre-course and post-course conditions across all learning goal domains A) content knowledge (t = 30.05; p<0.0001); B) literature literacy (t = 4.49; p<0.0001); C) translational ability (t =6.71; p<0.0001); D) civic engagement (t = 4.55; p<0.0001). (***p<.0001).

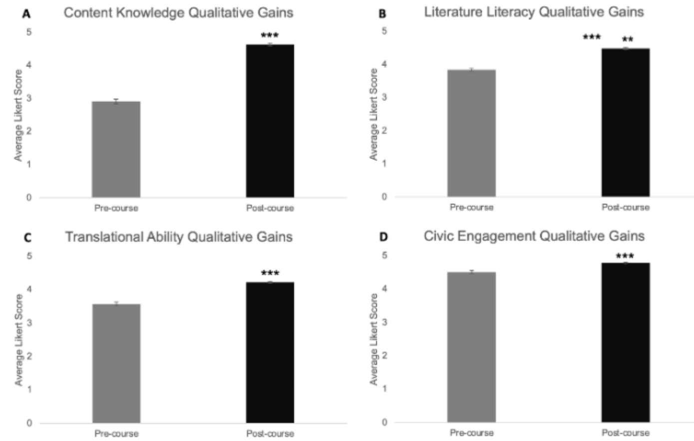

Figure 2. Likert self-perception of learning gains for enrolled students. Paired two-tailed t-test reveals significant growth in self-perception between the pre-course and post-course conditions A) content knowledge (t = 25.00, p<0.0001); B) literature literacy (t = 14.00, p<0.0001); C) translational ability (t = 11.31, p<0.0001); D) civic engagement (t = 5.86, p<0.0001). (***p<.0001).

Longer-term changes to student self-perceptions were evaluated via a 1x3 ANOVA (pre-, post- and alumni-) assessment of student self-perception across Likert responses. Analysis showed significant increases in self-perceptions of content knowledge (F(1,27)=22.52, p<.0001), with Tukey HSD post-hoc analysis indicating that self-perceptions of content learning gains persist over time (pre- vs alumni-, p<0.0001). Improvements of self-perceptions of literature literacy are significant (F(1,27)=5.54, p<0.01) but not maintained over time (pre- vs alumni-, p=0.06). Significant differences were seen over time with self-perceptions of translational ability (F(1,27)=4.92), p<.05), with significant perceptions of growth throughout the term (pre- vs post-, p<0.05), yet not maintained over time (pre- vs alumni-, p=0.07). Significant changes are seen in self-perceptions of civic engagement (F(1,27)=4.59, p<0.05), and Tukey HSD post hoc analysis identifies self-perceptions of civic engagement are maintained over time (pre- vs alumni-, p<0.05). ES for each category is 1.96, 1.16, 0.97, and 0.89, respectively. The large effect sizes for each of these categories lend support to the practical significance of the statistical findings. Figure

4 depicts longer-term changes in student self-perceptions, as identified by Likert self-reports.

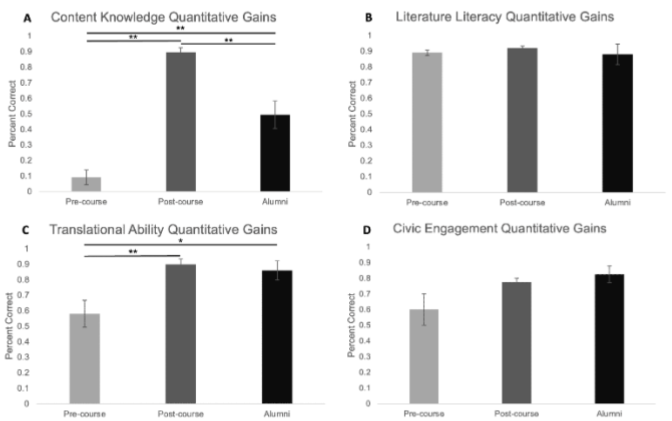

Figure 3. Quantitative learning gains across course-based written responses for pre-, post- and alumni- conditions. Two-tailed 1x3 ANOVA reveals significant differences in A) content knowledge ($F(1,27)=45.71$, $p<.00001$), including significant improvements in content knowledge that persisted over time (pre- vs alumni-, $p=.00016$). B) Significant differences were not found for literature literacy ($F(1,27)=0.27$, $p=0.769$). C) Significant differences were found between all groups for translational ability ($F(1,27)= 7.46$, $p<0.01$), with increased translational skill that persisted over time (pre- vs alumni-, $p<0.05$). D) Significant differences were not found between all groups for civic engagement ($F(1,27)=3.1$, $p=.061$). (*$p<.05$, **$p<.01$).

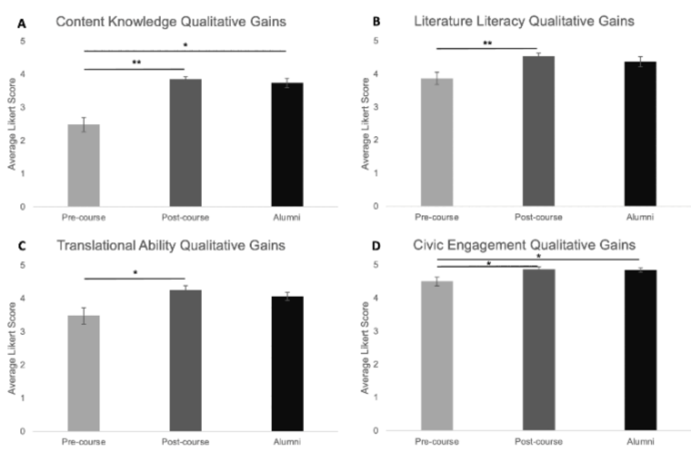

Figure 4. Likert self-perception of learning gains across pre-, post- and alumni conditions. Significant differences were found between all groups for A) content knowledge ($F(1,27)=22.52$, $p<.0001$) B) literature literacy ($F(1,27)=5.54$, $p<0.01$) C) translational ability ($F(1,27)=4.92$), $p<.05$) and D) civic engagement ($F(1,27)=4.59$, $p<0.05$). Post-hoc analysis using Tukey HSD identifies maintenance of growth in self-perceptions surrounding content knowledge (pre- vs alumni-, $p<0.001$) and civic engagement (pre- vs alumni-, $p<0.05$) over longer time periods (*$p<.05$, **$p<.01$).

DISCUSSION

The results presented above indicate that students taking the CBL-style developmental neuroscience course demonstrated learning gains in each of the four categories: content knowledge, literature literacy, translational ability, and civic engagement. This observed improvement was determined by a statistically significant increase in rubric-scored written post-course assessment, and parallel growth is mirrored in student self-perceptions via Likert responses.

Developmental neuroscience content knowledge showed significant improvements between pre- and post-course competencies. While alumni content retention was significantly lower than post-course scores, scores for alumni content knowledge were still significantly higher than pre-course assessment scores. These data indicate that alumni maintain significant long-term learning gains when compared to their pre-course scores. This pattern demonstrates that learning is occurring during the course, but specific knowledge of developmental neuroscience does decay with time. This stands to reason, following 'use it or lose it' principles of learning and memory. As students graduate and begin careers where developmental neuroscience content is not continually refreshed, it is natural for their knowledge to wane. These data support the need for continuing education for practitioners of a discipline, such that knowledge stays fresh and accessible for these individuals (“Continuing Medical Education”, 2023).

Scores associated with literacy of scientific literature significantly increased from pre- to post-course, demonstrating improvement in the ability to read and analyze scientific literature. No significant difference in scores was found between the post-course and alumni groups, indicating that the skill-based gains in literacy persist after completion of the course.

Translational ability scores also improved from pre- to post-course and persisted in the alumni. Through the CBL approach, students developed the necessary skills to effectively translate study findings into language that can be understood by non-scientists, long after completion of the course. An interesting question that was not probed with this data set is whether the long-term learning gains in skills associated with scientific literacy were in any way moderated by the skills and competencies developed for 'translating' the readings into lay terms or purely a result of course-based journal club style activities.

Although a significant increase in civic engagement attitudes were observed across the pre/post course-based assessment, with the addition of the alumni sample, no significant change was found across post-course and alumni scores. Although these data approached significance ($p=0.058$), a more robust sample size would be needed to determine if these findings were moderated by the small alumni sample size, or a true decay of motivation for civic engagement.

Overall, written survey results provide further support that a CBL course design achieves content, skill and attitude learning gains in a university STEM setting such as developmental neuroscience. During the academic term, students demonstrate learning gains in all four domains broadly assessed through their written responses on a pre/post survey, and learning gains in literature literacy and translational ability persisted over time in the alumni.

Given that the course-based data here were collected as part of standard course assessment, this data presented here have some notable limitations. The first major limitation is the lack of a comparative control group. While these results show that CBL-teaching prompted learning gains for these students, it is difficult to determine if these learning gains were due to CBL pedagogy, the course-based curriculum itself, or an outcome of the pairing of course- and community-based strategies.

In addition, the sample size of the alumni (n=10) is small and may also include selection bias in the alumni who chose to respond to the survey request. A repeated study with a greater number of alumni responses is needed.

This study was completed at the University of Notre Dame, a Catholic institution. The University of Notre Dame emphasizes the principles of Catholic Social Tradition (CST), a moral framework that guides individuals to cherish human life, seek the common good, put the needs of the poor and vulnerable first, promote peace, and care for the environment ("Seven themes of Catholic Social Teaching", 2005). A majority of the students at the university identify as Catholic and may already embrace the practice of CST in their life, skewing results related to civic engagement, even at the time of the pre-course survey. Replication of this study at a university without religious affiliation is recommended to gain further insight into the possibility of this confounding variable.

A final potential limitation is the use of student self-assessment to measure a component of student learning gains. Given this limitation, we pose that learning gains that were assessed using rubric-based scoring for written responses can be viewed as an accurate assessment of changes in knowledge, skills and attitudes. The written questions directly assessed specific criteria constituting student content knowledge, literature literacy, translational ability, attitudes of civic engagement. Responses only earned credit if the respondent could articulate specific competencies that support their perceptions. Students did not have access to the scoring rubric, and thus quantification of learning through written responses was assessed solely on a respondent's ability to answer the questions using key words or phrases, using the knowledge base and skills they developed throughout the semester. In addition, the data surrounding student self-perceptions of content knowledge, literature literacy, translational ability and attitudes of civic engagement *also* grew significantly throughout the semester. From this perspective, the authors believe it is actually quite heartening to see parallels between quantifiable learning gains as evidenced by written responses, and student self-perceptions of their own growth as indicate on Likert-style responding.

Despite the study's limitations, the CBL course presented here demonstrates student learning gains that persist over time. This style of course design also offers an opportunity for direct, protracted engagement between campus and community members. In recent years, we have witnessed a breeding ground for misinformation and doubt when the public lacks faith in the scientific system (Muhammed and Mathew, 2022). Strategies to "bridge the gap" between scientists and the public is needed, and CBL pedagogy offers one opportunity for students and faculty to collaborate with their community on a wide variety of social issues, offering cutting-edge scientific findings directly to organizational and community problem solving. Working in such a community-centered fashion fosters opportunities to build trust at a personal level and help to heal and unite communities (Bringle and Hatcher, 2002; Flaspohler et al., 2008), but is not without its challenges.

Forming relationships with community partners can be difficult and requires diligence, organization, and substantial motivation on the part of the faculty member to maintain communication as well as ascertain clear, collaborative goals for the partnership. Additionally, facilitation of classroom discussions and sourcing of relevant articles for student journal clubs requires an educator to not only have sufficient time, but also the ability to guide exploration of *how* the mechanisms of neuroscience (e.g. experience dependent plasticity) can become moderators of individual and community well-being (e.g. social correlates of health).

Class size is also always a moderator of how, whether and at what level an instructor can employ any engaged or active learning strategy. CBL is no different. This study was conducted in a classroom size of 30 students and has been successful in class sizes up to 40 students. Educators who are pressed for time or whose schedules prohibit sustainable, engaged partnership may experience differential results from the CBL approach presented here.

While this learning environment can be challenging to organize, when successful it is exceedingly rewarding for students, community members, and educators. Given the rapid decline in the public's trust in science, it might be relevant to ask: If not us then who? If not now, then when? While the cost of time and attention are significant when executing such a community engaged course, a critical consideration in this season is also: What is the cost of doing nothing and maintaining the status quo in our pedagogical and (non)engagement practice? To reduce some personal strain for instructors at colleges and universities, we suggest utilizing campus resources with connections to the community, such as centers for outreach and social connection. Establishing relationships with local libraries, community centers, schools, food banks, compassionate housing centers, religious centers, and more can also provide fruitful projects for students and the community alike. Student data from written responses support stable learning gains over time, CBL partner testimony supports the hope that engaged course styles can promote not only trust in science, but advocacy for the protection and continuation of scientific discovery.

Conclusion

The CBL approach to education within the Developmental Neuroscience course at the University of Notre Dame resulted in learning gains for all students in content knowledge, literature literacy, translational ability, and civic engagement. Persistent learning gains were observed in alumni in literature literacy and translational ability. CBL is an alternative teaching style to the traditional lecture approach in science classrooms that can result in student benefit. Educators are encouraged to consider implementing this pedagogy in their own university classrooms to bolster student engagement and promote transparent engagement with their community.

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