High-impact educational practices: participation of Chinese and American undergraduates during the COVID-19 pandemic

Xiting Zhou1 · Lanwen Zhang1,2 · Xuemeng Cao1

Received: 27 April 2022 / Revised: 6 October 2022 / Accepted: 15 October 2022
© Education Research Institute, Seoul National University 2022

Abstract
The COVID-19 pandemic has led to challenges in high-impact extra-curricular educational practice. Using cross-national, large-scale survey data, this study discusses the current state of participation of high-impact educational practices (HIPs) among Chinese and American undergraduates, changes in this participation over time, and the differences between undergraduates in the two countries in this regard, from 2018 to 2021. We find that participation in social practices was significantly greater than research-related and extended learning activities in both China and the U.S. The involvement of first-year undergraduates in the three typical HIP activities was lower than that of seniors, especially in doing research with faculty. American seniors participated more in service learning and study abroad than Chinese seniors. The proportion of senior students who had studied abroad was lower than the proportion of first-year students who planned to study overseas, particularly in China. COVID-19 led to a significant drop in participation in service learning and study abroad in China, and it also amplified the impact of institutional support on the participation of undergraduates in HIPs.

Keywords High-impact educational practices · The COVID-19 pandemic · Supportive college environment

Introduction
The worldwide COVID-19 pandemic has required traditional teaching and learning to take a sudden leap forward in virtual communication and IT-based teaching and learning (Pan et al., 2020). According to the OECD (2020), more than 1.5 billion students and youth were affected by this transition. College students have fought maladaptation to rapid digitization and emergency remote teaching practices, which reduces offline interpersonal interaction and highlights the importance of autonomous learning and engagement (Mishra et al., 2020). Further, we cannot ignore the difficulties that college students have faced during the COVID-19 pandemic outside of class, as high interaction, high autonomy, and high engagement are distinctive features of extra-curricular high-impact educational practices (HIPs). While some practices may suit particular students at certain levels, numerous studies have demonstrated that HIPs have a greater positive effect on the majority of students (e.g., Brownell & Swaner, 2010; Gonyea et al., 2008; Riehle & Weiner, 2013; Zhang et al., 2017). Moreover, given that both teachers and students are usually pressed for time and energy, it makes sense to pay closer attention to HIPs that can still be effective in the post-pandemic era.

China and the U.S. have adopted different policies in the face of COVID-19. On June 30, 2022, China had 225,638 recorded confirmed cases in total, while the U.S. had seen 87,383,429 cases (China Daily, 2022). China has kept continued to implement a dynamic zero-COVID policy, while U.S. policy has been relaxed. The Chinese government emphasizes centralized decision-making, collectivism, national coordination, and public support (Gao & Zhang, 2021). This system ensures a continuity of online or offline learning activities during COVID-19 but at the expense of reducing domestic and cross-border travel. Because lockdown was the dominant policy at the provincial and university levels, fewer Chinese students went abroad for exchange and social practice. In places affected by COVID-19, students were not restricted from attending school and...
continued distance learning. In the U.S., at the beginning of the COVID-19 pandemic, online classes were also required at many universities. However, after one or two years, an increasing number of people, including younger people in particular, began to take COVID-19 less seriously, regarding it as nothing worse than a severe flu, and universities tended to return to normal operations and offline classes. The differences between China and the U.S. in terms of HIPs were captured before and after the COVID-19 pandemic.

This study discusses the factors related to HIPs based on recent large-scale survey data from China and the U.S. that may contribute to a better understanding of the impacts of the COVID-19 pandemic on students’ learning by pursuing the following objectives:

1. Outline the current situation, changes over time, and compare the participation in HIPs in China and the U.S. It is helpful to understand how students’ high-impact engagement changes from 2018 to 2021. Further, a cross-country comparison of comparable items from national surveys of college students could provide a social-cultural perspective for understanding the differences between Chinese and American undergraduates.
2. Analyze the impact of the COVID-19 pandemic on college students’ participation in HIPs. Only when the emerging challenges are fully understood can we support college students engage in HIPs as higher education navigates the catastrophe of COVID-19.

**Literature review**

**Definition of HIPs**

Over the past four decades, extensive research has identified that the activities in which students engage are what matters most with regard to learning and development during their college years (e.g., Astin, 1993; Chickering & Gamson, 1991; Hu & Kuh, 2003; Pasarell & Terenzini, 2005). The Association of American Colleges and Universities (AAC&U, 2007) has defined HIPs as the educational activities that have been widely shown to benefit undergraduate students from diverse backgrounds. In particular, 10 HIPs are highlighted, including first-year seminars, service learning, learning communities, writing-intensive courses, collaborative projects, undergraduate research, diversity/global learning, internships, capstone courses/projects, and common intellectual experiences. Kuh, the director of the National Survey of Student Engagement (NSSE), considers that HIPs involve “deep-level processing that emphasizes both acquiring information and understanding the underlying meaning of information” (2008, p. 14), developed through purposeful tasks, frequent feedback, human-scale experiences, interaction with people from different groups, interdisciplinary inquiry, and opportunities to synthesize and apply knowledge. He reports six categories of HIP, namely, service learning, learning community, research with faculty, internship or field experience, study abroad, and culminating senior experience, drawing on the results of a large-scale annual survey (NSSE, 2009). These educational practices are designed to connect students to the real problems that are facing local, national, or global communities and can help students to develop twenty-first-century skills and disciplinary knowledge, including learning skills, literacy skills, and life skills (Pelco, 2022).

The properties of HIPs have remained relatively consistent as researchers have extended them to other different national and regional contexts. For example, according to AAC&U documents, NSSE documents, and other work on HIPs, California State University, Fullerton, located in Southern California designed experience, active learning, community, and human exploration as HIPs, developing a structure to increase HIPs participation for over 38,000 students (McMahan, 2015). The development of technology and its deep application in education have enriched the types of HIPs, and certain internet-related learning activities are also included, like the University of Waterloo’s increasing use of ePortfolios as an HIP.

A fundamental consensus has been reached on the essential characteristics of HIPs, such as being challenging, enabling high interaction, and producing high engagement. Additionally, specific types of HIPs can be interpreted and adjusted according to regional and cultural circumstances.

**HIPs among American undergraduates**

Many studies have explored and verified the positive impact that HIPs have on students’ persistence, cognitive and non-cognitive educational attainment, and academic achievements (e.g., Brownell & Swaner, 2010; Farrow et al., 2021; Kilgo et al., 2015; Morris et al., 2019; White, 2018). Kuh (2013) found that, among college seniors in America, HIPs are positively and significantly correlated with students’ self-reported gains across several dimensions of learning, such as inquiry and analysis, critical thinking, written and oral communication skills, and quantitative literacy. Because information literacy is necessary for survival in the digital information age, Riehle and Weiner (2013) examined recently published literature concerning five HIPs (capstone experiences, learning communities, service learning and community-based learning, undergraduate research, and writing-intensive courses) to identify how far they improved the integration of information literacy competencies. Faletta et al. (2016) explored ways in which combining carefully selected HIPs in the critical first year of college could benefit students, particularly among traditionally unobserved
student populations, as well as promoting cultural sensitivity and communication with a wider campus audience. Cotten and Thompson (2017) used both quantitative and qualitative data to show that the implementation of HIPs positively influenced the kind of transformative learning that social work programs strive to deliver.

Apart from their close relationship with learning and development gains during college, HIPs also have a long-term effect on students’ post-college careers and economic outcomes (Miller et al., 2017; Wolniak & Mark, 2015). College graduates who are well prepared for the workplace tend to have experienced HIPs showing collaborative problem solving, internships, senior projects, and community engagements (Hart Research Associates, 2013). Soria and Johnson (2017) explored the positive relationships between college students’ participation in HIPs and their self-reported development of leadership skills and multicultural competences.

Recently, research has increasingly focused on the specific effects of HIPs within a particular subject or a sub-population. Stebleton et al. (2013) investigated whether international students’ participation in HIPs is associated with their development of academic skills and academic engagement. Kilgo et al. (2015) used quantitative data from the National Study of LGBTQ Student Success to investigate whether participation in HIPs influenced academic development among lesbian, gay, bisexual, transgender, and queer (LGBTQ+) students. Multidisciplinary and virtualized HIPs are receiving increased attention. University faculties are increasing the use of HIPs by implementing multicourse collaborative research projects among students (Webb, 2019). The modeling of virtual place-based learning has been explored in the context of urban higher education (Lansiquot & MacDonald, 2019). MacDonald (2020) also indicated how the design and application of place-based learning and research in an interdisciplinary course forms a high-impact practice for students.

**HIPs among Chinese undergraduates**

In the context of China, the importance of HIPs has also been widely recognized (e.g., Bao, 2019; Peng & Liu, 2017). It has been shown that these activities stimulate students’ intrinsic learning motivation and enhance their initiative to learn, increasing their academic self-efficacy and clarifying the direction of their career development (Wen et al., 2014). HIPs help undergraduates communicate widely with others, developing their collaborative ability, learning freely, thinking deeply, and experiencing multiculturalism (Xu et al., 2020). For first-generation college students, in particular, universities should take measures to increase participation rates in some HIPs, which could require greater input of their personal resources (Zhang et al., 2017).

While many HIPs exist in both China and the U.S., students in the two countries show different attitudes to different types of HIPs, and a range of new HIPs have emerged in China. From localized surveys and interviews conducted with Chinese college students, the HIPs favored by Americans played a less important role in Chinese students’ learning and development, while other activities, such as learning a new language (Zhang et al., 2017), contributing to academic journals (Wen et al., 2014), obtaining a professional qualification certificate (Han et al., 2014), and joining a student association (Bao, 2019) were considered to be more essential. For Chinese students, educational practices required a wide scope of knowledge-created opportunities for them to discover and solve problems in real-life situations, encouraging them to communicate and cooperate with others from different disciplines under the guidance of instructors. The HIPs favored by Chinese students have a nature in common with American-favored HIPs (Xu et al., 2020) while reflecting the current characteristics of Chinese higher education. Making contributions to academic journals is an excellent example of this. The expansion of enrollment at Chinese universities has intensified competition among Chinese undergraduate students as they enter the postgraduate stage, which has resulted in undergraduates joining the race to publish to bolster their resumes. Working on academic journals thus become a Chinese-favored HIP, and students dedicated themselves to researching specific topics with the help of faculty and their learning community to improve their academic ability and achieving publication.

This difference between the types of HIPs preferred by American and Chinese students clarify that we should not only investigate the common features of HIPs across the country but also focus on various forms of local social-cultural contexts.

**Influential factors in HIP participation**

The factors that influence participation in HIPs can be divided into two broad categories, namely, the individual level and the organizational level. At the individual level, demographic factors influence whether college students adopt HIPs; these factors include race, gender, and family background, such that disadvantaged youth are less likely to participate in activities than their peers. Blacks and Hispanics participate less frequently in some activities, although Blacks participate more frequently in community-based youth programs (Bouffard et al., 2006). The participation of female college students in HIPs is significantly lower than that of males, with the exception of two HIPs with social attributes: attending student associations and doing part-time jobs (Guo, 2019). College students from poor family backgrounds have fewer opportunities and show less initiative to participate in HIPs (Gonyea et al., 2008; Zhang et al., 2017).
On one hand, the lack of family economic capital adds to their financial burden, allowing them to spend time working rather than engaging in extra-curricular educational practices (Prospero & Vohra-Gupta, 2007; Reid & Moore, 2008). Additional factors that are associated with some HIPs, such as the cost of extra-curricular studies or going abroad, also limit the participation of college students from poorer family backgrounds (Choy, 2001). Family cultural capital is also an influential factor in participation in HIPs. First-generation college students are generally less prepared for college life (Lundberg et al., 2007; Warburton et al., 2001) and find it harder to develop beneficial habitus (Deci & Ryan, 2012) from their families than their counterparts whose parents have more educational experience do. Without instruction and support from family members with higher education experience, they participate less in extended learning practices and research-related practices (Zhang et al., 2017).

At the organizational level, college students’ participation behaviors in HIPs are significantly differentiated by grade and discipline (Guo, 2019). College support, such as academic advising (Ellis, 2014) and career counseling services (Bailey et al., 2001; Lian & Shi, 2020) can also improve the participation of college students in HIPs, especially disadvantaged ones (Kilgo et al., 2015; Zhang et al., 2017).

The COVID-19 pandemic is a strong influential factor of recent origin. As our global experience and an unintended challenge for higher education, its impact on college students’ learning and development has been evaluated by various researchers. Temporary home schooling and emergency remote teaching practices during the COVID-19 pandemic have required classes to be moved online, and follow-up lockdown policy has been necessary to combat the COVID-19 pandemic, including as mass quarantine and stay-at-home orders, which have constantly reduced offline interpersonal communication and cooperation (Mishra et al., 2020), including reducing the opportunities for international exchange, investigation, fieldwork, internship and so forth. Scholars from various countries have discussed the effectiveness of online teaching and learning and introduced local actions to support students’ curricular learning in the pandemic and post-pandemic era (e.g., Chu et al., 2021; Fiho, 2020; Wu & Shen, 2020; Xue & Guo, 2020). However, little research has been done regarding the impact of the COVID-19 pandemic on students’ extra-curricular HIPs. HIPs have been more difficult to implement since the onset of the COVID-19 pandemic, as they have always required students to communicate and even collaborate with classmates and professors about meaningful topics and been intended to expose students to diverse ideas and people of different backgrounds (Kuh, 2008).

This study compares participation in HIPs between Chinese and American undergraduates under the impact of the COVID-19 pandemic. In particular, it examines participation in three types of high-impact practices: (1) social practices, (2) extended learning practices, and (3) research-related practices, in both China and America, before and after COVID-19. Social practices refer to those activities that require students to apply knowledge to realistic contexts outside of college and that enhance students’ experience in the society. Research-related practices refer to the performance of research based on students’ knowledge both within and beyond the classroom. The participants in this HIP show a strong academic motivation to engage, and the faculty provides regular guidance. Extended learning practices include in-depth or interdisciplinary learning that goes beyond the normal professional curriculum requirements.

**Conceptual framework**

This study is based on a conceptual framework with HIP patterns developed by Zhang et al. (2017). This comprehensive model, widely used in many subsequent studies (e.g., Hua, 2022; Lu & Jia, 2022), classifies various individual practices into three HIP types: social practices, research-related practices, and extended learning practices. Social practices include service learning, internship, social practice or field investigation, and attending student associations. Research-related practices include doing research with teachers, contributing to professional academic journals or conferences, and taking part in academic or design competitions. Extended learning practices refer to overseas study, a second bachelor’s degree, learning another language, and obtaining professional certificates.

The level of participation in all these HIPs is influenced by factors at the individual and organizational levels. However, the participation threshold of these three HIP types varies in terms of their respective requirements for the individual’s background and the supportive conditions provided by the colleges. The requirements for individual backgrounds include personal demographic characteristics, knowledge, skills, and how many resources the individual can input. College support refers to participation opportunities and a supportive environment at the specific college. The study developed a research framework as shown in Fig. 1. Of the three types, extended learning practices require more economic investment, and participant opportunities outside school mainly rely on the capitals from students’ families rather than from colleges. Research-related practices require that the participant have a strong willingness to participate and solid previous knowledge while the college and the faculty can provide guidance and feedback and even create opportunities for participation by organizing academic competitions. Social practices have few requirements for students’ own
high-impact educational practices: participation of Chinese and American undergraduates…

The COVID-19 pandemic represents a non-negligible, new, and influential external shock on participation in HIPs. To contain the spread of the coronavirus, people have been encouraged to minimize outdoor social contact; some colleges have even implemented exclusively online learning or learning supplementation, while some schools have been closed, all of which directly reduce participation opportunities for all these three HIP types. In addition to this kind of direct influence, inequalities have been magnified between learners, institutions, and countries in response to the pandemic (Kara, 2021). As Andreas Schleicher (2020), the director of the OECD Directorate for Education and Skills, noted, colleges are experiencing difficulty in providing student support as usual under these circumstances, and this crisis amplifies inequities between students from privileged backgrounds and disadvantaged students, such as first-generation college students. The impact of COVID-19 on HIPs participation is well worth exploring, as is its interactive effect on students’ backgrounds and a supportive college environment on HIPs. To be specific, the study proposes two hypotheses in the analysis of the impact of the COVID-19 pandemic to address research question 2:

**Hypothesis 1**: The COVID-19 pandemic decreased college students’ participation in HIPs.

**Hypothesis 2**: The COVID-19 pandemic moderated the effect of first-generation college students and a supportive college environment on participation in HIPs.

By testing these two hypotheses, we provide empirical evidence that contributes to the expansion of the conceptual framework of high-impact practices for college students in the post-pandemic era.

---

**Research design**

**Data and samples**

We use data from the China College Student Survey (CCSS) 2018–2021 and published data from the NSSE 2021 Multi-Year Report. The CCSS is an annual survey conducted by the Institute of Education and Tsinghua University adapted from the NSSE (Luo et al., 2009), both of which are annual surveys of college students’ learning and engagement. A two-stage stratified sampling strategy is used by CCSS to guarantee that samples are representative of the population of college students in Mainland China. The average response rate to the survey is 69.31%. Post-stratification sampling weighting is used to adjust for the uneven probability of being sampled. From 2018 to 2021, 302,500 students (51.20% female, 48.40% male) from 57 colleges were randomly selected for and participated in the survey. For the NSSE, the published data included 505 (2018), 534 (2019), 704 (2020), and 521 (2021) valid samples. The average response rate was 34.5%. All the results for NSSE are unweighted due to nonstandard population file or survey administration.

**Method**

We use descriptive statistics to compare timely trends and differences in HIP participation among undergraduate students in the U.S. and China before and after the onset of the COVID-19 pandemic. Adopting a theoretical framework, we enrich HIPs and divide them into three categories, according to three indicators: social practices, extended learning practices, and research-related practices (the items are shown in the following results). Participation in the three HIP types by first-year and senior students in the two countries was obtained using a four-level scale (Done or in progress, Plan to do, Do not plan to do, and Have not decided), which was the same across both the CCSS and the NSSE from 2018 to 2021.

The following model is used to examine the effects of COVID-19 on HIP participation, in addition to determining whether a supportive college environment and students’ backgrounds play the same role before and after COVID-19 in getting students into a high-impact educational experience. Specifically, we estimate the following model to examine Hypotheses 1 and 2.

\[
HIP_i = a_0 + \beta_0 \text{Cohort\_year}_i + \beta_1 \text{SCE}_i + \beta_2 \text{COVID}_i + \beta_3 \text{FG}_i + \beta_4 \text{Control}_i + \epsilon_i
\]
where the dependent variable HIP, refers to participation in the specific HIP. Among the independent variables, Cohort_year, is a series of year dummy variables, with 1 indicating being surveyed in 2019, 2020, or 2021, respectively, based on being surveyed in 2018. SCE represents how supportive the environment that the students experience is, measured on a 4-point Likert scale, and COVID-19, is a dummy variable, with 1 indicating the presence of the COVID-19 pandemic and 0 indicating before the onset of the pandemic. The selected key explanatory variable for students’ backgrounds indicates whether they are in the first generation of college students in their families because, in China, such students form a representative disadvantaged group that has drawn much social solicitude (Bao, 2015; Lu & Hu, 2015; Zhang et al., 2016). In addition, other students’ background factors, including family income and parents’ occupation, are controlled. Control indicates a set of covariates, including the above-mentioned students’ family backgrounds, educational experience before college, and college characteristics. The definition and descriptive statistics of the variables are presented in Table 3 in the Appendix.

The model is estimated via logistic regression. The estimate of $\beta_0$ in the model indicates an overall year gap in access to HIP. Hypothesis 1 is supported if the odds ratio of students participating in HIPs after the onset of COVID-19 is significantly lower than it is for the 2018 results. The estimates of $\beta_2$ in the model show whether a supportive college environment influences the opportunity to participate in the HIP in a different way before and after COVID-19 across the whole sample. Estimates of $\beta_4$ show changes in influences of the identity of first-generation college students on participating in HIPs caused by COVID-19. Hypothesis 2 is supported if $\beta_2$ and $\beta_4$ are significant. Sampling weights are applied in regressions.

### Results

#### Trends in HIP participation in the U.S. and China

Participation in HIPs is shown in Table 1, and the trend over time in the three types is shown in Fig. 2. For social practices, service learning and internships or field experiences are investigated in NSSE, while student association was also included by CCSS in 2021. Students’ participation rate in social practices decreased after the COVID-19 epidemic. In China, this rate constantly dropped from 72% in 2018 to 52% in 2021. Participation in the U.S. increased slightly to 71% in 2021 relative to 67% in 2020, while it was lower than the participation rate before the COVID-19 epidemic (80% in 2018 and 73% in 2019).

Research-related practices include conducting research with the faculty, participating in a culminating senior experience, and joining up the learning community in NSSE. American seniors participated in research-related practices were at around 47% prior to 2021 but fell to 42% that year. Chinese students do not tend to have culminating senior experience; instead, they take part in competitions and contribute to academic journal writing as research-related practices. An apparent increase was seen from 28% in 2020 to 39% in 2021, but this was still lower than the rate of participation among American students.

Extended learning practices included studying abroad (tracked by both surveys) and learning a new language, and obtaining a second degree, and a certification (only tracked by the CCSS). Participation decreased significantly after the onset of the COVID-19 pandemic in both the U.S. and China.

### Table 1 Seniors’ participation rate (%) in HIPs

| Types of HIPs                | NSSE 2018 | NSSE 2019 | NSSE 2020 | NSSE 2021 | CCSS 2018 | CCSS 2019 | CCSS 2020 | CCSS 2021 |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Social practices            |           |           |           |           |           |           |           |           |
| Service learning            | 89        | 85        | 82        | 82        | 61        | 62        | 56        | 55        |
| Internship or field experience | 70        | 61        | 52        | 60        | 76        | 74        | 67        |           |
| Student association         |           |           |           |           |           |           |           |           |
| Research-related practices  |           |           |           |           |           |           |           |           |
| Research with faculty       | 29        | 35        | 41        | 29        | 31        | 29        | 25        | 32        |
| Culminating senior experience | 81        | 84        | 86        | 62        |           |           |           |           |
| Learning community          | 27        | 23        | 19        | 36        | 52        | 53        | 46        |           |
| Competition                 |           |           |           |           | 31        | 29        | 31        | 45        |
| Contributing to academic journals |           |           |           |           | 15        | 14        | 11        |           |
| Extended learning practices |           |           |           |           |           |           |           |           |
| Study abroad                | 21        | 25        | 29        | 15        | 7         | 6         | 5         | 8         |
| Second degree               |           |           |           |           | 8         | 6         | 5         | 8         |
| Non-native languages        |           |           |           |           | 21        | 20        | 18        |           |
| Obtaining certificates      |           |           |           |           | 57        | 60        | 57        |           |

Types of HIPs are drawn from Zhang et al. (2017)

“/” represents the participation rate of this practice that is not collected this year.
Typical HIP activities participation

Service learning, conducting research with faculty, and studying abroad were observed in both investigations from 2018 to 2021, which can be regarded as typical activities of these three types of HIPs. Figure 3 shows levels of participation across these three educational practices. American senior students outperform Chinese seniors in service learning (82–89% versus 55–62%) and studying abroad (15–29% versus 5–8%), but Chinese students have a superior rate of doing research with faculty (returning to pre-pandemic levels of 29% in 2021 but still 3% lower than rates in China). The participation of first-year undergraduates was lower than that of seniors due to the lack of college experience in both countries, especially with respect to doing research with faculty.

It is worth noting the difference between the willingness of first-year students to participate and seniors’ actual participation status in studying abroad. 42%–49% of first-year students had initially planned to study abroad during their time at college, but only 15–29% of seniors eventually did so. In China, the opportunity to study abroad is even rarer: 24–34% of first-year students planned to do this, but only 5–8% of seniors accomplished it.

Effect of COVID-19 on HIP participation

To explore why one student may have a HIP experience and another may not, this paper uses logistic regression to estimate the influential factors in the above three activities across grades in China, the results of which are shown in Table 2.

The COVID-19 epidemic has had a significant influence on HIP participation among college students, and Hypothesis 1 was supported by the results. After 2019, the odds of participation in these three practices are lower results in others and all senior results are the percentages who actually achieved the activity during their time in college until being surveyed.
Table 2 Logistic results

| Survey year (based on 2018) | Service learning Odds ratio/se | Research with faculty Odds ratio/se | Study abroad Odds ratio/se |
|----------------------------|---------------------------------|-------------------------------------|---------------------------|
| 2019                       | 1.038*                          | 0.936*                              | 0.887*                    |
|                            | (0.021)                         | (0.025)                             | (0.046)                   |
| 2020                       | 0.682**                         | 0.805                               | 0.133**                   |
|                            | (0.044)                         | (0.106)                             | (0.024)                   |
| 2021                       | 0.823**                         | 0.856                               | 0.214**                   |
|                            | (0.052)                         | (0.077)                             | (0.037)                   |
| SCE                        | 1.022**                         | 1.022**                             | 1.010**                   |
|                            | (0.001)                         | (0.001)                             | (0.002)                   |
| COVID-19*SCE               | 1.002*                          | 1.003**                             | 1.019**                   |
|                            | (0.001)                         | (0.011)                             | (0.002)                   |
| First-generation           | 0.985                           | 1.010                               | 0.657**                   |
|                            | (0.023)                         | (0.033)                             | (0.043)                   |
| COVID-19*first-generation  | 1.031                           | 0.998                               | 0.871                     |
|                            | (0.037)                         | (0.051)                             | (0.095)                   |
| Female                     | 1.471**                         | 1.111                               | 0.772**                   |
|                            | (0.021)                         | (0.022)                             | (0.027)                   |
| Ethnic minority            | 0.849**                         | 0.807**                             | 0.756**                   |
|                            | (0.019)                         | (0.026)                             | (0.046)                   |
| Rural                      | 1.001                           | 0.927**                             | 0.766**                   |
|                            | (0.015)                         | (0.019)                             | (0.029)                   |
| Family income              | 1.000                           | 1.000**                             | 1.000**                   |
|                            | (0.000)                         | (0.000)                             | (0.000)                   |
| Parents’ career            |                                 |                                     |                           |
| Common occupation          | 0.949*                          | 1.074**                             | 1.186**                   |
|                            | (0.019)                         | (0.029)                             | (0.066)                   |
| Manager                    | 0.936*                          | 1.234**                             | 1.997**                   |
|                            | (0.024)                         | (0.043)                             | (0.129)                   |
| High school                | 1.003**                         | 1.005**                             | 1.006**                   |
|                            | (0.000)                         | (0.000)                             | (0.001)                   |
| Leader in high school      | 1.202**                         | 1.350**                             | 1.834**                   |
|                            | (0.017)                         | (0.026)                             | (0.057)                   |
| NCEE score(std)            | 1.131**                         | 0.997                               | 1.040*                    |
|                            | (0.009)                         | (0.011)                             | (0.019)                   |
| Grade (based on first year)|                                 |                                     |                           |
| Second year                | 1.475**                         | 3.060**                             | 1.462**                   |
|                            | (0.026)                         | (0.091)                             | (0.071)                   |
| Third year                 | 1.587**                         | 3.958**                             | 1.959**                   |
|                            | (0.028)                         | (0.115)                             | (0.090)                   |
| Fourth year                | 1.786**                         | 6.426**                             | 2.873**                   |
|                            | (0.036)                         | (0.195)                             | (0.135)                   |
| Enter Type (based on GaoKao)|                                 |                                     |                           |
| Recommended                | 0.912                           | 1.889                               | 3.066**                   |
|                            | (0.219)                         | (0.664)                             | (0.754)                   |
| Independent enrolment      | 0.797**                         | 0.827**                             | 1.048                     |
|                            | (0.034)                         | (0.051)                             | (0.096)                   |
| Independent enrollment but not use | 0.783   | 3.246**                             | 1.569                     |
|                            | (0.211)                         | (1.126)                             | (0.714)                   |
| Strengthening foundation plan | 0.800                           | 0.669                               | 1.645                     |
|                            | (0.246)                         | (0.293)                             | (0.770)                   |
each year than the rates in 2018, given the same students’
personal characteristics and college characteristics. The
rate of participation in service learning was 31.8% lower
in 2020 and 17.7% lower in 2021. The magnitudes of the
effects on study abroad were even larger, ranging from
86.7% (in 2020) lower to 78.6% lower (in 2021).

In addition, the significant interaction term between
COVID-19 and SCE (Support of Campus Environment, which
means materials, facilities, service and culture on campus
which can benefit and support students) showed the influence
of COVID-19 in different supportive college environments.
The level of college support felt by students improved their
participation in service learning (102.2%, \(p < 0.001\)), research
with faculty (102.2%, \(p < 0.001\)), and study abroad (101%
, \(p < 0.001\)), but COVID-19 strengthened the level of influ-
ence of supportive college environment significantly. First-
generation college students participated significantly less in
study abroad than non-first-generation college students (65.7%
, \(p < 0.001\)), but this gap was not influenced by the COVID-19,
as shown by the non-significant interaction term. Hypothesis
2 was partly supported by the results.

### Table 2 (continued)

|                                | Service learning | Research with faculty | Study abroad |
|--------------------------------|------------------|-----------------------|--------------|
|                                | Odds ratio/se    | Odds ratio/se         | Odds ratio/se |
| Rural special plan             | 1.137**          | 0.835**               | 0.686**      |
| Special talent in arts or sports| 0.837**          | 1.101                 | 0.954        |
| Early approval                 | 0.824**          | 0.668**               | 1.014        |
| International project          | 0.745            | 0.768                 | 2.131*       |
| Major Area (based on Humanity) |                  |                       |              |
| Social science                 | 1.227**          | 1.205**               | 0.849**      |
| Science                        | 1.095**          | 2.623**               | 0.614**      |
| Engineering                    | 1.115**          | 2.023**               | 0.755**      |
| instType                       |                  |                       |              |
| 211 colleges                   | 0.884**          | 1.009                 | 0.830**      |
| 985 colleges                   | 1.239**          | 1.275**               | 1.207**      |
| SD                             | 1.002**          | 1.004**               | 1.013**      |
| Constant                       | 0.093**          | 0.004**               | 0.005**      |
| Observations                   | 302,498          | 302,498               | 302,509      |
| Pseudo \(R^2\)                | 0.053            | 0.107                 | 0.115        |

Robust standard errors in parentheses; **\(p < 0.01\), *\(p < 0.05\)

### Discussion

**Differences in participation in HIP types**

The time trends in the HIP participation of Chinese and
American students showed some common features. It is
clear that social practice participation was greater than in
research-related and extended learning activities. The result
was also similar to existing studies (e.g., Zhang et al., 2017;
Liu, 2020). Some studies have been conducted on the dif-
ferences between the three types of HIPs in terms of the
dependence on resource inputs and students’ knowledge
and ability requirements. Relative to social practice activi-
ties, extended learning activities can be influenced by stu-
dents’ backgrounds and require more financial support. For
example, with reference to language study beyond course
requirements and studying abroad, students are required to
have sufficient financial support and the opportunity to par-
ticipate. The amount of support that schools can provide is
relatively low, due to their reduced resources. Meanwhile,
research-related activities have more stringent conditions for
participation, such as a higher levels of personal ability and a certain level of expertise. For these two activities, many opportunities for participation are competitively available, and additional support and guidance from families are particularly important. Compared with certain research-related practices and extended learning practices, the demand for participation in social practices is relatively low. Activities such as service learning have become a compulsory part of students’ development work at some colleges and universities, and schools require and encourage students to participate in such activities and provide them considerable support to enable their participation.

The results indicate that more pertinent help and support are needed. Colleges must provide support and opportunities for disadvantaged students (including first-generation college students, who are in a disadvantageous position due to their family backgrounds). Teachers could also show more attention to them and to enhance the interaction with students on substantive matters, typically over long periods of time (AAC&U, 2008). In the context of home schooling, during the COVID-19 pandemic, universities and teachers have the chance to innovate teaching pedagogies and enrich their extra-curricular activities to increase all types of student participation in HIPs. The most interesting results of the data analysis also support the deduction that the COVID-19 pandemic did not exacerbate the difficulties of first-generation college students in terms of their participation in HIPs. One possible explanation for this is that participating in HIPs leads to additional requirements in terms of students’ backgrounds, and the onset of the pandemic did not change the requirements for student antecedents. A more likely explanation is that the COVID-19 pandemic sped up the digital transformation of HIPs in a fairer direction, moderating the negative impacts. In the post-pandemic era, virtual events eliminate geographical barriers and successfully motivated a larger audience while improving multicultural communication. In addition, a large number of open and free resources in the network reduced the costs for students in obtaining relevant resources. Some universities have made attempts to show that virtual activities have also achieved good results. For example, a university in Hong Kong held a series of learning activities including flight simulation and virtual tours for 35 undergraduate aviation students (Ng, 2022a). Although these activities are virtual and take place online, they have also been proven to effectively motivate students to learn about aviation and improve their aviation knowledge, both cognitively and socially, which likely played a similar role to realistic research-related practices. In addition, it gives them the chance to connect with other students in Mainland China to enjoy online flight simulation in a supportive learning environment. From this perspective, the connotation HIPs were enriched in the period of the COVID-19 pandemic.

Features across cultures in typical activities

As shown in Fig. 2, Chinese and American college students’ participation in typical HIPs shows both similarities and differences. In general, China and the U.S. present similar trends. First, participation in service learning occurs at a much higher rate than research with faculty among both first-year students and senior students. This observation is in line with our usual perceptions, as service learning is relatively easier to participate in, while doing research with faculty is more difficult, especially for first-year students. The same trend is shown in the comparison between social practice and extended practice. It is encouraging to see the growth in service learning and research with faculty between 2018 and 2021 after four years of study on campus in the two countries, especially in the ratio of those doing research with faculty. This shows that both Chinese and American research universities recognize the importance of promoting faculty-student interactions.

Second, it was found that the actual number of people who go abroad is much lower than the number of those who intend to go abroad in their first year. This is not entirely explained by epidemic factors. In 2020, because China had a strict pandemic-mitigation policy in place, it can easily be understood why fewer Chinese students go abroad for exchange, but the number who did rose in 2021. It is also difficult to explain the changes in American universities, as the drop appeared in 2021, not 2020. A plausible conjecture that would explain the variation but not the change is that the college offers insufficient opportunities for international communication, especially for Chinese colleges. Students have too few opportunities and resources to study abroad, suggesting that the majority of institutions may lack an international atmosphere. Colleges and universities should set up an international concept of school running, strengthen teachers’ international development, expand the scale of international training of students, and promote international exchange and cooperation.

Some differences appeared in this study. First, over 75% of American respondents did service learning during their first year, but only 35–46% of Chinese students reported the same. This shows that American universities place additional emphasis on involving students in community service beginning in their first year. Participation in community affairs is an excellent opportunity to develop students’ citizenship, which deserves to be learned in Chinese universities. Second, the difference in research with faculty in 2020 and 2021 is worth exploring. From 2020 to 2021, the proportion of U.S. seniors researching with faculty decreased by 12% but increased by 17% in China. This may result from the differences in curriculum arrangement. After suspending school opening for the new semester in 2020, the Ministry of Education in China launched the initiative entitled “Ensuring
Learning Is Undisrupted When Classes Are Disrupted.” Chinese universities reacted rapidly and shifted all coursework education online. Online teaching forced faculty to increase their interaction with students to enable all of them to concentrate (Liu et al., 2020), possibly increasing research collaboration as a result. A study in Hong Kong used multiple case analyses to indicate that meaningful cognitive activities rely on teachers’ leading role to build a blended model of asynchronous and synchronous learning as an effective tool of pedagogy that allows learners flexibility, autonomy, and opportunities to socialize with each other, which can be applied at any education level, and to offer learning and teaching as usual after the COVID-19 pandemic (Ng et al., 2020). These cases also prove that although the COVID-19 pandemic had a negative impact on students’ autonomous and cooperative learning and decreased students’ HIPs participation rate, their adverse impact can be addressed by renewing teaching strategies and allowing teachers to assume a leading role.

**COVID-19 decreased HIP participation in China**

The most obvious issue is the low rate of HIPs participation after COVID-19, including social practices and extended practices. This is closely related to the Chinese pandemic-mitigation policy. On the one hand, it limited students’ free movement from one province to the other; on the other, the recurrence of the epidemic has resulted in certain practical activities that would otherwise normally be done offline to be taken online. Concerns about the epidemic have also discouraged many people from studying abroad, naturally reducing participation in extended learning activities.

A deeper analysis shows a moderating effect of the COVID-19 pandemic on the institution’s support for HIPs. The lower the institutional support, the lower the possibility for students to participate in HIPs, and vice versa. In other words, the pandemic amplified the impact of institutional support on participation in high-impact educational activities. This indicates that additional attention should be paid to the important role of institutional support in the post-epidemic era, and universities must build a more supportive environment to mitigate the negative effects of COVID-19. Some universities’ reforms have proven this point. Interviews with teachers have shown how their investments in new technological equipment and knowledge to support the digital transformation could effectively enhance students’ knowledge and motivation gain both in Hong Kong and in Mainland China during the lockdown (Ng, 2022b). Universities can develop and design online informal learning, improved laboratory settings (for engineering subjects), and academic exchange to enhance HIP participation among students.

**Conclusion**

This study examines the impact of the COVID-19 pandemic on undergraduate participation in HIPs, comparing the horizontal differences between China and the U.S., and summarizing the longitudinal features from 2018 to 2021. It was found that: (1) social practice participation was greater than research-related and extended learning activities in both China and the U.S. from 2018 to 2021; (2) there were both similarities and differences in the participation of typical HIPs in China and the U.S. The participation of first-year undergraduates was lower than that of seniors because of the lack of college experience in both countries, especially in terms of doing research with faculty. However, American seniors participated more in the other two typical HIPs, service learning and studying abroad, than Chinese seniors. The proportion of students who studied abroad during their final year is lower than that who plan to study abroad in the first year, especially in China, due to the lack of opportunities for international exchange; (3) in China, the COVID-19 pandemic amplified the impact of institutional support on students’ participation in HIPs. This study provides a cross-cultural comparative perspective for a deeper understanding of the learning characteristics and behavioral traits of Chinese undergraduates in HIPs, as well as a more objective perspective with large, immediate data.

This study had certain limitations. Above all, the open report of the NSSE survey was the only source of the limited American data and information with unweighted samples due to nonstandard population files or survey administration. Thus, we were only able to use the Chinese data to estimate the impact of the COVID-19 pandemic on HIPs participation. In addition, in the post-COVID-19 scenario, the definition of HIPs may have changed with the use of online learning technologies in an online environment. There is a difference in the definition of HIPs between the two countries. This may be a potential area of future research and collaboration. HIP measurements should be made more accurate in future surveys. In addition, due to limitations of space, we do not discuss effective countermeasures for this impact. Although we did produce one important finding, that the COVID-19 pandemic amplified the impact of institutional support on the participation of the undergraduates in HIPs, a full discussion of how educational institutions can offer more support remains to be performed in future research.

**Appendix**

See Table 3.
| Variable                  | Definition and measurement                                                                 | M(SD)/%          | Missing rate (%) |
|--------------------------|-------------------------------------------------------------------------------------------|------------------|------------------|
| **Dependent variables**  |                                                                                          |                  |                  |
| HIPs                     | Whether participate in this HIP                                                           |                  |                  |
| Service learning         | Binary: 1 = Yes, 0 = No                                                                   | 53.07% 0.01      |                  |
| research with faculty    | Binary: 1 = Yes, 0 = No                                                                   | 18.72% 0.01      |                  |
| study abroad             | Binary: 1 = Yes, 0 = No                                                                   | 5.03% 0.01       |                  |
| **Key explanatory variables** |                                                                                   |                  |                  |
| Survey Year              | Survey year                                                                               |                  |                  |
|                          | Categorical: 1 = 2018, 2 = 2019, 3 = 2020, 4 = 2021                                       | 20.28% 0         | 23.50% 20.31% 35.90% |
| SCE                      | Supportive campus environment, constructed with self-reported scores on college environment, resources, and satisfaction (8 items, Cronbach’s alpha = 0.80) | 73.45(17.83) 0   |                  |
| First-generation         | Whether one of the students’ parents has once got higher education                       | 27.27% 0         |                  |
| COVID-19                 | Whether undertake the COVID-19 epidemic                                                   | 56.21% 0         |                  |
| **Covariates**           |                                                                                          |                  |                  |
| Individual level         |                                                                                          |                  |                  |
| Female                   | Gender                                                                                    | 48.79% 0.02      |                  |
|                          | Binary: 1 = Female, 0 = Male                                                              | 51.18%           |                  |
| Ethnic minority          | Ethnicity                                                                                 | 9.60% 0.02       |                  |
|                          | Binary: 1 = Ethnic Minority, 0 = Han                                                      | 90.38%           |                  |
| Rural                    | Region of origin                                                                          | 46.71% 0.5       |                  |
|                          | Binary: 1 = Rural, 0 = City                                                               | 52.78%           |                  |
| Family Income            | ln(Family Income)                                                                        | 0.00(0.00) 0     |                  |
|                          | Continuous                                                                                |                  |                  |
| Parents’ career          | Parents’ highest occupation level                                                        | 14.56% 0.14      |                  |
|                          | Categorical: 1 = No job, 2 = Common occupation, 3 = Manager                              | 63.71% 21.58%    |                  |
| High school              | How difficult does the student feel it was to attend his or her high school               | 58.16(31.62) 0   |                  |
|                          | Continuous scale: 1–100                                                                   |                  |                  |
| Leader in high school    | Whether the student was a student leader in high school                                   | 30.58% 0.02      |                  |
|                          | Binary: 1 = Yes, 0 = No                                                                   | 69.40%           |                  |
| NCEE Score(std)           | Standard GaoKao score by province, exam year, and subject                                | 0.04(0.85) 0     |                  |
|                          | Continuous                                                                                |                  |                  |
| Organizational level     |                                                                                          |                  |                  |
| Grade                    | Year in college                                                                           | 28.22% 0         |                  |
|                          | Categorical: 1–4 = year 1–4                                                               | 27.24% 26.89% 17.66% |                  |
| Enter Type               | Whether benefit from special GaoKao policies                                             | 86.54% 0.03      |                  |
|                          | Recommended, binary: 1 = Yes, 0 = No                                                      | 0.28%            |                  |
|                          | Independent enrollment, binary: 1 = Yes, 0 = No                                           | 3.04%            |                  |
|                          | Independent enrollment but not use, binary: 1 = Yes, 0 = No                               | 0.05%            |                  |
|                          | Strengthening foundation plan, binary: 1 = Yes, 0 = No                                    | 0.04%            |                  |
|                          | Rural special plan, binary: 1 = Yes, 0 = No                                               | 4.13%            |                  |
|                          | Special talent in arts or sports, binary: 1 = Yes, 0 = No                                | 3.32%            |                  |
|                          | Early approval, binary: 1 = Yes, 0 = No                                                   | 1.49%            |                  |
|                          | International project, binary: 1 = Yes, 0 = No                                            | 1.09%            |                  |
Table 3 (continued)

| Variable | Definition and measurement | M(SD)% | Missing rate (%) |
|----------|----------------------------|--------|-----------------|
| Major area | Area of an academic major in college | 11.13% | 6.09 |
| | Categorical: 1 = Humanities, 2 = Social sciences, 3 = Sciences, 4 = Engineering | 24.11% |
| | | 15.87% |
| | | 42.79% |
| instType | Institute level | 89.68% | 0 |
| | Categorical: 1 = Common college, 2 = 211 Project college, 3 = 985 Project college | 7.02% |
| | | 3.31% |
| Other | Social desirability | 51.78(23.21) | 0 |
| SD | Continuous scale: 1–100 |

**Funding**  This work was supported by Tsinghua University Initiative Scientific Research [Grant Number 2021THZWJC22].

**Declarations**

**Conflict of interest**  We declare that the data collection methods used in this study were approved by the Tsinghua University’s ethics committee. We have no financial or personal relationships with other people or organizations that could inappropriately influence our work, and we have no professional or other personal interest of any nature in any product, service, and/or company that could be construed as influencing the research presented in or the review of the manuscript.

**References**

Andreas, S. (2020). How can teachers and school systems respond to the COVID-19 pandemic? Some lessons from TALIS. Retrieved March 23, 2020, from https://oecdORIZEDay.com/howteachers-school-systems-respond-coronavirus-talis.

Association of American Colleges & Universities (AAC&U). (2007). College learning for the new global century: A report from the National Leadership Council for Liberal Education & American’s Promise (LEAP). AAC&U.

Association of American Colleges & Universities (AAC&U). (2008). High-impact educational practices. AAC&U.

Astin, A. W. (1993). What matters in college? Jossey-Bass.

Bailey, T., Badway, N., & Gumport, P. (2001). For-profit higher education and community colleges. National Center for Postsecondary Improvement.

Bao, W. (2019). Bridging the gap between research and practice: Identifying high-impact educational practices for Chinese undergraduate education. *Peking University Education Review, 17*(03), 105–129+190. in Chinese.

Bao, W., & Chen, Y. (2015). The effects of different financial aid patterns on the academic development of rural first generation college students. *Peking University Education Review, 13*(02), 80–96+190. in Chinese.

Bouffard, S., Wimer, C., Caronongan, P., Little, P., Dearing, E., & Simpkins, S. (2006). Demographic differences in patterns of youth out-of-school time activity participation. *Journal of Youth Development, 1*(1), 24–40. https://doi.org/10.5195/jyd.2006.396

Brownell, J., & Swarer, L. (2010). Five high-impact practices. Association of American Colleges and Universities.

Chickering, A. W., & Gamson, Z. F. (1991). Seven principles for good practice in undergraduate education. In A. W. Chickering & Z. F. Gamson (Eds.), *Applying the seven principles for good practice in undergraduate education* (pp. 63–69). Jossey-Bass.

China Daily. (2022). Latest on COVID-19 pandemic. Retrieved 11 August, 2022, from https://www.chinadaily.com.cn/a/202208/29/WS629c30b3a310d229e60bca.html

Choy, S. P. (2001). Students whose parents did not go to college: postsecondary access, persistence, and attainment. U.S. Department of Education, National Center for Educational Statistics.

Chu, M. Y., Liu, K. W., So, K. P., & Lam, S. Y. (2021). Factors for sustainable online learning in higher education during the covid-19 pandemic. *Sustainability, 13*, 5038.

Cotten, C., & Thompson, C. (2017). High-impact practices in social work education: A short-term study-abroad service-learning trip to Guatemala. *Journal of Social Work Education, 53*, 4, 622–636.

Deci, E. L., & Ryan, R. M. (2012). Motivation, personality, and development within embedded social contexts: An overview of self-determination theory. In R. M. Ryan (Ed.), *The oxford handbook of human motivation* (pp. 85–107). Oxford University Press.

Ellis, K. (2014). Academic advising experiences of first-year undecided students: A qualitative study. *NACADA Journal, 34*(2), 42–50. https://doi.org/10.12930/nacada-13-001

Faletta, J. P., Meier, J. A., & Balderas, J. U. (2016). High-impact practices: Integrating the first-year experience with service-learning and study abroad. In *Handbook of research on effective communication in culturally diverse classrooms* (pp. 337–355). IGI Global.

Farrow, C. B., Wetzel, E., & Leathem, T. (2021). An initial investigation of student experiences with the elements of high impact educational practices. *37th Annual Associated Schools of Construction International Conference.*

Gao, J., & Zhang, P. (2021). China’s public health policies in response to COVID-19: From an “authoritarian” perspective. Retrieved 11 August, 2022, from https://doi.org/10.3389/fpubh.2021.756677/full

Gonyea, R. M. (2008). High-impact activities: What they are, why they work, and who benefits. Presentation at the Annual Meeting of the Association of American Colleges and Universities (AAC&U), Washington, DC.

Guo, J. (2019). The match between high impact practices and post-graduation goals of undergraduates: based on the 2019 China college teaching & learning survey. *Research in Educational Development, 39*(23), 18–26. in Chinese.
Wen, W., Jing, C., & Jinghuan, S. (2014). On high-impact educational practices in Chinese “985” Universities. *Journal of Higher Education, 35*(08), 92–98. in Chinese.

White, A. (2018). Understanding the university and faculty investment in implementing high-impact educational practices. *Journal of the Scholarship of Teaching and Learning, 18*(2), 118–135.

Wolniak, G. C., & Engberg, M. E. (2015). The Influence of “High-Impact” College Experiences on Early Career Outcomes. 2015 AERA Annual Meeting, April, 2015.

Wu, D., & Shen, Z. (2020). Rational thinking of online teaching in Chinese Universities——Based on the empirical investigation of 6 undergraduate colleges. *Education Science, 36*(02), 1–8. in Chinese.

Xu, D., Lv, L., & Fu, D. (2020). On the characteristics of high-impact educational practices for undergraduates in China research universities. *Journal of Higher Education, 41*(02), 58–65. in Chinese

Xue, C., & Guo, Y. (2020). Reflections and recommendations on the reform of online teaching reform in universities. *Journal of East China Normal University Educational Sciences, 38*(07), 65–74. in Chinese.

Zhang, H., Zhao, L., & Guo, F. (2016). A portrait of first-generation college students in China: an analysis based on the China College Student Survey. *Tsinghua Journal of Education, 37*(06), 72–78+94. in Chinese.

Zhang, H., Guo, F., & Shi, J. (2017). On improving first-generation college students’ participation in high-impact educational practices. *Education Research, 38*(06), 32–43. in Chinese.

**Publisher’s Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.