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Progression from Chinese High School onto a TransNational Chinese-UK University joint BSc degree in chemistry; an international study focussing on laboratory practical skills

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An investigation was carried out into laboratory practical skills development and students' specific challenges in transition from laboratory chemistry at Chinese High School (HS) to a fully English style university laboratory course. To the best of our knowledge this is the first study of its type investigating practical laboratory skills for a TransNational Education (TNE) Chemistry BSc (3 + 1) degree programme between the United Kingdom (UK) and the People's Republic of China (PRC). Internationalization of such courses have become popular in recent years. The two universities in this study are Nanjing Tech University (NJTech) and the University of Sheffield (UoS). Our study is exploratory with the aim to determine the level of practical laboratory skills the NJTech students gained from High School and the challenges they encountered as they joined a UK degree laboratory programme delivered in English. For this international study, a mixed-methods approach was followed using qualitative inductive and deductive methodologies. Using open-ended questions it was found that particular challenges in the transition were around the lack of prior laboratory experience and the development of many new skills, laboratory notebook documentation, laboratory safety, and studying laboratory chemistry in a second language. Students welcomed these challenges and felt they were developing into professional chemists. Specific recommendations are made for international TNE degrees with laboratory programmes, particularly for those students who progress from Chinese High School through the Chinese GaoKao system into a western university chemistry laboratory programme. The scaffolded/structured curriculum design allowed for total and successful integration of the NJTech with the Sheffield home students during the final year of their BSc in Chemistry. After graduation, having gained high class degrees and becoming fluent in English many of the students progressed into Industry, and onto Masters or PhD programmes in the UK and throughout the world, suggesting internationalisation of students on our TNE programme was successful.

Introduction

Theoretical approaches

Internationalisation through Transnational Education (TNE) for undergraduate BSc degree courses has become popular during the last 15 years. (Cuiming *et al.*, 2012; Fang and Wang, 2014, Bovill *et al.*, 2015). Many students from the Peoples Republic of China (PRC) have started to consider these courses as an alternative to studying in their home country. Gaining a BSc through a TNE course allows for different study options with a variety of packages such as (3 + 1) or (2 + 2) degrees (Peelo and Luxon, 2007, Cranwell *et al.*, 2019). In TNE programmes, students study in English and start studying for their degree in their home country so they do not need to travel abroad for the whole course (Heffernan *et al.*, 2010; Knight, 2011; Cuiming *et al.*, 2012, Cranwell *et al.*, 2019). By comparison to studying for the full degree programme at home or abroad, a TNE degree can be considered as a ''halfway house'' because the first part of the course is studied at home and the degree is completed abroad. This means the overall cost of the programme is less, but students still gain the opportunity to live and study in a foreign country. Students will study in another language, gain valuable employability skills and as well as being international, they gain two degrees upon graduation (Guo and Chase, 2011; Culver *et al.*, 2012; Fang and Wang, 2014).

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Internationalisation is seen as valuable for students developing intercultural employability skills, future career progression or studying for higher level degree courses such as Masters and PhDs (Knight 2003, 2011; Altbach and Knight, 2007; Guo and Chase 2011; McMahon, 2011). Many TNE courses are offered in business (Heffernan *et al.*, 2010), management (Li and Rivers, 2018), social sciences (Peelo and Luxon, 2007), mathematics, and engineering (Culver *et al.*, 2012; Yu and Moskal, 2019), however, the chemistry BSc programme between NJTech and Sheffield features a different dimension, whereby UK staff travel to China to deliver three years of hands on practical chemistry.

The University of Sheffield (UoS) and Nanjing University of Technology (NJTech) started their joint TNE (3 + 1) Chemistry degree in 2011. There are more than 1200 joint degrees or institutes offering a variety of subjects where students can gain two degrees, and where they experience a degree programme in two cultures (Culver *et al.*, 2012). Indeed, "pre-pandemic" over a million Chinese students per year were choosing to study abroad for at least part of their higher or postgraduate education, (Ministry of Education of the People's Republic of China (MOE), 2017c). The (3 + 1) style of joint degree presents a particularly attractive way of gaining a degree abroad as it requires students to leave their home country for only one year, (Cuiming *et al.*, 2012).

Introduction and development of chemistry education

Chemistry is an important part of modern science with the development of chemical education being valued by Chinese and English educators. In 1951 Weaver and Webb proposed a number of objectives related to High School (HS) chemistry education as offering "*intensive laboratory work in every high-school chemistry course*", "*enrichment of classroom instruction in chemistry far beyond the text*", providing "*an ample library of books on chemistry*", encouraging students to pay attention to current developments in chemistry such as "*the reading of periodicals*", allowing access to "*audio-visual programs in chemistry classes*", together with the need for high quality "*broad training for chemistry teachers*", and "*todays chemistry must be fun even while it is work*". The course needs to be interesting "*motivate your chemistry course by the helpful understanding of certain home problems*". Even in the 1950s it was proposed to "*include a strong vocational slant*" (Weaver and Webb, 1951). These objectives proposed by educators seventy years ago are still important today.

Almost all secondary/high schools have libraries and multimedia equipment where students use these facilities to learn more about chemistry rather than only using textbooks, (Stieff, 2019). Latest chemistry news is delivered *via* the Internet, and there are many video websites such as YouTube and the Royal Society of Chemistry (RSC), (RSC Education, practical resources, 2022) all of which contribute to students understanding of chemistry.

Chemistry is an experiment-based discipline, and the laboratory plays a major role in secondary/high school chemistry education, being an important place for students to understand, learn chemistry and gain skills. At University, the laboratory remains a central place for gaining practical skills as students develop into competent practical chemists (Agustian and Seery, 2017a; Bretz, 2019; Seery *et al.*, 2019a; Mistry and Gorman, 2020).

High schools (HS) in China are now equipped with chemistry laboratories, (Yang, 2015). However, due to the competitive pressures in China, laboratory classes are seldom carried out in many HS with students spending more time practicing exam skills, (Wei, 2019). Chinese students are well prepared in learning (Chalmers and Volet, 1997; McMahon, 2011; Li and Rivers, 2018) but their application of the theory and its link to practical work still remains a challenge. The Ministry of Education (MOE) in China has led several major reforms, 1999–2003, 2013, 2018 with the aim to develop such skills for future generations, however, the latest reform had not been in place long enough to prepare our students so we are unable to comment on its effect at this time. (Li, 2001; MOE, 2017a, 2017b; Wei, 2019, 2020).

In contrast, British secondary schools deliver laboratory classes weekly with final examinations testing students' competence in experimental skills (GCE "A" level Subject Guidance for Science; Biology, Chemistry, Physics, 2015). Pre-University education by studying for Advanced ("A") levels or for a vocational Business Technician Education Course (BTEC) in the UK are well documented and not investigated for this study. Curriculum updates periodically occur, (GCE "A" level AQA specification, 2015; GCE "A" level Edexcel specification, 2015; Read and Barnes, 2015; Palermo *et al.*, 2016; GCE "A" level OCR A specification, 2017; GCE "A" level OCR Salters B specification, 2017; Gibney, 2018).

Chemistry is an expensive discipline where various apparatus, reagents and consumables are needed for experiments (Boesdorfer and Livermore, 2018). Modern Virtual Reality (VR) technology offers a virtual laboratory where students can try some dangerous experiments safely as well as saving money (Clemons *et al.*, 2019). Interactive simulations used to gain laboratory experience before or during a laboratory session is now popular, (Agustian and Seery, 2017a; Learning Science, 2022).

Teachers are central to chemistry education and delivery of the curriculum is very demanding. With rapid progress of modern science and technology, chemistry theories are constantly improving, and older theory from decades ago may no longer be the same today, which is challenging for the teacher. Initial Teacher Training (ITT) of school teachers is increasingly important. Ensuring teachers are kept up to date with new methodology means training is continued on a regular basis. Regular training facilitates mutual communication between teachers where they can improve their own teaching methods by learning from each other's experiences. (Morgan-Deters, 2003; Palermo *et al.*, 2016; Wang, 2016; MOE, 2017a; MOE Report, 2017b; Gibney, 2018; Ma, 2019; Continuing Professional Development (CPD) STEM, 2022; ITT, 2022; PGCE Courses with QTS, 2022).

Chinese development of the chemistry curriculum

Chemistry education has undergone several changes in China. From the original imitation of the Soviet model that was introduced between 1950–1958, to the inclusion of modern teaching methods from the UK and the USA (Li, 2001; Wang, 2001). After 1980, a set of chemistry courses suitable for China's national conditions were developed (Wei 2005, 2020, 2022), however, even today, the education model is still based on exam results. For progression into a Chinese University, students need to complete three years of high school study to successfully gain the **GaoKao** (university entrance examination). Universities use GaoKao results to decide whether to accept a student or not.

Unfortunately, the HS chemistry curriculum was designed independently and is not closely aligned to the university curriculum, (Wei, 2005), meaning for students entering university to study chemistry there will be some knowledge gaps. Several chemistry curriculum reforms have led to improvements in the quality and overall educational standards, (Wei, 2019, 2020, 2022). The latest HS programme, 2018 known as the Senior High School Chemistry Curriculum (SHSCC) considered the chemistry course structure from the UK and other western countries which allow progression from High School (HS) to university to be smoother. The GaoKao offers two routes, compulsory and elective. Students who are keen to study chemistry after High School follow the compulsory route and other students follow a more general elective route, (MOE, 2017a, 2017b; Wei, 2005, 2019, 2020).

Traditionally sciences in China focused on remembering, transfer of knowledge, and training of skills, but ignored the cultivation of the scientific spirit and scientific thinking. They focused on training scientists and elites but ignored the popularization of knowledge, (Wang, 2016). Before reform, Chinese chemistry education overemphasized the knowledge framework whilst ignoring the connection between chemistry and life, leading to knowledge not being related to life situations (Wei, 2005, 2020). HS students tended to ''remember'' more than ''understand'' when learning chemistry, (Li and Rivers, 2018). This style of learning is called surface learning, prioritising memory over understanding, (Chalmers and Volet, 1997; McMahon, 2011). Although this teaching style allowed students to obtain high marks in the exam, they did not necessarily observe and understand the world from the perspective of chemistry, and the application of chemistry knowledge to life situations had not been developed, (Wang, 2016). The GaoKao continues to evolve throughout China as regional differences are gradually phased out, although different examination styles continue across mainland China.

UK development of the chemistry curriculum

Chemistry education in England started from as early as 1869 (Liu, 2003). In the 1960s, the British Science Education Association (BSA) (BSA, 2022) together with the Nuffield Consortium, developed a general level chemistry program (Nuffield Chemistry STEM, 2021). This curriculum was divided into theory and practical work and became very popular, particularly the experiments, many of which are still in use today (Nuffield Chemistry: Collected Experiments, 2021; Nuffield Practical Collection RSC, 2021).

In the 1970s, educators believed that setting up three separate courses in physics, chemistry and biology for students to choose would undermine the balance of science education, so curriculum reform was proposed. In the 1980s, with the worldwide education movement Science Technology Society (STS), the UK implemented a unified national curriculum for the General Certificate of Secondary Education (GCSE). Traditional sciences would no longer exist and were replaced by ''Science for the Citizen'' where the curriculum was divided into two parts, with mandatory core content and additional content for students who want to continue with specific sciences at higher levels: ''A'' level, BTEC vocational qualification (BTEC National Diploma in Applied Science, 2016), or a mix of academic and vocational studies in a General Vocational National Qualification (GNVQ). The Salters chemistry GCSE and corresponding ''A'' level were developed during this time and became a popular academic-vocational qualification (Burton *et al.*, 1995; Liu, 2003; Mai, 2011; Department of Education UK, 2015; GCE ''A'' level OCR Salters B specification, 2017).

After GCSEs, UK students typically study for higher qualifications at Level 3 (Framework for Higher Education Qualifications, FHEQ), either three ''A'' levels, or a mixture of theoretical and practical sciences including maths in the BTEC vocational qualification. Studying chemistry ''A'' level in the UK means students attend one or two laboratory sessions each week with a component of assessment, together with practical related questions in the final exam. In the UK it is mandatory to gain Level 3 qualifications in chemistry for entry to university chemistry degrees. The chemistry curriculum in the UK aims to keep up to date with current guidelines, and the school curriculum will continually change and modernise accordingly, (Read and Barnes, 2015; Palermo *et al.*, 2016; Gibney, 2018).

Alignment of Chinese and the UK curriculum for progression onto a UK chemistry degree

There are differences between the Chinese and British education systems. Generally the academic content in both educational systems is similar, Table 1, although the style of qualifications differ.

Table 1 Comparison of the education systems in China and the UK (Burton *et al.*, 1995; Liu, 2003; Wei 2005, 2019, 2022; Mai, 2011; Department of Education UK, 2015)

China	UK (England)
High School (HS) General/HS Vocational and University qualifications	School/College and University Qualifications
(HS) GaoKao/Adult GaoKao	*Level 2* – [GCSE (academic)/BTEC (vocational)/GNVQ (vocational)] *Level 3* – [A-level (academic)] *Level 3* – [BTEC (vocational)/GNVQ]
BSc University/Adult Education *e.g.* BSc at University	*Level 4–6* – BSc at University/Masters at University

Table 2 An example of GaoKao structure in the JiangSu province for **science students** (2008–2020)

Compulsory subjects: *Total Marks allocated*	**Chinese** *160 marks*	**Maths** *200 marks*	**English** *120 marks*	**Physics** *Grade*
Optional subjects **Select one**: *Total marks*	Chemistry, Biology, Politics, Geography *Graded*			
For example, 'Graded' subjects are simply marked as a letter grade in the GaoKao transcript and as such do not necessarily act as a distinguishing item between candidates, as much as the core subjects receiving a numbered score in the transcript.				

Chinese students study 3 majors at HS whilst working towards the GaoKao for their university entry Table 2. Students need to gain both a high score and high grades in their GaoKao. Different universities in China have varying score/grade requirements in a similar way to the different ''A'' level grade requirements by UK universities (Nanjing Tech. University, 2022; University Applications UCAS, 2022).

China's High Schools (HS) train students in practice exam questions (Hwang *et al.*, 2002). The GaoKao does not focus on assessment of students' development of chemical practical skills. Many students watch chemical experiments through teachers' demonstrations or videos, rarely having the opportunity to conduct the experiments themselves. It is therefore arguable and anecdotally evident that HS students in China have little practical laboratory experience. Chemistry is graded, although its grade is low priority in the calculation of the final GaoKao score, Table 2. Less time is allocated to chemistry in school lesson plans, but teachers still need to deliver the required subject matter. Occasionally, chemistry teachers must make compromises for other subjects such as Mathematics or English, which is another reason that students often lack chemistry knowledge.

China is a large country with many provinces all having different education and university admission systems. In some provinces educational facilities are limited due to geographical extremities (mountain, desert, grassland, plateau areas), where education is mainly for popularising knowledge. Education conditions in the JiangSu province where the NJTech/Sheffield degree programme was delivered were favourable because this province imitated the British education model to a certain extent. In this publication, we only compare the education model of the JiangSu province in China with that of England in the UK.

Chinese students typically study English from primary school, and their written work and understanding in English Language develops throughout their school years. Progression onto a chemistry degree that is delivered totally in English is still a real challenge. Apart from spoken language, all the practical and theoretical chemistry needs to be learnt in another language. Delivery of practical and theoretical chemistry on joint degree programmes delivered in China such as the NJTech/Sheffield degree require careful consideration and preparation to ensure students can progress directly into a UK university for the final year of their degree, (Cranwell *et al.*, 2019). Internationalization of the curriculum meant that although the course materials were the same, they were designed specifically to account for the needs of the Chinese students, such as language issues. Discussions were included during delivery of the course to broaden students knowledge about Sheffield and the type of students they would be integrated with during their final year and to help build their confidence before travelling, (Guo and Chase, 2011).

Introducing the NJTech/Sheffield joint degree programme

The international TNE chemistry programme between two universities NJTech/Sheffield is a (3 + 1) BSc, joint degree. Chinese students study exactly the same chemistry as UK students, but the first 3 years of their degree is delivered in China where they are taught in English by UK staff as ''flying faculty'', (Bovill *et al.*, 2015; Szkornik, 2017). During this time, students need to achieve University of Sheffield academic and language requirements for progression to complete their fourth and final BSc year in Sheffield. In Sheffield they are totally integrated with the final year home students. Large student cohorts with as many as 40 travelled from Nanjing annually to join the Sheffield students, (Cranwell *et al.*, 2016).

Specific details about the degree and laboratory practical work have been previously published (Hyde, 2014a, 2014b, 2019; Cranwell *et al.*, 2016, 2019; Wright *et al.*, 2018; Read *et al.*, 2019). Six cohorts of Chinese students equating to approximately 200 students successfully graduated from the joint programme, where they gained two degrees (Culver *et al.*, 2012; Fang and Wang, 2014). The NJTech/Sheffield TransNational (TNE) degree was fully accredited by the Royal Society of Chemistry (RSC) in 2016, (RSC Accreditation, 2022). Delivery of the practical component by UK staff travelling to teach in China was different in comparison to other similar joint international programmes.

The NJTech students needed to be ready to be fully integrated with the Sheffield cohort in the final year. When the laboratory programme was developed, the Sheffield approach for delivery in China was different to other equivalent Higher Education Institutions (HEIs) who were offering similar (3 + 1) BSc programmes, (Cranwell *et al.*, 2019). Typically, UK staff do not deliver the laboratory programme abroad but English-speaking Chinese staff are employed to deliver the UK laboratory classes, so our programme was unusual as UK staff themselves travelled abroad to teach these sessions. On TNE programmes where the laboratory component was delivered by Chinese staff, when the students travelled to the UK for their final year, they were not fully integrated with a UK cohort, (Cranwell *et al.*, 2016). The joint NJTech/Sheffield TNE programme was very successful. During each of the six years of graduation in the UK, a high proportion of the Chinese students were in the upper quartile of the overall degree cohort. Many graduated students have continued to study for Masters then PhD degrees in the UK and around the world.

Development of the NJTech laboratory programme

Prior teaching experiences of Chinese students in the UK led to an awareness that their laboratory practical skills were not very well developed when they entered a UK University to study Chemistry. China has been undergoing several HS curriculum reforms, although at the time of this research it was not complete so there was still limited practical delivered at HS for our students, (MOE, 2017a, 2017b; Wei, 2005, 2019, 2020, 2022). These observations meant the new laboratory programme for NJTech students needed to develop many new practical skills quickly during the initial three years in China. The development of the programme needed to consider the fact that students' HS chemistry may have gaps in practical skills. It was important to carefully plan and develop the curriculum considering the needs of these international students (Guo and Chase, 2011). Development of the NJTech/Sheffield laboratory programme was scaffolded for their practical skills (Hyde, 2014a, 2014b, 2019). Scaffolding is becoming popular for laboratory-based activities to enhance the learning process, (Agustian and Seery, 2017a; Varadarajan and Ladage, 2022).

At NJTech all laboratory chemistry together with associated theory was delivered to students in English, meaning that language challenges were inevitable. Initially in year one, theory was introduced at the start, during, and at the end of the session. It quickly became apparent that extra academic support was required for the students, particularly regarding scientific language. Therefore extra half day laboratory classes were timetabled for theory, pre-lab and post-lab feedback. During year 1 and 2 the laboratory was delivered during one full day. Year 3 lab was delivered over one and a half days.

For each laboratory experiment students completed initial research and preparation through pre-labs, wordsearches, crosswords, word definitions and independent or directed reading (Joag, 2014; Schmidt-McCormack *et al.*, 2017; Agustian and Seery, 2017a; Seery *et al.*, 2019a). Feedback from marked pre-labs were given before the laboratory during the dedicated laboratory theory sessions. Each experiment was discussed in English, with many questions before the experiment was carried out. A Chinese Professor, fluent in English also worked with the teaching team ready to explain difficult concepts, translate unusual words or challenging theory if needed. These sessions usually led to further discussions in English.

Style of laboratory delivery at NJTech

In the UK, laboratory students are given a pre-lab exercise requiring reading and answering questions about theory behind the experiment to understand the method used in the laboratory, (Schmidt-McCormack *et al.*, 2017; Agustian and Seery, 2017a; Seery *et al.*, 2019a). This education style is active learning, and because the work is not duplicated during the laboratory session, it is an example of "laboratory flipping". Flipping is an active learning technique used to deliver pre-class work where concepts are developed that are not repeated in the classroom session. The NJTech pre-lab included answering question sheets, completing quizzes, reading, or research prior to the experiment and handing in question sheets for marking to prepare the students for the practical class, (Lancaster and Read, 2013; Read *et al.*, 2014; Seery, 2015). Practical demonstrations for new or challenging techniques were delivered before students started the experiment, with opportunities for questions, and discussions. Students then carry out the experiment themselves, typically in pairs.

After the laboratory session, students write up their work individually as a scientific report, (Hyde, 2014a, 2014b, 2019). Developing students practical skills quickly during the three years was important. Known aids such as the use of badges, video recordings, and peer discussions have all proved valuable in skill development, (Towns *et al.*, 2015; Hensiek *et al.*, 2016; Schmidt-McCormack *et al.*, 2017; Seery *et al.*, 2017b; Gallardo-Williams *et al.*, 2020). We used a different approach at NJTech, using the **Practical Skills Portfolio** (**PSP**) which enhanced the development of practical skills and chemical language. Students were required to take photographs of apparatus, observations or techniques and then reflect on the skill during their PSP write up, which helped their language development, (Wright *et al.*, 2018; Read *et al.*, 2019).

Whilst in the laboratory during experiments students record individual results in their laboratory notebooks. Prior to leaving the laboratory students' notebooks are marked, and they receive individual feedback. Students then write up their experimental work which they submit for marking to Sheffield staff and Graduate Teaching Assistants (GTAs) (Smallwood *et al.*, 2022). Marked work is returned to students during the theory-feedback session before the next experiment.

Development of research questions (RQ)

We were interested in differences of Chinese students' previous experience of High School (HS) laboratory practical chemistry (Wei 2005, 2020) as compared to their experience of laboratory practical chemistry at the start of the NJTech/Sheffield joint degree. To our knowledge this is the first investigation of its type looking at international students laboratory practical experiences during their transition from a Chinese HS to a UK university TNE course. This led us to investigating the following four questions:-

RQ1. How familiar with practical laboratory techniques are Chinese students prior to university, or are all the techniques totally new?

RQ2. What particular aspects of University laboratory practical work are the most significant challenges for the NJTech students as they progress from High School?

RQ3. What challenges do the NJTech students find in practical laboratory chemistry as they progress from High School to a University laboratory chemistry course delivered in English, in China by UK academic teaching staff?

RQ4. Were the Chinese students confident in the transition from year 3 at NJTech to year 4 in Sheffield?

Methodology

The aim of this research was to gain understanding about Chinese students' practical laboratory experiences, their struggles, and their successes as they progressed from HS into a UK university laboratory programme delivered in China. As well as practical skill development, we were interested in students' language challenges during the laboratory course. We want to understand students' adaptation to a new style of laboratory delivery and learning. Upon successful completion of the first three years, students will be able to transfer from NJTech to Sheffield where they can work confidently in the laboratories with their UK peers for the final year of their degree. Throughout delivery of the laboratory programme, it was continuously updated and adapted where it evolved to become a more comprehensive course.

The research used a mixed method approach with both quantitative and qualitative questions, followed by a focus group to further probe the nature of the students' laboratory practical skills during their progression from HS to university.

Throughout the research, we wanted students to talk about their experiences in their own words so open-ended questions were included which could be analysed using thematic analysis by looking at the raw data using a combination of inductive and deductive coding (Thomas, 2006). This would allow themes and sub-themes/category descriptions to be developed giving us a better idea about the students' experiences of their transition from HS to University. Selected quotes from deductive raw data from the second questionnaire and the focus group are included appropriately throughout the results and discussions in italics.

As this type of research study has not been carried out previously, we needed to develop our own instruments to ensure they were fit for purpose. By using our own instrument, it allowed for inductive and deductive development of two questionnaires and a focus group. The first questionnaire was analysed inductively, then the second questionnaire and focus group questions were devised deductively from the raw data outcomes of the first questionnaire. The questionnaires used a selection of open-ended questions together with some Likert questions which were appropriate to gather the information we were looking for.

Qualitative data analysis was carried out using Thematic Analysis for the short answer questions from the second questionnaire and for the responses from the focus group according to methodology published in the literature, (Braun and Clarke, 2006; Thomas, 2006; Saldana, 2021). Findings were analysed and are presented later in the manuscript, with selected quotes in italics to support the findings.

Research instruments

The first questionnaire asked students about their HS demographics; the province where they studied their GaoKao (University entrance exam), the three majors they studied, did they follow the science or humanities route, what their final score was, and their previous practical experience at HS. It was inductively developed as it did not depend on a previous questionnaire. We needed more detail after the students' initial responses, particularly the nature of their practical skills as they left HS and progressed to University. Where the practical skills are aligned with those of the UK students with whom they would be joining after three years of practical laboratory at NJTech in China, further information was required.

The second questionnaire was deductively developed to clarify some questions from the first questionnaire, such as which ''major'' students studied at Chinese HS and specifically what basic chemical skills they gained from HS, Table 5. The skills selected are typically what UK teachers expect students to have gained as they progressed from school/college into a UK university (Read and Barnes, 2015). Three Likert questions on a scale 1 (completely disagree) to 10 (completely agree) were asked about how confident students were with their practical skills with respect to their progression from NJTech to Sheffield laboratories. A 10 point Likert scale was selected in accordance with principles for Likert scale design (Jamieson, 2004; Norman, 2010; Lalla, 2017).

After analysis of the data from the second questionnaire, four focus group questions were developed deductively looking at new skills gained, what students found easy or hard about university laboratories compared to HS, and specific chemical skills such using a laboratory notebook and laboratory safety.

Participants, data and context

Participants. Prior to data collection the research was ethically approved by the University of Sheffield's Ethics Department. There were no incentives offered to participants to encourage them to take part in this study. Before taking part in the questionnaires and focus group, all the participants had experienced the whole of the experimental practical programme that was delivered during the three-year laboratory programme at NJTech. There were 37 participants who volunteered to take part in the first questionnaire and 35 in the second questionnaire. Eight of these students volunteered to participate in the focus group. All students were from the joint NJTech/Sheffield degree programme after they attended a Chinese HS. In all cases the participants were introduced to the study and only chose to take part after listening to and reading the guidance, which allowed them to decide to sign the official consent documentation forms or not. The focus group was administered by a member of Chinese Staff who was fluent in English, it was conducted in English, and recorded.

Data collection and analysis

The first questionnaire was general and used to gain an overview and understanding about students' demographics and educational experience at HS. Results were analysed, and the outcomes used for development of the second questionnaire to generate more directed questions and to probe the actual practical skills gained from HS, Table 5. This enabled us to identify students' experiences of specific laboratory techniques from HS. These findings allowed focus group questions to be developed which would probe specific aspects of laboratory

Table 3 The second questionnaire – Likert questions (scale 1–10 where 1 = completely disagree and 10 = completely agree), mean and standard deviation (SD) values, (n = 35 or 34) (Jamieson, 2004; Norman, 2010; Sullivan and Artino, 2013; Lalla, 2017)

Quantitative questions and data analysis	Mean	SD	$\bar{x}$ ($\pm s$)
First statement. High School practical chemistry prepared me well for the practical Chemistry at University. (n = 35)	4.94	2.400	5 (±2.4)
Second statement. After three years at University carrying our practical Chemistry with Sheffield staff, I now feel confident in my practical skills. (n = 35)	6.74	1.615	7 (±1.6)
Third statement. I feel confident and ready to join the UK group in the lab, in year 4, my final BSc year. (n = 34)	6.56	1.673	7 (±1.7)

work encountered as they progressed from HS to University. This information was valuable to inform our practice and curriculum development.

The questionnaires contained a mixture of yes/no, multi-choice, short answer, and Likert scale questions. Three questions in the second questionnaire were quantitative, where students were asked to respond to a ten point Likert scale statement, from 1 (completely disagree) to 10 (completely agree), Table 3. Responses to all three questions showed a normal distribution, (Jamieson, 2004; Norman, 2010; Sullivan and Artino, 2013; Lalla, 2017).

Quantitative data analysis. Data collection was carried out on the Likert scale questions and analysed using statistical analysis with SPSS (Muijs, 2013; Field, 2018) and Excel. Both packages were used independently to cross reference the data to ensure accuracy, and the results are summarised in Table 3. Internal consistency was confirmed by correlation of Likert scale responses to the Second and Third Statements, Table 3. These statements assess participants' self-reported confidence in laboratory skills after the three years of teaching at NJTech and reported their readiness to begin the next semester of laboratory classes in Sheffield; measures which should closely relate a participant's self-efficacy in laboratory Chemistry at the time of reporting. A positive correlation (Pearson's r 0.626) was observed, and was statistically significant ($p < 0.01$), indicating consistency.

Qualitative data analysis. Data collection was analysed using an inductive thematic analysis approach to develop a framework (Thomas, 2006). This method is less complicated than some other approaches, being a more straightforward procedure allowing a non-technical data analysis from the raw data to find new concepts or themes. Findings from the first questionnaire were used to generate the second questionnaire, and then these findings were used to produce focus group questions.

The focus group recording was transcribed verbatim and analysed by two independent researchers to allow validity. Inter-rater reliability was established by two researchers independently conducting individual thematic analysis. The transcript was used to code and identify main themes and sub-themes, Table 4. To ensure nothing was missed the transcript was freshly read again, re-themed and coded before the final analysis was made. Themes were refined and discussed between the two reviewers who jointly agreed on the final themes. Quotes in italics from the students are used to support the dialogue.

Theme summaries of students skill development from HS (Table 4)

Table 4 Focus group questions (FGQ), thematic analysis and coding

Focus group question (FGQ) – (1) (2) (3) (4)	Theme	Sub-theme/coding
(FGQ1) New skills learnt when joined the Year 1 chemistry at university – has it been difficult to learn these new skills?	The professional chemist	* Attitude * Professional skills * Scientific writing * Language * Experiments * Literature references
(FGQ2) What was easy and what was hard about the Sheffield Y1 laboratory? Compare to High School (HS).	Difficulty	* HS prescriptive * HS impress * Scientific writing * Language * Thinking * Skills
(FGQ3) Why was keeping a laboratory notebook so challenging?	Understanding	* Observations * Differences between HS & University teaching * Language
(FGQ4) Safety, why was this so different/challenging compared to High School?	Development	* HS teacher demonstrations * Dangerous experiments * Safety * Chemical disposal

Results and discussions

The research carried out in this publication differs in comparison to other publications that consider laboratory development within one education system or one country, (Seery *et al.* 2019a; Mistry and Gorman, 2020). This is because our work focuses on chemistry students' progression from a Chinese HS to a UK laboratory degree programme, in particular we are interested in the development of their practical laboratory skills. Mistry and Gorman investigated undergraduate laboratory programmes to consider laboratory skills that students think they have gained from school/college at the start of their undergraduate programme, (Mistry and Gorman, 2020). Their research was from UK students progressing from UK schools to a UK university which is different to the progression of students from Chinese HS to UK University. Our findings are new, and further research in this field would be very valuable.

Initial findings and prior experiences of NJTech students from HS

NJTech is a university in the JiangSu province of Nanjing. Our student cohorts were mostly from this province and have all experienced a very similar High School (HS) examination system. 97% of the Nanjing cohort were from major Jiangsu cities such as Nanjing, Suzhou, Wuxi, Changzhou, Nantong, Huangshan, and other large cities within the province, Fig. 1. Different educational systems are employed in different provinces in China, (Wei, 2019) with localised differences in the curriculum across mainland China.

Chinese students study three majors at HS, and all of our students studied Chinese Language, English and Maths which are the three compulsory GaoKao subjects. 97% of our students selected to follow the sciences route where they study two sciences, of which Physics is mandatory, and students could choose either Chemistry or Biology as their second science, Table 2. 84% of our cohort chose Chemistry, and 16% selected Biology as their second science, Fig. 2. One student came from a humanities specialised GaoKao without a science background. Even without specialising in chemistry, students who achieve a high score from their GaoKao were allowed to progress onto the joint chemistry degree (Cao and Gao, 2010). This presented a major challenge in developing practical laboratory skills for students without previous chemistry experience or limited practical opportunities from HS. During the development of the laboratory course for the joint degree, lack of practical skills were anticipated so careful planning and support was required, (Guo and Chase, 2011).

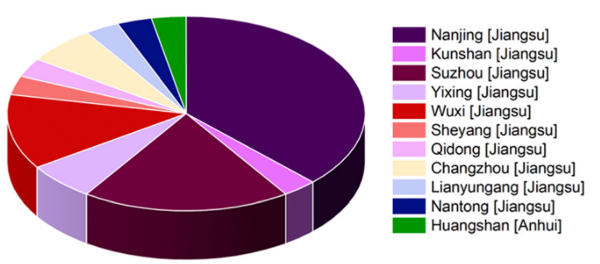

Fig. 1 Distribution of participants from High School taking the GaoKao examination shows the significant majority come from the Jiangsu province.

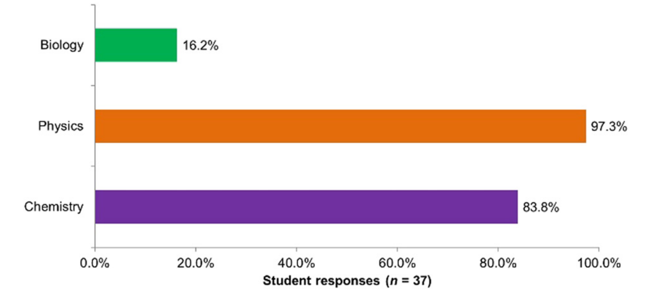

Fig. 2 Sciences selected at Chinese HS for NJTech students in their GaKao where physics is mandatory.

University entrance exam scores from the GaoKao did not significantly differentiate between students who did, or who did not, carry out previous practical work. Anecdotally, for students to achieve the grades required for university during their HS studies they tended to spend 5–6 hours per week outside of the classroom studying chemistry, which essentially focussed on the theoretical aspects of the subject and exam preparation, rather than development their practical skills, (Hwang *et al.*, 2002). The theoretical aspect of chemistry has been the basis of the GaKao exams, (Hwang *et al.*, 2002; Wei, 2005; 2019). Some of the extra classes outside of HS gave an opportunity to carry out practical work. There has been a major reform to the Chinese HS curriculum and teachers are introducing more practical work, (MOE, 2017a, 2017b; Wei, 2005, 2020, 2022).

We were interested in students practical chemistry classes at HS, with many saying they had some practical classes, and some students had even carried out individual practical work. However, practical experience tended to be through group work rather than individual, or there was no opportunity to carry out practical work at all, "*Actually most of us had no chance to do any experiments in high school*", *[Focus group]*.

Many HS students watched the teacher carry out a practical demonstration but there were few practical opportunities available to the students, "*Not regular, only have several times throughout the whole 3 years*". "*Very few, 1 or 2 per them, most of experiments are shown by teachers or videos, in groups*", *[Focus group]*.

Initial findings suggested practical skills from Chinese HS laboratory chemistry is limited, and it depended upon the particular HS the students attended before university. The situation varies throughout different provinces in China, (Wang, 2016; MOE, 2017a). Student experience of practical work was varied between some individual work, some group work, some teacher demonstrations, and some watching videos. Where practical classes did occur at HS the frequency varied from irregular to one per week. These responses about prior practical chemistry experiences from HS were not unexpected based on our teaching experiences of Chinese students in the UK.

UK students and practical skills gained from school/college

In the UK when incoming chemistry undergraduates progress from school/college we expect they will be able to think independently and apply scientific knowledge to practical situations. They should be able to present data, handle numerical data to plot graphs and think about the precision of their results. UK students should be able to evaluate their results and make conclusions, be aware of variables, and apply scientific methods and practices. UK students should have gained a number of practical techniques, have used certain instruments, and be aware of instrumentation that they have not used. We expect UK students to be able to apply their knowledge and build on previous studies when they progress to university (Read and Barnes, 2015). Exams in the UK assess practical skills, with approximately 15% of the total marks being allocated for knowledge of practical skills. "A" level students should have encountered a minimum of 12 practical activities whatever UK syllabus the school/college followed, and they are also taught how to practice chemistry safely. Students need to keep a laboratory notebook that will be assessed and which must be passed, and they are given a separate grade for their practical skills along with their final "A" level grade, (Read and Barnes, 2015).

Development of practical skills for NJTech students

To develop NJTech students skills quickly, the first year programme was designed to compensate for the lack of basic laboratory techniques. The first two experiments were titrimetric analysis to allow development of accurate skills, documentation, safety and data handling, (Hyde 2014a, 2014b, 2019). Students felt titration skills still needed developing at university "*…. like the acid–base neutralisation, we need to improve our skills to make sure we make it perfect and we can calculate the amount of the product accurate*", *[Focus group].*

The next two experiments were organic synthesis, introducing general skills such as filtration, melting point, use of quickfit apparatus, distillation for isolation of liquid samples, and collecting and labelling samples. Simple chromatography was introduced at this stage so students gained the skills needed to monitor reactions later. The synthetic experiments were much more challenging, and they required students to think and link organic theory and mechanisms. "*… in high school we just used very simple techniques, just like add something to a beaker and shake it, and it will precipitate", [Focus group].*

The final two experiments were physical chemistry extending titrimetric technique, and introducing basic instrumentation, data collection and handling, and documenting results in their laboratory notebooks. "*In high school when we did the experiments we didn't have to write anything down…*", *[Focus group].*

To help with practical skill development, the first-year programme included many pre-experimental demonstrations, discussions in English and a considerable amount of hands-on practical work to develop and gain a wide variety of laboratory skills quickly (Seery *et al.*, 2019a). Pre-labs are well known in helping gain understanding before the laboratory session, (Schmidt-McCormack *et al.*, 2017; Agustian and Seery, 2017a; Clemons *et al.*, 2019), however, additional support was required, so the Practical Skill Portfolio (PSP) was introduced.

The PSP teaching methodology required students to take photographs visually of specific aspects of their practical work in the laboratory, explain the photograph and reflect on the technique, (Wright *et al.*, 2018; Hyde, 2019; Read *et al.*, 2019). Visual records are helpful in remembering skills in the same way as watching videos (Schmidt-McCormack *et al.*, 2017; Clemons *et al.*, 2019; Stieff, 2019). The students compiled a PSP for each experiment they carried out during the 3 years laboratory course at NJTech. Interestingly students referred to previous PSPs throughout the course, finding them valuable even during their final year in Sheffield as a reminder of various techniques they had already carried out, (Wright *et al.*, 2018; Read *et al.*, 2019).

What practical skills needed developing from Chinese HS (RQ1)

Exactly what practical skills our NJTech students gained from Chinese HS was important. In the second questionnaire students were asked if HS prepared them for University, Table 3, and what practical skills they had gained in four categories; analytical, synthetic, instrumental, documentation, Table 5. These are categories we expect UK students to have carried out and gained skills during school/college prior to University.

First statement, Table 3 gave an average spread of students' responses which did not suggest that there was a strong feeling either way if HS had prepared them well for practical chemistry at university. We were interested in specific techniques as this would allow us to gain detailed information about what actual practical skills students had previously gained, Table 5. These Laboratory practical skills were developed before university through opportunities at High School (HS) or extra-curricular activities.

During HS, the students experience in basic analytical techniques was good for use of a balance (69%) and preparing a solution (57%). However, some students did not have any opportunity at HS, during extra-curricular study, or competitions to use a balance (6%) or prepare a solution (9%). A high proportion of the students had carried out a titration themselves or in a group before university (51%) although less of them had gained quantitative skills such as preparing an accurate volumetric solution (46%) and using a pipette (34%), Fig. 3.

Synthetic and purification techniques were more difficult to develop at Chinese HS. Many students had not encountered some of these skills before university apart from filtration (40%) and some students only watched a video or a teacher demonstrating the technique, Fig. 4. (51%) had a limited experience of paper chromatography although (49%) had not. This was a surprise to the teaching team because separation of inks is safe to carry out, easy and fun. Many had never carried it out, watched a video or seen a teacher demonstration of chromatography before university. It was good fun for the team to teach this technique where students used it later it for monitoring reactions during organic synthesis.

Table 5 The second questionnaire. Please use the grid below to explain the practical experience you had in your High School chemistry classes. Percentages rounded to nearest integer (n = 35)

	Never saw or did it before University	Only watched a video online	Only watched a Teacher	Did it myself (or in a group) in High School class	Saw or did it outside of High School class
Analytical					
Using the balance	6%	3%	14%	69%	9%
Preparing a solution	9%	6%	17%	57%	11%
Preparing a volumetric solution	11%	9%	29%	46%	6%
Using a pipette accurately	20%	6%	34%	34%	6%
Titration	11%	11%	23%	51%	3%
Synthetic & Purification					
Synthesising a compound	9%	29%	29%	23%	11%
Filtration	11%	11%	29%	40%	9%
Recrystallisation	20%	29%	17%	20%	14%
Melting point determination	51%	11%	9%	26%	3%
Distillation	9%	20%	34%	26%	11%
Paper Chromatography	49%	6%	26%	11%	9%
Instrumental					
Spectrophotometry	63%	17%	9%	6%	6%
Documentation					
Keeping a lab' notebook	77%	3%	0%	14%	6%

It was not a surprise to find most Chinese students had not encountered analytical **instrumentation** at HS such as using a spectrophotometer, (63%), Fig. 5. In pre-university chemistry courses in the UK, most exam syllabuses include introductory Infrared (IR), Mass spectroscopy (MS), Nuclear Magnetic Resonance Spectroscopy (NMR) and UltraViolet (UV) or Visible spectroscopy
(GCE ''A'' level Subject Guidance for Science (Biology, Chemistry, Physics), 2015). The majority of UK schools/colleges do not own instruments as they are far too expensive. To overcome this, many UK schools/colleges are linked to local universities (Harrison *et al.*, 2011), attend Royal Society of Chemistry (RSC) ''Spectroscopy in a Suitcase'' (SIAS) session, or attend a spectroscopy day allowing students to visit university to gain hands on instrumentation experience. Alternatively, UK schools/colleges can invite a speaker into their classes to deliver an RSC instrumentation session (SIAS, 2016). When UK students' progress from school/college onto university chemistry courses, they have some familiarity with instrumental techniques in contrast to the Chinese students progression from HS.

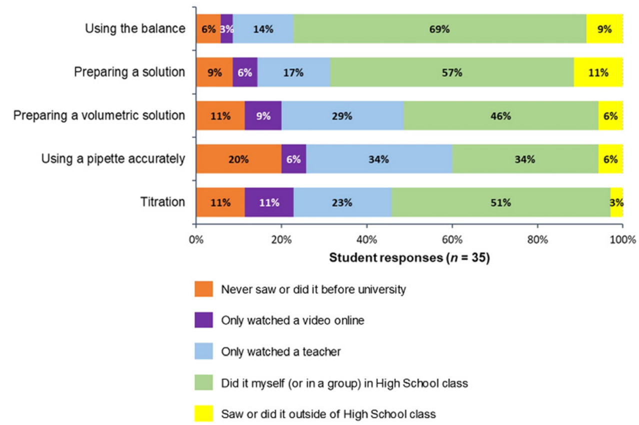

Fig. 3 Analytical skills (Table 5).

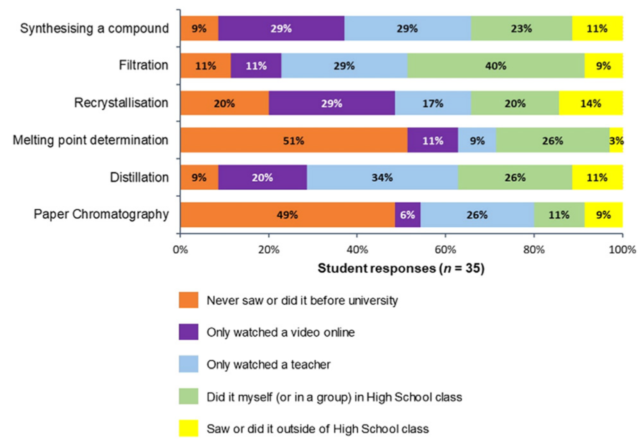

Fig. 4 Synthetic & purification skills. (Table 5).

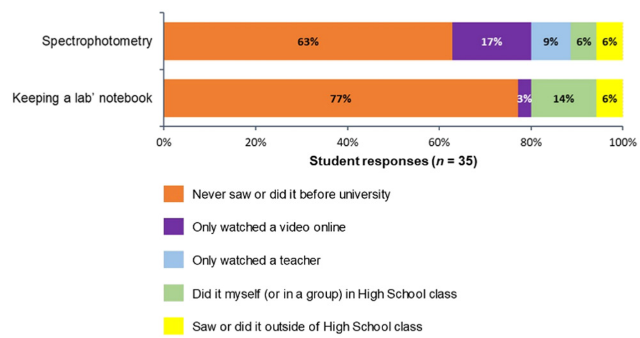

Fig. 5 Instrumentation & documentation skills. (Table 5).

The most surprising response for the NJTech students was the lack of previous experience about how to **document** their results. The majority of the students had not used a laboratory notebook (77%), Fig. 5. NJTech students were not used to documenting results, so time was spent in developing this skill; "*I think the biggest skill that we have learned is writing the lab notebook*", *[Focus group]*. Students were not familiar with writing up their reports using scientific writing either as this was not taught at HS, so this skill was developed during university laboratory and classroom sessions, "*…to write a science report is still challenging…. to present your experiment fully*", *[Focus group]*.

The findings from Table 5, were supported through student focus group discussions after thematic analysis and coding, Table 4. Each focus group question (FGQ) is discussed below in terms of its theme and sub-themes, and reinforced by student quotes in italics.

(FGQ2) easy or hard "difficulty". Chemistry experiments at HS lacked "difficulty", they were easier and "highly prescriptive". HS relied on watching demonstrations and following the teacher's thinking, or just watching videos alone. "*Actually, most of us had no chance to do any experiments in high school. We just watch the videos*", "*So videos are fine*", *[Focus group]*.

The importance of HS chemistry was to remember observations for the final exam and gain the highest score possible even though no specific grades were awarded. "*The reason why my chemistry teacher asks us to do the experiments in high school, is he wanted us to remember it more clearly and know some colour changes and know there are some solid or gas….*", *[Focus group]*.

The teacher's aim at HS was to "impress" students, which can attract students to study further chemistry, although it does not develop skills, techniques, understanding and independent "thinking". "*In my high school, we do experimental for a group, just the whole class to do one experiment.*" "*…in college, we did the experimental for two people. And, I think it is more difficult*", *[Focus group]*.

Generally students found skills at HS were simple techniques, meaning they did not start to develop the dexterity needed as practical chemists and there was little opportunity to gain hands on experience. "*….in high school we just used very simple techniques, just like add something to a beaker, and shake it, and it will precipitate. …have some bubbles ….*", *[Focus group]*.

The value of fun and visual experiments should not be underestimated, and this demonstration style is used routinely at outreach events in the UK and worldwide to inspire students (Harrison *et al.*, 2011; Houck *et al.*, 2014; Schwarz *et al.*, 2016; Santos-Diaz and Towns, 2020; Salters Chemistry Festivals, 2022). Although impressive and inspirational this style of delivery is not valuable to develop hands on practical skills in becoming a professional chemist. "*…the aim of the experiments in high school is just to impress you, and to help you to remember the mechanism or the change for the examination of chemistry…. You don't need to analyse anything, just remember it and use it in your examination*", *[Focus group]*.

(FGQ3) laboratory notebook "Understanding". At HS in China, teacher demonstration for classroom chemistry experiments is normal. Students "observe" techniques, but they don't consider outcomes or record results in a laboratory notebook. Consequently, students don't fully "understand" or think about the chemistry behind the experiment, (Hwang *et al.*, 2002). Students are encouraged to remember specific colour changes relating to theory for their examination, with the aim to get good marks in the GaoKao for progression to University. "*…We have laboratory classes, but its just, the teachers shows us how to do the experiments, … I see the experiment going but we don't have to record anything; just the teacher 'said' and 'do'*", *[Focus group]*.

At HS students do not write up experiments so "understanding" and reasoning is not the focus. Research is rarely carried out and students use just one course textbook for their information (Wei, 2020). "*I think the big challenge is that we haven't done that in high school or middle school....*", *[Focus group].*

(FGQ4) safety "development". Chemistry at HS allowed students to gain knowledge but for most students, not practical or safety skills. "Teacher demonstrations" are normal at Chinese HS, especially if chemicals are "dangerous/hazardous" which does not allow students the chance to develop the hands-on practical skills that are required for the "professional chemist". "*... if the experiment contains some dangerous part and includes safety, we should know the teachers just don't let us do it, just demonstrated it*", *[Focus group].*

In the case of "hazardous" experiments at HS, students watched videos, so "development" of "safety" knowledge was limited, particularly safe "disposal" of chemicals. Experiments that were carried out would be as a group such as acid–base chemistry in the form of a simple titration. "*In high school, the most dangerous compound is acid.... But you just don't touch it.... And we don't know how to dispose it. All the dangerous compound acid and base can just dispose in the sink and add water.... ... maybe if acid is on you then add sodium hydrogen carbonate......That's the only safety points*" "*In Chinese experiment in high school or college, we don't focus on safety like in the English, ...our Chinese teacher won't ask you to wear the glasses or the gloves...*", *[Focus group].*

As very basic safety knowledge was not "developed" at HS, NJTech students were very apprehensive about the "danger" or hazardous nature of the chemicals at university. Students found "safety" at university had a much greater focus for each experiment. "*High school chemical experiments don't have many poisonous or flammable. All this are under the teachers' control... in the university, the experiments we do now, we have to handle these things by ourselves.......*", *[Focus group].*

Practical skill challenges as students progressed from HS through the NJTech laboratory programme (RQ2)

The findings from the second questionnaire open question, Table 6 and student focus group discussions, Table 4 about practical skill challenges during their university course are discussed after thematic analysis and coding. Each question is discussed below in terms of its theme and sub-themes and reinforced by student quotes in italics.

Table 6 Students response about difficulties of joining the undergraduate NJTech programme after High School (HS) (n = 35)

General theme/difficulty sub-themes/coding (below)	% of students responding
New skills/apparatus	32
Communication/scientific writing	20
Laboratory notebook	17
Safety	11
Organic & inorganic terminology	6
No response	14
	100

Open Question "apart from English Language, what do you think was the most difficult part of starting the year 1 Sheffield Laboratory course at NJTech University". Results from the second questionnaire are summarised in Table 6.

"New skills" and the use of new and complicated "apparatus" were found to be the most "difficult" part of joining the NJTech laboratory programme (32%), "*use the apparatus accurately*", "*to use experimental equipments that I have never used before*", *[Second Questionnaire].*

"Communication" and "scientific writing" was a challenge for a number of students (20%) who quoted "difficulties" such as "*the language*", "*write references*", "*the experimental report is difficult to write*", *[Second Questionnaire].*

Using a "laboratory notebook" (17%) was "difficult" for the students, it was a new skill that needed to be mastered which students found very challenging, "*learning to use and keep the notebook since I'd never learnt to use before*", "*prepare the lab notebook*", *[Second Questionnaire].*

Students had some awareness about "safety" as they progressed from HS to the UK University course, although there were differences in the regulations which they adapted to well during the three years as they recognised their importance (11%), "*knowledge of safety*", "*serious rules about the experiment*", *[Second Questionnaire].*

The NJTech students were studying chemistry in English which is their second language so together with learning new "chemical language" they had to get to grips with the "chemical laboratory language" as well. Students found important academic concepts challenging such as organic and inorganic terminology (6%), "*naming organic compounds*", *[Second Questionnaire]* was a "difficulty".

(FGQ1) new skills "the professional chemist". Gaining new skills during their first year at university was probably the most significant challenge about the laboratory course for the NJTech students. Students felt that carrying out experiments by themselves, either alone or in a pair developing teamwork skills, were significant to becoming a "professional chemist" in comparison to teacher demonstration or class group experiments experienced previously at HS. "*Cooperation with your partner is another important thing....It's very important to know how to get along with your partner and to get a better result*", *[Focus group].* New skills were developed through learning new techniques, setting up apparatus by themselves or in pairs which students found challenging, "*...we have to set up a huge apparatus*", *[Focus group].*

University chemistry developed students' "attitude" which encouraged them to think critically. They learnt about the safety and how to behave in the laboratory, these were seen as a positive development of their "professional skills". "*Attitude maybe should be learnt, and being critical and being careful during the experiment. Being critical to your results and writing down all what you think and all what may be possible...... a skill that chemists should be equipped with*", *[Focus group].*

"Professional skills" were developed through practical and theoretical laboratory work to ensure correct use of the laboratory notebook at the time of the experiment. The importance of recording observations and data was an important skill allowing their results to be used to write up their final report, which was also a preparation for future research projects. "*I think the biggest skill that we have learned is writing the lab notebook*", *[Focus group].*

At Chinese HS, the chemistry course relies on using one textbook (Wei, 2020) so students were not used to wider reading, researching and referring to the literature. During the first NJTech "experiment"; **Analysis of Vinegar**, students were asked to consult the literature to find the amount of ethanoic acid that was present in standard vinegar samples and compare them with their experimental findings. They needed to interpret the results and "scientifically write" about it in their reports, (Hyde, 2014a, 2014b, 2019). Students needed to develop the skill to consult and interpret literature information and not just copy it. Journal access was difficult in China as not all websites were available. "Literature referencing" using the correct RSC style was also new. "*Another one is to reference to the literature*", *[Focus group].*

The requirement to write an organic electrophilic addition mechanism was a challenge during the first-year "experiment"; **The extraction of limonene from oranges or lemons** (Hyde, 2014a, 2014b, 2019). During the laboratory session students practically confirmed the presence of a double bond and were required to explain this result using a mechanism (Clayden *et al.*, 2007). Teaching the basics of mechanisms is what university teachers assume to be base knowledge taught at "A" level in the UK, (GCE "A" level AQA specification, 2015; GCE "A" level Edexcel specification, 2015; GCE "A" level OCR "A" specification, 2017; GCE "A" level OCR Salters "B" specification, 2017). This absence of knowledge was unexpected, however, students quickly picked up the intricacies of the curly arrow! "*... the organic experiments, the mechanism is very difficult for us to understand in the first year*", *[Focus group].*

The "experimental" style at University taught NJTech students to really think about their practical work, relate it to the theory and interpret their findings to gain a full understanding of their whole experiment, (Seery *et al.*, 2019a; 2019b), "*... in high school maybe the aim is just to observe to see what happens, but I think that now our chemistry experiments should have aims like "Why this happens."* "*...in university the experiments will focus on research, but in Chinese experiments, the aim is to study techniques, to depend on techniques*", *[Focus group].*

(FGQ2) **easy** **or** **hard** **"difficulty".** Laboratory progression from HS to University was found to be "difficult". Students suddenly needed to work alone or in pairs giving them real opportunities to develop practical "skills". "*...in university we learn more techniques. And we know how to recrystallize*" "*....we have more freedom in our experiments...", [Focus group].*

After the laboratory, students need to write a report for the experiment so developing "scientific writing" skills was important. Students needed to analyse, calculate and interpret their results, which meant that they needed to "think" about the chemistry. "*The results and discussion is the hardest part in our first year.... This is hard...* "*The format is another thing; ...in high school we don't have to think about experiment, we don't look back to experiments to think why this happens and why this goes wrong.... Is the result good or the result bad?.*" "*In this English experiment we conclude after every experiment, like the Skills Portfolio, future work. But the Chinese experiments never do this. PSP paper*", "*...experiments in UK ... is more hard, because you will pay more attention to the experiment itself*", *[Focus group].*

(FGQ3) **laboratory** **notebook** **"understanding".** At University, the use of a laboratory notebook was new to the NJTech students, with 77% having never used a laboratory notebook previously as there was no need to document "observations" and results. At University it was a challenge to teach "understanding" the importance about the laboratory notebook and its value in future research or employment. "*Need to form the habit to write the observations when doing the experiment, at the same time, is challenging for Chinese students....*" "*To have to take notes on your lab notebook is require you to... understand the experiment. ...and prepare in advance....*" "*...the aim of the experiments in university is completely different to the aim of the experiments we did in high school or middle school. Now we will analyse the results and get some conclusions from the observations or the spectrums, so we have to do the notebook very perfectly, completely...*", *[Focus group].*

(FGQ4) **safety** **"development".** "Safety" at University was introduced during laboratory preparation for each experiment by the tutors. Students were taught exactly what chemicals they would be working with, particular hazards and experimental "safety" points. "*...they were not aware of safety*" "*The safety is a big point.* "*Also how to dispose the waste*", *[Focus group].*

Safety is an important "development" of the "professional chemist", a part of students learning, what to wear and how to behave in the laboratory, the need for safety glasses, laboratory coats, use of a fume cupboard and monitoring experiments at all times. Appreciating during an experiment it is not just sitting in the front of a fume cupboard but keeping alert about the hazards, being prepared and ready to carry out the next steps of the experiment at all times. "*I think that because in the university we are exposed to more dangerous chemical compounds, and when we were in the middle or high school the most dangerous chemical compound were under the control of the teacher. Now we are going to be professional chemists, ...we should have developed the skills to know how to handle these dangerous chemicals properly*", *[Focus group].*

NJTech students also researched "safety" aspects for each experiment before attending the laboratory, knowing what chemicals are hazardous and how to "safely dispose" of them. Students appreciated that "safety" is taught at university, (Alaimo *et al.*, 2010) and although there were far greater experimental risks there was better pre-lab preparation and Personal Protective Equipment (PPE). "*I think that the safety part in our university experiments is very good. Every method sheet has the dangerous things about our compounds written on the method and also how to dispose them, actually perfect. I think that's good. High school doesn't have that kind of things about the chemicals we face. Also the lab coats and gloves and glasses; every chemist should pay every attention of these kind of things*", *[Focus group].*

Challenges with studying chemistry in a second language (RQ3)

With the laboratory course delivered in the NJTech students second language, we were aware that this was a huge challenge.

The focus group questions asked about specific aspects of HS progression, and students discussed issues about studying chemistry in a second language. Students said that new skills and names of chemicals, apparatus, and techniques were challenging. Probably the most difficult aspect was writing their results, the use of the laboratory notebook and using the scientific language for their reports. Deng and Flynn have recently looked at international students studying in a second language. Scientific English and being able to write in another language was particularly challenging, which we also found with our students. (Deng and Flynn, 2023).

(FGQ1) new skills "the professional chemist". Through practical work students were helped in mastering "scientific language" in English by using names of techniques, apparatus, and learning the skill of observing and documenting their findings. "*I also learned the English names of all the equipment and apparatus*", *[Focus group].*

In English, students were introduced to organic mechanisms, data handling skills and names of unusual colours. It is taken for granted about knowing names of less familiar colours in your own "language". The students first encountered the lovely turquoise blue of aqueous copper(II) sulfate during an iodometric titration with sodium thiosulphate; **Determination of the percentage of copper in a copper salt**, (Hyde, 2014a, 2014b, 2019). Students were required to document their observations for colour changes and photograph them for their PSP. Absence of intricate "language" led students to describe the beautiful turquoise colour of copper(II) solution as fake blue. Such important "language" information needed developing throughout the laboratory course. "*For the observations on the lab notebook, the name of the colours, hard to describe sometimes in English! We just know some very simple words for them but hard colours we don't know how to describe it*, *[Focus group].*

"Scientific writing" in English was a major challenge and was developed from the first undergraduate year and throughout the laboratory degree programme. Apart from "language" issues, students had not developed "scientific writing" skills at HS, and they were not used to using terms and concepts such as; aim, introduction, method, observations, results, discussions, conclusions and references. Translations were not always obvious for some headings such as results, discussions, and conclusions because a direct translation into Chinese left ambiguity about their meaning. It was therefore difficult for students to understand these specific differences which were valuable discussion points during the scientific writing feedback class.

(FGQ2) easy or hard "difficulty". UK University experiments tend to be open-ended and a very different investigative style. (Seery, *et al.*, 2019b). The "language" was challenging for non-English speaking Chinese students, and they needed to develop independent "thinking" as well as being able to communicate outcomes and conclusions of their experiments through "scientific writing" in English. "*…I think the big difference between the Chinese experiments and the English style is the point; the focus, …the Chinese experiments focused on the result, just there is no thinking, …the English style experiments can give us focus on the progress of thinking about reasons why this experiment's results are this,…and why it should be that product*", *[Focus group].*

Pre-preparation for "experiments" was new and "difficult" to the students during their first undergraduate year. Students needed to complete and submit a pre-lab showing understanding and knowledge of the experiment. (Schmidt-McCormack *et al.*, 2017; Agustian and Seery, 2017a; Seery, *et al.*, 2019b). Students were required to prepare for the experiment in their laboratory notebooks, which was also new. "*…the difficult part is the pre-lab and the method sheet. The two things are very difficult. The pre-lab, it has a lot of experiment questions and theory questions. Combining together, I think that's a difficult part for Chinese students*", "*…record the experiment on your lab notebook is also difficult, in English*", *[Focus group].*

(FGQ3) laboratory notebook "understanding". Being able to document their laboratory notebook in English was hard. Students spent considerable time on laboratory preparation, as they needed to be ready to document results in actual lab time in English, and they appreciated the importance of focusing on the practical part in the laboratory. To encourage students further the teaching team marked their laboratory notebooks before they left the laboratory, so they were given immediate and individual 1 : 1 feedback from the marker. Students were always keen to receive feedback and guidance for future improvements which they made for their next laboratory experiment, (Hyde, 2014a; 2019). "*We need to use English to write the laboratory notebook, before these experiments we didn't even know the name of the material we used; so it is a bit of a challenge for us*", *[Focus group].*

Students were taught not to copy methods from the laboratory script directly into their laboratory notebook but still felt they needed to copy some parts to help develop "understanding" and "language" skills because of the many new names for equipment, chemicals and techniques during year 1. "*…you have to know why this experiment should be done this way. This is the difficult part for us when we are in university, you have to read through the manual and then write the things in the lab notebook after we understand it. That is the difficult part first*". "*When we did experiments, not everything is the same as in the method, like the amount of compound we added, and also we did something else which the method doesn't have. These things will change the outcome of our experiment, but if you don't record that, you don't know why the outcome is different*", *[Focus group].*

Scientific writing guidance during the three years in China saw significant improvements before the NJTech students entered their final year in Sheffield.

Practical skill confidence for transition from NJTech to Sheffield laboratories (RQ4)

Were the Chinese students confident in the transition from year 3 at NJTech to year 4 in Sheffield? From Likert scale analysis, the NJTech students felt confident with the practical skills that they gained from three years of the UK style laboratory chemistry delivered in China. These results indicated a narrowing of the range of responses with a mean of 6.74 (sd 1.62) which is higher than average agreement.

What was the confidence of the NJTech students joining their Sheffield peers? The NJTech students felt confident about their practical skills and were ready to join the Sheffield group, this was also supported by fairly similar responses to the second statement, the mean of 6.56 (sd 1.67). Anecdotally during the final class laboratory feedback session at NJTech, students were very positive about their practical ability and were looking forward to joining the Sheffield students.

Correlation, Table 3. Further investigation of the data to consider if there was a relationship between students feeling confident about their practical skills (***statement 2***) and about joining the Sheffield group (***statement 3***) was positive. The Pearson's r correlation coefficient was found to be 0.626 significant at the p = 0.01 level (2 tailed test), potentially suggesting that the confidence gained from the NJTech lab course was the likely driving force behind moving from a position of relative unpreparedness after HS, to readiness and to merge with the Sheffield cohort.

Conclusions

RQ1

It was found that although many Chinese students gained simple analytical skills from HS, others did not due to the fact they did not have the opportunity in class or they did not study chemistry in their GaoKao. The skills that were clearly the weakest were synthetic chemistry, instrumentation and scientific writing which required significant development throughout the 3 year laboratory programme at NJTech.

It was good to find out that many Chinese students had used a balance (69%), prepared a solution (57%), carried out a titration (51%) and used a pipette (34%) before University, Table 5. Students mentioned that precision used in the NJTech/Sheffield Year 1 lab was higher than they had experienced at HS. Currently many educational reforms are happening in China so HS chemistry is becoming more laboratory based and future students will be better prepared to join University chemistry programmes in China or worldwide, (MOE, 2017a, 2017b; Wei, 2005, 2019, 2020, 2022). Many techniques were new for the NJTech students in comparison to the UK students who will have met them at school/college previously, (Read and Barnes, 2015). Students found the new skills challenging but embraced the opportunity to carry out experiments by themselves or in pairs and they adapted well to the new delivery style.

RQ2

From our findings, development of laboratory practical skills for the professional chemist was highly regarded by the NJTech group, giving students a new independence, so working alone or in a pair was welcomed. For many of the techniques typically delivered pre-university in the UK (Read & Barnes, 2015), Chinese students had either not experienced them or if they had seen an experiment previously, they did not have a hands-on practical opportunity to develop many laboratory practical skills during their HS years, Table 5. Significant challenges for many Chinese students were synthetic skills, using complicated apparatus, instrumentation, documentation and scientific writing. Experience of simple techniques such as paper chromatography (49%) Fig. 4, melting point determination (51%), documenting findings in a laboratory notebook (77%), Fig. 5 were limited.

RQ3

Real challenges for development of students' laboratory experiences related to language, documenting laboratory notebooks, inorganic and organic nomenclature and drawing out organic mechanisms. The skill of writing up a practical report in a new language, English, was a significant challenge. The teaching team worked hard to develop students understanding as well as speaking and writing skills. When introducing experiments, students were encouraged to use and speak new words both verbally and written, through question and answers during the laboratory introduction theory class. Pre-lab's, PSPs (Wright *et al.*, 2018; Read *et al.*, 2019) and wordsearches for each experiment which required students to define new scientific words was helped further by end of semester practical course crosswords.

Discussions about the context of using new scientific words was necessary because students needed to include them in their final written reports. After marking, students were given very specific feedback, which was important. Becoming confident in the use of scientific language in English for international students has been reported as challenging (Deng and Flynn, 2023). During the third year at NJTech, students command of their written English was noted by UK academic staff to have reached an ''impressive standard'' suggesting the hard work was paying off.

The NJTech students appreciated they were progressing to become professional chemists and were successfully integrated with the Sheffield students for the final year of their BSc Chemistry degree in the UK.

RQ4

After a challenging three years at NJTech, it was good to find out that students were not only looking forward to joining their Sheffield peers but felt confident with their own laboratory skills to take on their final year challenge. The students gained the skills to integrate safely and practically with the home students for their final degree year in Sheffield.

Final outcomes

Delivery of a UK chemistry practical laboratory in China was a challenge for all of the UK flying faculty staff involved but very rewarding (Bovill *et al.*, 2015; Szkornik, 2017). It required careful planning and development with delivery following a clear progression route that would not only develop the practical skills and language, but also the professional skills of the NJTech students allowing progression from their High School to joining a University group in the UK three years later, (Guo and Chase, 2011).

A positive outcome from the joint degree between NJTech and China is that upon gaining BSc degrees a high proportion of these students were in the upper quartile of the overall degree cohort. Not only did they develop good practical skills together with a firm theoretical basis, their language development in

English during the four years allowed them to graduate with high class degrees.

Future progression for the NJTech students has seen many progressing onto Masters degrees worldwide with a number remaining in the UK or moving to other English speaking countries. Successful achievement of their Masters led many of the students to continue their studies in Chemistry or Chemistry related PhD programmes. A number of students have already become "Doctor of Philosophy". Such achievements are a strong motivation for Chinese students to consider TNE courses for their study abroad, enabling excellent prospects for their future careers by gaining qualifications from foreign universities (Counsell, 2011). Overall, the joint BSc degree programme in Chemistry between Sheffield University and Nanjing Tech University was very successful.

Implications for future teaching of international students

From our international experiences working with the NJTech/Sheffield programme, we make the following proposals. These are for colleagues who are teaching international students on TNE joint degree programmes in their home countries, or for staff who are working in a foreign country delivering a university degree programme to students in a different language that is not their first language.

Initially, be aware about previous High School (HS) education of their students as this will be helpful in developing their own TNE programme enabling them to recognise previous limitations and experiences of students (Cuiming *et al.*, 2012; Fang and Wang, 2014; Bovill *et al.*, 2015; Szkornik, 2017).

It is important that all classes need to be delivered totally in English (or the host language). Also it was beneficial for both UK staff and Chinese students for the UK staff to be paired with a member(s) of NJTech staff whilst teaching in China because some difficult concepts needed to be explained in their native language to help with the translation into English.

Sheffield Graduate Teaching Assistants (GTAs) (Smallwood *et al.*, 2022) were allowed to join the teaching team and teach laboratory classes with UK academics, which was an excellent support mechanism for both the students and staff. This support continued when students travelled to Sheffield to complete their degree as there were the familiar faces of the GTAs who were demonstrating to them in the laboratory in China.

Timetable "extra laboratory lecture classes" that can be delivered in a classroom setting. These are valuable for discussions, feedback on pre-labs, laboratory reports and language development, (Hyde, 2014a, 2014b, 2019; Seery *et al.*, 2019a, 2019b).

During the first academic year of teaching the international students, be prepared to spend time on language development related to the degree subject, as well as delivering the actual chemistry. Include many demonstrations of the skills that students will encounter as well as plenty of hands-on opportunities for students to gain new laboratory practical skills. Where possible, allow a particular emphasis on instrumentation and synthesis during their first year as this is new.

Using quizzes such as word searches and crosswords, the practical skills portfolio (PSP) (Wright *et al.*, 2018; Read *et al.*, 2019), together with repeated word use including definitions of new and unusual technical words. This really helped to develop students' language together with their knowledge and understanding. (Hyde, 2014a, 2014b, 2019; Agustian and Seery, 2017a).

Introducing the professional use of the laboratory notebook at the very start of the course is important in developing students' documentation skills. Continue with regular laboratory notebook training throughout the course. It was found that in-class marking and giving individual feedback was very valuable.

Developing scientific writing from the start of the degree programme was a real challenge for staff and the NJTech students. Although challenging it was beneficial for the students' course progression and completion of their BSc in a UK University during their final year.

For detailed guidance about setting up and teaching a laboratory programme abroad in China, see information and tips previously published, (Hyde, 2014a, 2014b, 2019).

Limitations and considerations

The focus of this publication was to investigate an international TNE programme and the transition experiences of students from High School to University, in the Framework for Higher Education Qualifications (FHEQ) at level 3. As such the study participants were in the first few years of their programme (FHEQ level 3 to 5) during data collection. Although this adds valuable context to their reflection, a broader study of students' views on the difficulty of the transition across qualification (FHEQ) levels 3 to 6 would provide a more holistic view.

The questionnaires and focus group were carried out entirely in English due to the limited Mandarin capacity of the investigators. This may have introduced a selection bias in the focus group participants' willingness to volunteer.

Also, the exact content of student quotes reported here may contain some grammatical errors. Perhaps a better approach would be to conduct focus groups in native language only, then obtain professional translation. In addition, bilingual questionnaires could be provided to prevent any misunderstandings.

Conflicts of interest

There are no conflicts to declare.

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