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Embracing Neurodiversity by Increasing Learner Agency in Nonmajor Chemistry Classes

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ABSTRACT: In this work we focus on neurodiversity, a recently defined facet of diversity. Chemical education is in its early stages of recognizing the value that neurodiversity brings to the field. After an overview of current terminology, we discuss general challenges that neurodivergent students face in chemistry classes. To create an inclusive class experience for students with diverse neurocognitive functioning, we focus on increasing learner agency. Our premise is that neurodiversity is supported by a well-structured, learner-driven class-experience. On the basis of this, we developed a design that we applied in nonmajor chemistry courses taught remotely due to the COVID-19 pandemic. Our premise is supported by data extracted from student-teacher interactions, student surveys, and student course evaluations.

KEYWORDS: *Internet/Web-Based Learning, First-Year Undergraduate/General, Dyes/Pigments, Nonmajor Courses, Nutrition, Student-Centered Learning*

INTRODUCTION

Neurodiversity: Definition and Terminology

Diversity, equity, inclusion, and respect are concepts traditionally associated with the coexistence of individuals with differences such as race, ethnicity, gender, sexual orientation, socioeconomic status, or parents' postsecondary experience. In recent years, we saw an expansion of these categories to include an increasing number of neurological differences. The term "neurodiversity" was introduced about two decades ago[1] and initially used in relationship with autism; later its meaning was expanded. The definition of neurodiversity and related terms is still an ongoing process. A brief summary of current terms and definitions[2] is presented in Table 1.

Table 1. Neurodiversity-Related Terms

Term (Abbr.)	Definition
Neurodiversity	Neurodiversity is the diversity of human minds, the infinite variation in neurocognitive functioning within our species.
Neurodivergent (ND)	Neurodivergent means having a brain that functions in ways that diverge significantly from the dominant societal standards of "normal".
Neurotypical (NT)	Neurotypical means having a style of neurocognitive functioning that falls within the dominant societal standards of "normal".
Neurodiverse	A group of people is neurodiverse if one or more members of the group differs substantially from other members in terms of their neurocognitive functioning.

Table 2. Comparative Class Settings for the Described Chemistry Courses

Section Number/ Total Sections	Online Delivery Day and Time	Semester and Year	Number of Students
CHEM 115—Chemistry and Art: Textiles and Dyes			
1/2	Monday 3:30 pm −6:20 pm	Fall 2020	23
2/2	Tuesday 3:30 pm −6:20 pm	Fall 2020	23
1/2	Monday 3:30 pm −6:20 pm	Spring 2021	25
2/2	Tuesday 3:30 pm −6:20 pm	Spring 2021	25
CHEM 150—Chemistry of Food and Nutrition			
1/1	Friday 8:30 am −12:20 pm	Fall 2020	23
1/1	Friday 8:30 am −12:20 pm	Spring 2021	25

The philosophical basis of this work is inspired by the Neurodiversity Paradigm.[3] According to this paradigm, neurodiversity is a natural and valuable form of human diversity. The

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idea that there is one "normal" or "right" style of neurocognitive functioning is a cultural construct. The Neurodiversity Paradigm offers an inclusive perspective, different from the outdated belief that all nonstandard functioning brains must be somehow flawed or diseased. According to this paradigm, the social dynamics of neurodiversity is similar to the social dynamics of other forms of human diversity. When embraced, neurodiversity acts as a source of creative potential.

Neurological variations that can make a person ND include autistic spectrum, dyscalculia, dysgraphia, Meares-Irlen syndrome, hyperlexia, Tourette syndrome, synesthesia, anxiety, epilepsy, post-traumatic stress disorder, traumatic brain injury, etc. Our perspective is strictly educational; debating which neurological variations can or should benefit from medical treatment, and which are an integral part of one's identity, is beyond the scope of this work.

Neurodiversity in Higher Education

Embracing neurodiversity in higher education is still in its infancy. While most colleges and universities have support services for students with documented learning disabilities, classifying all ND students as individuals with a disability excludes students who do not identify their neurocognitive functioning as pathological. This classification also excludes students who have difficulty obtaining the documentation necessary to qualify for support. Often these "undocumented" students belong to marginalized racial and socioeconomic groups—groups with limited access to general and mental health care. In most colleges and universities, there is a disconnect between student support services and the classroom experience of ND students.[4] There are only a handful of institutions that have explicit neurodiversity initiatives.[5] While teaching practices directed at specific ND conditions, such as autism,[6] are becoming more popular, focus on pedagogical initiatives that support students with a wide range of neurocognitive functioning[7] is just beginning. Due to established tradition, biases, or instructors' own neurocognitive functioning, in spite of the emerging evidence, there is resistance to consider the benefits of neurodiversity in higher education.[8]

We are in the early stages of recognizing the value of neurodiversity in college chemistry classes. According to a recent search effectuated of all ACS publications, the term "neurodiversity" gave zero hits. Comparatively the term "diversity" came up approximately 18,000 times.

The work presented in this article originated during the COVID-19 pandemic, with students informally sharing their ND identity with the instructor and asking for specific accommodations.

Inclusive Learning and Teaching Designs

Exclusive teaching practices have a cultural origin. Societal standards, including those of normal neurocognitive functioning, were historically defined relative to the dominant culture. In science education, if we consider that "one culture is better than the rest" than only those who are part of this "superior" culture can achieve.[9] To embrace neurodiversity, we examined inclusive learning designs. Two main practices stood out: culturally responsive teaching (CRT) and universal design for learning (UDL). There are varied descriptions of these practices in the literature. UDL is based on providing multiple means of representation, action, and engagement.[10] CRT's overarching themes are cultural awareness, learning partnerships, information processing, community of learners, and learning environment.[11] Both practices were used in a wide variety of settings. UDL was implemented to assist students with ADHD,[12] students with autism,[13] and students with physical and/or intellectual disabilities.[13,14] Beyond helping students with disabilities, principles of CRT[16] and UDL[17,18] were used for web-based instruction of diverse learners. CRT was used to support linguistically diverse students during the COVID-19 pandemic.[19] UDL was suggested as a framework to disrupt assumptions about rurality, socioeconomics, race, ability, gender identity, and privilege[20] and for assisting indigenous students in higher education.[21]

An overlap between many key areas of UDL and CRT was described.[22] The universal approach supports an accessible learning structure for all students, including but not limited to students with disabilities. UDL does not generally view differences as weaknesses.[23] Cultural responsiveness focuses on awareness about diverse communities and on reducing the threats related to cultural stereotypes. Without an awareness of how experience, culture, and identity can affect learning, there is a danger of confusing disability with diversity.[24] CRT views neurodiverse students as members of an emerging culture, addressing inequities that a special education approach cannot alone address.[25]

Considerations for Teaching Remotely During a Pandemic

Considering the unprecedented situation of remote teaching during the COVID-19 pandemic and the variety of physical spaces that students are expected to function during the instruction, we took a closer look at the original principles of universal design as it was first defined in architecture.[26] The idea of giving access for all who enter in the physical sense is built on the principles of equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and appropriate size and space for use. These principles gain an increased importance when the space around the students during the learning process is not the safe and controlled physical classroom.

We also kept in mind that all students were experiencing effects of the pandemic in some form. Our differences are important and so are our similarities. We are all human. The human brain is hardwired to avoid threats to safety at all costs.[11] When the flight, fight, or freeze response is activated, this gives less space for working memory in the hippocampus and it also inhibits the activity of the frontal lobes responsible for rational thinking. Teachers should have high expectations, however extra care is needed when choosing the manner of communicating them as not to be perceived as an added threat in the already threatening environment.

Due to the nature of remote instruction, autonomous learning is very important. A direct link between learner agency and students' capacity for autonomous learning was found in the context of language learning.[27] Furthermore, agential actions were found to be intimately linked to the learning structure.[28] In the virtual environment of the class, focusing on fostering learner agency is important because students might disengage if they feel that they are not in control of their learning. In both pandemic and nonpandemic teaching, special attention has to be paid to the agential actions of students who identify as different than the main cultural norm. The general concept of human agency is inseparable from social structure and the diverse spheres cultural systems.[29]

Class Settings

The settings for the classes discussed in this work are presented in Table 2. Students enrolled in these classes major in fields such

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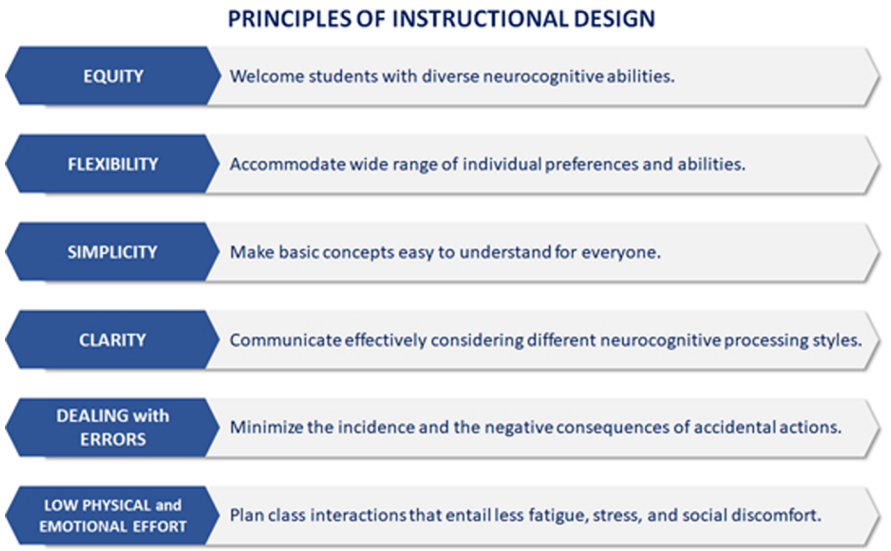

Figure 1. Principles of instructional design for a neurodiverse learning environment.

as acting, ASL-English interpretation, animation, comedy, creative writing, English, fashion, film, television, fine arts, game design, graphic design, illustration, interior architecture, journalism, marketing, music, photography, and theater. These classes are part of their general science requirement.

PRINCIPLES AND METHODS

To fully embrace neurodiversity, the entire cultural assumptions of a "normal" classroom experience has to be examined. We must look past the piecemeal approach of different support services and embrace a cultural shift that consists of (ref 4, p 775): "the creation of a trusting and inclusive environment tolerant of difference that does not need labels, adjustments or special measures that will allow all students to flourish."

Table 3. Channels of Communications Used in the Described Chemistry Courses

Flow of Communication	Group Communication Channels	Individual Communication Channels
I → S	Canvas—all communication options; Zoom	Canvas—individual messaging, assignment comments; email; Zoom; grades
S → I	Canvas—messaging; Zoom	Surveys (start of course, RSVP Zoom); Canvas—messaging; email; Zoom
I ↔ S	Zoom; Canvas—messaging, assignments; email	Zoom; Canvas—assignment; emails
S ↔ S	Canvas—discussions; Zoom	Social media (Instagram, TikTok, Twitter, YouTube, Facebook, etc.)—optional

Our principles of instructional design for a neurodiverse learning environment (Figure 1) draw inspiration from the principles of universal design in architecture,[26] UDL,[7,10−15,17,18,20−23] CRT,[11,16,19,22,24] and considerations that all human brains are vulnerable to unprecedented stressors during a pandemic. The premise of this work is that neurodiversity is supported by a well-structured, learner-driven class-experience. Within this framework, we focus on increasing learner agency, giving students the power to define their own way of participation. When applying the principles, we made sure to maintain the integrity of the learning objectives of the course. We implemented our principles in the chaotic times of a pandemic within the confines of an online environment. In the given circumstances, the instructor had limited power over student−student interactions but had the means to generate multiple opportunities for instructor−student interactions and for self-guided learning.

Principles of instructional design for a neurodiverse learning environment were implemented in 100-level courses taught remotely due to the COVID-19 pandemic at Columbia College Chicago. These courses are Chemistry and Art: Textiles and Dyes (CATD) and Chemistry of Food and Nutrition (CFN). These courses are part of the general science requirement. Students in these classes do not major in chemistry or any other of the STEM fields.

Equity

Dealing equitably with students who have a wide range of neurocognitive functioning is a delicate task. Building relationships with each individual student, establishing a culture of trust and collaboration, empowers students to define their own learning environment. Building trust is an arduous process, and it cannot be done without good communication. For the classes in the examples, we established multiple and diverse channels of communications (Table 3).

To be able to offer an equitable learning environment, the content and the tone of the communication is as important as having multiple channels. From communications that inform the instructor about disparities that students might face to communications that empower students to be in control of their learning experience, keeping in touch with each individual student is a perpetual balancing act between trusting and setting boundaries. An example of building trust within boundaries can be seen in the way the weekly *RSVP Zoom* survey is constructed. Students can respond to "I will attend the Zoom meeting this week", with a simple "Yes", but the "No" option has three subchoices. These choices are "No, I successfully completed these week's assignments", "No, I need this week off", or "I'm more than 1 week behind and I'm requesting help in an email." These choices allow students to take a week off without having to justify it but also keeps them from falling more than 2 weeks behind.

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Table 4. Flexible Elements of Instruction Incorporated in the Described Chemistry Courses

Element of Instruction	Design of Flexible Accommodations
Synchronous and/or Asynchronous	Students can choose whether they engage synchronously or asynchronously. Canvas weekly modules have content that can be completed asynchronously (with elements of real-time feedback), or synchronously during Zoom meetings. For those who choose synchronous instruction, Zoom-time is divided in shorter sessions allowing meetings of six or fewer students. Students make their weekly choice through the RSVP Zoom survey.
Pacing of the Instruction	Students may choose even-pace work or cramming. The Canvas due date is used for even pacing. There are no repercussions if the due date is missed. Canvas availability date (due date +1 week) is used to help students cram. Assignments are no longer available after their availability date has passed, but students can request an extension.
Type of Communications and Learning Preferences	Multiple ways of conveying, receiving, and exchanging information are used: oral (speaking/listening), written (writing/reading), symbolic (emojis, diagrams, formulas, drawings, etc.), and nonverbal communication on Zoom (hide/show video, chosen background, personal picture, facial expressions, gestures, posture, tone of voice, choice to introduce a pet, etc.)
Assessment Flow	Students can choose the amount of work performed in one sitting. The classes are designed to have multiple short weekly assignments. For example, every week there is a quiz, a test, a laboratory assignment, and a group discussion. To preserve the integrity of the course, tests and quizzes include comprehensive questions. For the classes in the examples, this design can work without a final exam.
Assessment Type	Using various types of assessments minimizes any negative effect that one type can have on student performance. For some assignments, students may request to be assessed orally on Zoom. Private Zoom time is reserved for such requests.
Assessment Time	Students can take as long as they need to complete an assignment. Problems are designed to emphasize thinking and understanding rather than how fast a concept can be recalled, plugged, and chugged. Credit is granted for quality and not speed.

Designing an equitable class environment is only possible if students have the power to be their own agents. Learner agency might look different for different individuals, and only in reciprocal discourse with each student can we understand their goals, actions, and thought process.[27−29]

Flexibility

Our premise is that, if given clearly formulated, reasonable choices and incentives to try them, most students, including ND students, are able to opt for the settings that favors them the most. Students have similar preferences for special accommodations regardless of how they view their ND identity: as a difference that incorporates strengths and weaknesses or as a documented disability.[30] We examined traditionally rigid elements of instruction and related them to frequent requests for special accommodations on the Services for Students with Disabilities (SSD) forms for students who had a documented learning disability. Frequent SSD accommodation requests include extended time for exams and quizzes, reduced distraction, alternative formats, etc.[31]

On the basis of this analysis, we built flexibility into elements of instruction that previously needed to be altered to accommodate specific cases (Table 4).

Simplicity

Repetitive weekly modules (RWMs) on Canvas, ensure that, once the students understand how a week is structured, they can rely on this structure without having the burden of adapting to an everchanging class. RWM, interspaced with one or two Out of Box Modules (OBMs), gives students a chance to rest or to catch up with overdue work. The OBMs consist of a discussion on a recent science-documentary. OBMs do not contain quizzes, tests, or laboratories. Examples of RWMs and OBMs are shown in Figures 2 and 3, respectively.

Clarity

The clear flow of the course is assured by a linear structure, composed of a succession of simple modules. All course materials for the week are accessible through the module of the week. Every week a new module is posted with clear *due-dates* and *availability-dates*. Students get real-time or 24 h feedback on their assignments. Only actionable modules are visible. For an overall view of the class, students have access to an inactive visual of all modules for the semester.

Clarity is present on multiple levels, starting from the structure of the class to the way assignment questions are formulated. To actively emphasize the importance of clarity, students too are expected to communicate clearly. For example, one short laboratory assignment requires that students formulate one clear and logical sentence about a prerecorded experiment. Usually this request is received with disbelief; most students will ask the instructor if it is only one sentence that they have to write. This interaction gives the instructor the chance to explain that all good lab reports start with one clear sentence and are based on a logical succession of such constructs.

Dealing with Errors

There are two interrelated components of dealing with errors: tolerating errors[26] while teaching error reduction skills. Humans learn by making mistakes. Letting students know that being temporarily wrong is part of the learning process, creates a safe climate for intellectual risk-taking and experimentation. Making it clear that shame, blame, and punishment do not belong in this class will encourage students to improve. Grades are used to communicate and not to judge.

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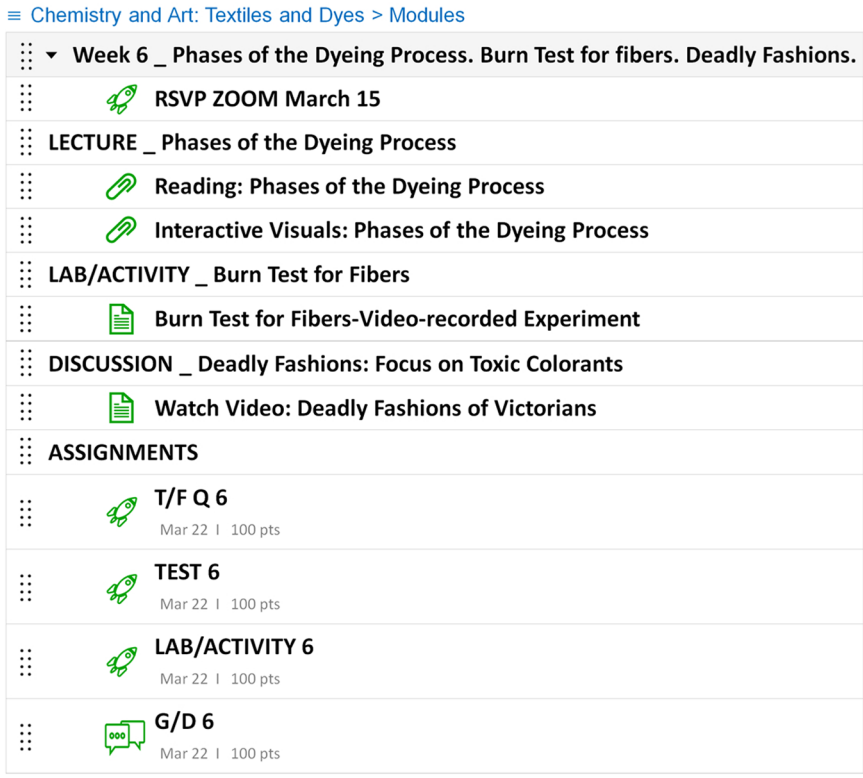

Figure 2. Example of a Repetitive Weekly Module in Canvas (T/F Q—true or false quiz; TEST—multiple choice test; LAB/ACTIVITY—laboratory activity report; G/D—group activity and discussion)

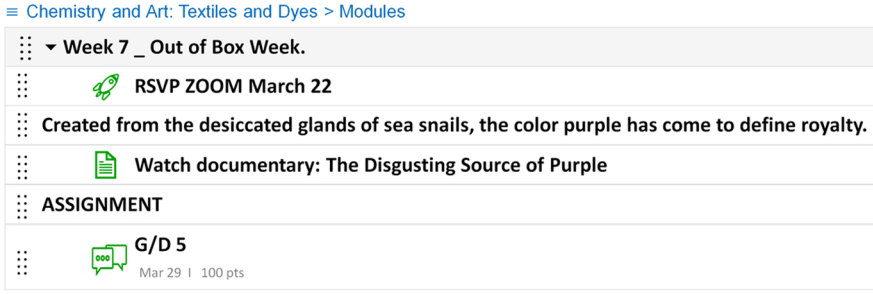

Figure 3. Example of an Out of Box Module in Canvas (G/D— group-activity and discussion)

While acknowledging the role of errors in the learning process, teaching students how to make fewer mistakes is also important. This can be accomplished through specific comments to individual students and by including elements of personal wellness as part of the class assignments. For example, in CFN, (a week before a more traditional laboratory exercise that involves the gustatory and olfactory systems), we assigned a short mindfulness meditation exercise where students had to share with each other their experiences (including awareness of smells). In response, additionally to describing the sensorial experience, students discussed the importance of mindfulness when coping with stressful situations. Some students noted that mindfulness improved their mental focus.

Low Physical and Emotional Effort

For remotely taught classes, there is a significant physical effort[26] in sitting hours in front of a screen, often without breaks. To reduce time wasted on unnecessary scrolls and searches, we used specially designed lecture materials that we called *Interactive Visuals*. These visuals contain key concepts that can be accessed by a single click. Created using a widely available program, PowerPoint, the *Interactive Visuals* do not work as a traditional presentation. The first slide is a set of logically connected clickable tabs. Under each tab there is a key concept page that can be accessed by a single click. At the end of each concept-page is a return-to-the-first-slide button. This makes the search of key concepts almost effortless.

The issue of breaks has been addressed by having multiple short assignments instead of one large assignment. This setup gives students a chance to take breaks when they feel tired. On the basis of this principle, the classes in the examples have a total of 40−50 strategically grouped small assignments, evenly spaced out during the entire length of the semester.

Besides the physical effort of interreacting through an electronic device, some students have to exert emotional effort[34] during Zoom to overcome the feeling of being watched in their own home. Giving students the chance to opt out of Zoom meetings while still benefiting of the instructor's support helps minimize this effort.

Methods of data collection are described in the Table 5.

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Table 5. Data Collection Methods to Aid Instructional Design for Neurodiverse Student Groups

Sources	Description
Neurodiversity data of students enrolled in the described chemistry courses, Fall 2020	Formal documentation requesting special accommodations from the SSD[a] was used.
	Students who reported to the instructor one or more conditions consistent with neurodivergent functioning were counted as ND. The instructor took a note when students shared information related to their neurocognitive functioning, for example, phrases such as "I am having increased trouble with my pre-existing mental illnesses", "My anxiety and depression have never been worst", "I have ADHD", "Can you tell that I'm Autistic?", and "No motivation to do the things I enjoy."
	Students who did not share communications that contained information on their neurocognitive functioning were presumed NT.
Neurodiversity data of students enrolled in the described chemistry courses, Spring 2021	Formal documentation requesting special accommodations from the SSD[a] was used.
	A beginning of the class survey asked students if they identify as one of the following: "Definitely ND"; "Somewhat ND"; or "NT". The option "I do not wish to answer this question" was also available.
Prior science class experience	A beginning of the class survey asked students whether their prior science class experience was "Good", "Bad", or "Mixed" or whether they had no prior science class experience.
Student course evaluations	Anonymous data collected by the college for each class separately
	Likert-scale data generated by the college
	Written comments analyzed and grouped by themes by the author

[a]Services for Students with Disabilities form used at Columbia College Chicago.

Table 6. Example Student Course Evaluation Written Responses from the Described Chemistry Courses

Theme	Student Course Evaluation Excerpts Exemplifying Each Theme
Equity	"A very welcoming environment"; "Set us up for success I have excelled in this course, something I previously thought impossible with sciences"; "Dr. B was very understanding in regard to mental health"; "Professor was exceptionally thoughtful, patient, and helpful"
Flexibility	"My favorite format I've seen an instructor practice, which consisted of us joining in small groups"; "I found that visual learning (interactive Microsoft slides) made the content more interesting and it was easier to understand"; "[The instructor] let students do the work on their own schedule, and checked in when she felt help was needed"
Simplicity	"Modules were very easy to follow"; "This class was organized very well in terms of modules. It was very straightforward, and I was able to access and learn the content with no issues"; "Efficient methods of teaching"
Clarity	"Organized very clearly"; "Instructions for each assignment were very clear"; "Materials were all organized very clearly"
Dealing with error	"When I did not understand why I got an answer wrong on my test, Beatrix was there to help me understand the lesson and explain to me the correct answer"; "Allowed us that time to get our work and tasks done"; "Dr. B was very understanding in regard to mental health, sleep [···] this, made me realize I need to also put my health first, then my studies so I can focus and actually learn"
Physical and emotional effort	"I learned a lot in this course without a ton of pressure and stress"; "The class was very effective"; "Chemistry doesn't have to be boring or frustrating"; "Class moved at a very nice pace with a reasonable amount of work each week"; "Discussed mental health a lot and went over how everyone is doing. I found this to be very helpful and important during these stressful times"
COVID-19 restrictions-related	"The format and week-to-week expectation for this class was one of the best transitions to an online format I've had this semester"; "There are just some things that are better done in person"; "This course was adapted to the pandemic really well"; "The labs [in-person] also didn't exist because the class was moved online so I think a big portion of the material was missing. However, I know this is a difficult time, so everyone has to adjust"
Learning-process related	"This was the only chemistry class that I have ever enjoyed"; "Left every class feeling like I learned something"; "I enjoyed the material in this class and gained a better understanding of textiles and dyes"; "Helped me better understand certain foods' nutrition and how cooking them affects them"; "Super interesting course and kept me intrigued and ready to learn each week"; "Teaching style has an emphasis on learning and understanding, rather than just memorizing and scraping by"
Dissatisfaction (other than not being in-person due to COVID-19)	No responses in this category

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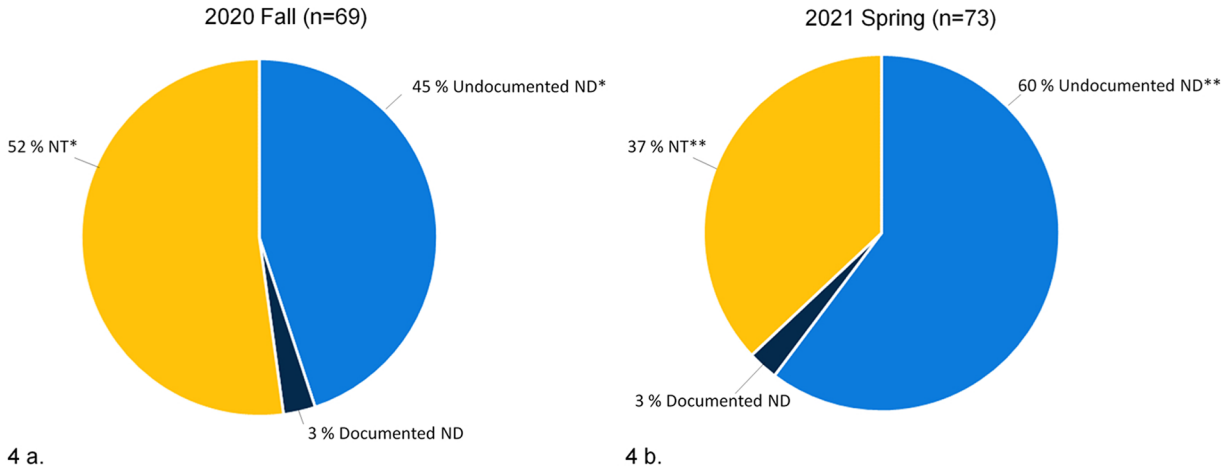

Figure 4. Proportion of ND students in two sections of Chemistry and Art: Textiles and Dyes and one section of Chemistry of Food and Nutrition. (a) ND students 2020 Fall (n = 69) Documented ND—ND students with documented learning disability possessing formal letter from SSD; Undocumented ND*—students who identified themselves having one or more conditions consistent with neurodivergent functioning through unrequested disclosure initiated by the student during the length of the semester; NT*—presumed neurotypical students, calculated as total number of students minus all ND students. (b) ND students 2021 Spring (n = 73) Documented ND—ND students with documented learning disability possessing formal letter from SSD; Undocumented ND**—students who identified themselves having neurodivergent functioning in response to a survey at the beginning of the class; NT**—students who identified themselves as neurotypical in response to a survey at the beginning of the class.

RESULTS

The data below comes from classes taught remotely due to the COVID-19 pandemic. All class interactions took place exclusively online. The same set of three classes was taught in similar formats during the Fall 2020 and the Spring 2021 semesters. These classes are section one and section two of Chemistry and Art: Textiles and Dyes (CATD) and section one Chemistry of Food and Nutrition (CFN). Each class had an enrolment between 23 and 25 students. There were no other parallel sections of these classes taught in Fall 2020 or Spring 2021.

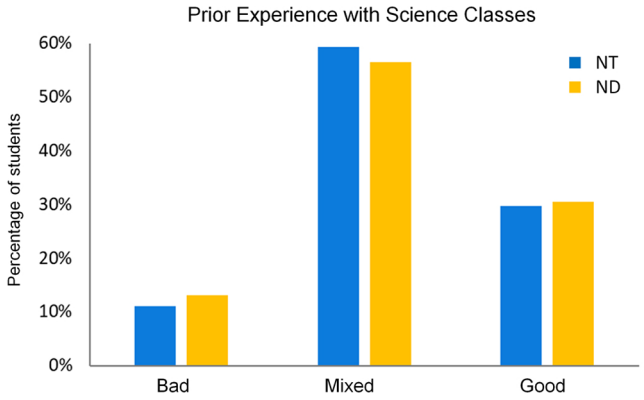

Figure 5. ND and NT students' prior experience with science classes, 2021 Spring (n = 73) in two sections of Chemistry and Art: Textiles and Dyes and one section of Chemistry of Food and Nutrition. ND—all students who identify as ND; NT—students who identified as NT in response to a survey at the beginning of the class. Note: there were zero students with no science class experience.

During the Fall 2020 semester, out of a total of 69 students, two students (~3%) had formal documentation requesting special accommodations from the SSD. During the length of the semester, an additional 31 students (~45%) reported (without being specifically asked) having one or more conditions consistent with neurodivergent functioning. The remaining 36 students (~52%) were presumed NT (Figure 4a). Note that the number of NT students could be overestimated because it might include ND students who remained silent.

During the Spring 2021 semester, out of a total of 75 students, two students did not wish to disclose how they view their neurocognitive functioning, the data presented in Figure 2b refers to the remaining 73 students. Two students (~3%) had formal SSD documentation requesting special accommodations. On the basis of a beginning of the class survey, 23 students identified as "definitely ND" and 21 as "somewhat ND"; these give a total of 44 ND students (~60%) and this number does not include students with SSD documentations who identified as "definitely ND" in the survey. The remaining 27 students (~37%) identified as NT.

During the Spring 2021 semester, the beginning of the class survey also asked students about their prior experience with science classes (Figure 5). There was no apparent correlation between identifying as ND and either good, bad, or mixed prior science class experience.[32]

Student Course Evaluations (SCEs) are administered by the college anonymously. End of semester SCE results are only available for Fall 2020 at the time this article is submitted for publication. For the Fall 2020 semester, 50 out of a total of 69 students completed the SCE. Thirty-four students had written comments in response to each of the following items: "Please provide evidence/examples supporting your ratings." and "What is the most valuable idea, concept, or lesson you are taking away from this course and, in particular, from this instructor? Please be specific."

The SCE response rates were 78% and 70% for sections one and two of CATD, respectively, and 61% for section one of CFN. Figure 6 shows student responses to questions using a simplified Likert scale: strongly disagree, disagree, agree, and strongly agree. The cumulative wordcount of SCE written responses was approximately 2200 words; excerpts grouped by themes (approximately 420 words) are presented in Table 6. All written responses are available in the Supporting Information.

Limitation of the data: Comparison between teaching to a presumed NT audience versus teaching to a neurodiverse

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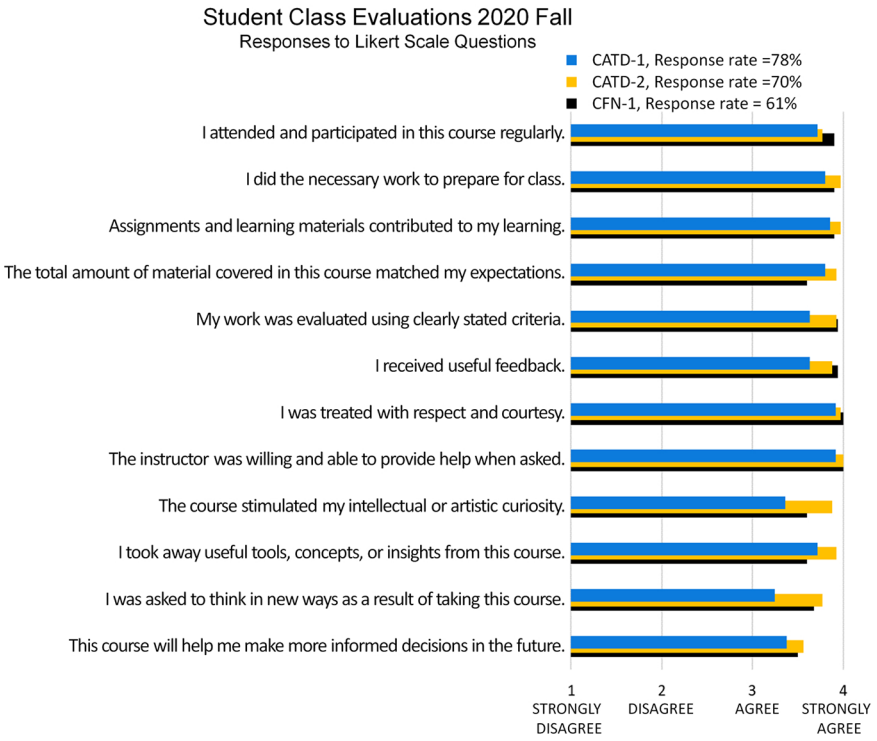

Figure 6. Student course evaluations, 2020 Fall. CATD-1, Chemistry and Art: Textiles and Dyes section one; CATD-2, Chemistry and Art: Textiles and Dyes section two, CFN-1, Chemistry of Food and Nutrition section one.

audience would be desirable but it is not available with the current data. Historical information about the same courses cannot be used for comparison. There are multiple differences, unrelated to teaching strategies, between the past and the current courses. The classes were taught by different instructors using different modes of delivery and formats to a very different student population. The College's SCE questionnaire was also different in the past.

DISCUSSION

While there is some data on the prevalence of conditions, such as ADHD, autism, and dyslexia, there is very little cumulative data on the prevalence of all the various conditions that could make a person ND. According to a UK-based peer support group[33] 30−40% of adults may be ND, however there are no comprehensive data on the proportion of all ND individuals in the US.

Our findings suggest (Figure 4) that in the classes used as an example there are significant number of ND students. The fact that we found a smaller percentage of ND students in the Fall 2020, (48%) ND, comparatively to Spring 2021, (63%) ND, is most likely due to different measuring methods: unprompted disclosure in 2020 versus prompted disclosure in 2021. It is also possible that the stress of the prolonged pandemic is affecting the neurocognitive functioning of students and that students who would have functioned NT in regular times are becoming ND. It has been demonstrated that the COVID-19 pandemic might affect standard functioning of emerging adults.[34] Studies that use the same measuring methods would be necessary to determine if this is the case.

In order to get an idea whether ND students tend to have a different science class experience than NT students, we looked at ND and NT status versus prior science class experience and found no correlation.

Data from SCE, Figure 5, and Table 6 suggest that the applied instructional design that increases learner agency works well in neurodiverse student groups. Besides the high response rate, it is worth noting that almost all students strongly agree that "I was treated with respect and courtesy." Regarding the intellectual integrity of the course, an aspect that has to be kept in mind whenever making any instructional changes, students agree that "Assignments and learning materials contributed to my learning." SCE written comments mirror the applied principles of instructional design. Overall, students had a positive class experience, and they describe this experience in terms consistent with the applied principles.

The limitation of the presented design is the number of students that an instructor can teach. Based on the personal experience of the author, 10−30 min per student per week are necessary. This is additional to the designated Zoom time. The author dedicated between 25 and 50 h per week to teach the classes in the examples.

This article was written from the perspective of embracing one facet of diversity. Beyond neurodiversity, in the real-life practice of teaching, we embraced our multiply diverse student community. Increasing student agency helps each student to validate their own identity and helps them value the varied perspectives that others bring to the collective. Diversity, equity, inclusion, and respect are concepts that cannot be separated. One facet of diversity is inextricably linked to other facets of being different. A wholehearted and strong focus on the underrepresented group of ND students leads to an atmosphere of respect and inclusion that was valuable for everyone. This work was possible because it was not done in isolation but rather under the umbrella of a broader college-wide DEI initiative.[35] This work was ethically cleared by the office of Academic Diversity, Equity, and Inclusion, Columbia College Chicago.

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■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00247.

Canvas modules for Chemistry of Food and Nutrition (PDF)

Canvas modules for Chemistry and Art: Textiles and Dyes (PDF)

Student course evaluations written comments (PDF)

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Notes

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