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ARTICLE

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The power of the virtual client – using problem-based learning as a tool for integration in a pharmaceutical sciences laboratory course

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ABSTRACT

This paper describes the design of a new practical class in pharmaceutical chemistry, which creatively guides the students through the subject area of physical and analytical sciences with the help of a 'virtual client'. The design focuses on the active integration of knowledge and professional skills in an area which has been seen to be typically least popular with the students. The course is designed for a duration of 20 teaching weeks, categorized into four 5-week blocks, where the same set of learning outcomes are repeatedly approached from different angles. Students are provided with feedback and feed-forward points after each 5-week block. Evaluation of the design has shown that the students actively learn to integrate knowledge and positively engage with the practical and their 'virtual client'. Engagement parameters, such as peer observations and marks, grades, and attendance are all very encouraging compared to traditional practical classes.

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Introduction

Pharmacy is an area, which must constantly act on changing patient needs and medical advances. In response to this, Pharmacy education heavily emphasises continuous developments and innovative teaching approaches to prepare the students for their future challenging career. (Hutchings, Huber, & Ciccone, 2011; Wright, Hornsby, Marlowe, Fowlin, & Surry, 2018) It is important to create innovative learning environments that allow students to absorb the ever-growing body of information, and to foster the development of critical thinking and problem-solving skills. In addition, it is crucial to expose students to teamwork, collaborative working and activities where their professional skills are trained. (Cooke, Irby, & O'Brien, 2010; Wosinski et al., 2018)

At present, pharmacy educators worldwide have responded by developing integrated courses; ensuring discipline integration and translation of science into practice. (Bandiera et al., 2018; Pearson & Hubball, 2012) Historically, medicinal chemistry has played an important in traditional Pharmacy education and it is still important to remember its relevance. However, Das, Fernandez, Shah, Williams, and Zagaar (2018)

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have shown that the best learning outcomes are achieved when medicinal chemistry is delivered as part of an integrated teaching approach.

Past experience has clearly shown that integration of knowledge and professional skills cannot be left to the student alone; students have to be guided and must learn how to integrate their newly acquired skills and information to prepare themselves to respond to new developments around patient care. (Cunningham, Leveno, Bloom, Spong, & Dashe, 2014) Pharmacy courses are characterized by the intertwining of basic and clinical disciplines; these are interdependent and it is important to integrate both. Therefore, pharmacy educators strive to break down barriers between individual disciplines through integration. (Mawdsley & Willis, 2018; Ratka, 2012)

Integrative learning is defined as "an understanding and a disposition that a student builds across the curriculum and co-curriculum, from making simple connections among ideas and experiences to synthesizing and transferring learning to new, complex situations within and beyond campus.' (Hutchings et al., 2011) An integrated program or curriculum is characterized by the presence of four attributes. Firstly, it strives to provide an authentic and natural learning experience. Secondly, it encourages students to construct meaning, and aspire to investigate further and apply new knowledge. Thirdly, integrative learning requires and promotes higher order thinking as concepts are transferred. Finally, it is a cyclic learning process requiring several repetitions. (Lipson, Valencia, Wixson, & Peters, 1993)

Independent of how integration within a program is achieved, it is clear that learning changes from the inefficient and passive learning style in lectures to a highly efficient active learning style. Students learn to understand and interpret concepts and, even more importantly, apply them to a number of scenarios. Students learn to think critically, to process a huge body of information, rationalize and apply knowledge to different problems. It is important to change the students' focus from what's required to achieve passing grades, to a mindset of being able to process knowledge to make a correct decision depending on the situation they are exposed to. (Hubball & Burt, 2004; Huber, Hutchings, Gale, Miller, & Breen, 2007)

In this paper, we report the design of a novel practical class for 2nd year Pharmacy students. It is based upon the integration of knowledge and professional skills obtained in Years 1 and 2, which aims to prepare students for their future careers. This so-called 'Integrated Practical' uses problem-based learning (PBL) as the main medium of delivery in order to create an active learning environment.

Design

The MPharm course at the University of Reading (UK) is a 4-year undergraduate course, which prides itself in using a fully integrated curriculum throughout. The program hosts up to 150 students per year. The student cohort is very diverse and therefore the course offers a varied repertoire of delivery modes for its teaching. We employ a spiral curriculum design, where concepts are revisited several times under different aspects within the 4-year duration of the course.

The 'Integrated Practical' is a teaching activity placed in Year 2 and integrates physical science teaching with concepts of quality control and quality assurance. In particular in relation to pharmaceutical preparations, teamwork and therapeutic aspects. The practical refers back to concepts introduced in Year 1, particularly to basic analytical skills, the theory of quality control and quality assurance. Within Year 2, students are introduced to the testing of physical properties of tablets and therapeutic knowledge in parallel to the 'Integrated Practical'. This means that students have been exposed in advance to the theories they will apply during the 'Integrated Practical'.

The 'Integrated Practical' runs for 20 teaching weeks and can be divided into four 5-week blocks. At the beginning of the year, the students form teams with 5–6 members and 'found' their own pharmaceutical analysis company. Within the teams, the members decide who is assigned to specific roles, such as team leader, secretary, Health & Safety (H&S) officer etc. The teams have their 'own' laboratory (scheduled laboratory classes) and office space (scheduled workshops). In addition to these activities there are optional biweekly drop in session with the facilitator of the 'Integrated Practical'.

PBL is the main form of induction used within this teaching approach. Students are provided with the resources they need, such as space, literature, databases, relevant forms and access to the facilitator for questions. However, there is no laboratory manual or instruction booklet provided. The students receive a brief from their client at the beginning of the academic year via a video link. In our case, the virtual client in the video message is an actual expert in quality assurance from the pharmaceutical industry. This expert also presents the final lecture of the course on quality assurance and quality control. At all other times, the client is 'virtual' and all emails etc. are answered by the academic using a business type approach to communication.

The video message states the following: *'Hello, my name is Martin Nicholson, I am the CEO of RSOP Pharmaceuticals. We have produced the following tablets, but unfortunately we cannot release this batch, as our analytical testing laboratories are currently out of order. Therefore, I would like to hire your company to undertake the necessary testing and produce a Certificate of Conformity in order to release the tablets to the public market in the UK. All testing procedures have to be agreed with my company.'*

The students receive a batch of tablets containing an active pharmaceutical ingredient (API) relevant to the therapeutic areas taught in Year 2 of their course. They have also access to the relevant template forms to be used and are encouraged to refer back to material learnt in Year 1 or material taught in parallel to the 'Integrated Practical'. The ultimate goal of the practical is to produce a Certificate of Conformity for the client. The template forms guide them on what work to undertake in order to gather all the relevant data for their Certificate of Conformity. The students first have to research the chemistry and pharmacology of the API, and the formulation of their drug in relation to relevant procedures and legislation. This requires the students to refer back to and apply analytical methods learnt in Year 1 as well as integrate knowledge they have learnt within all modules of Year 1.

The students typically start with the analysis of the Conformity of Content (how much of the active pharmaceutical ingredient (API) is present in the tablets), which follows the principals of our recently published PBL-inspired chemistry practical. (Strohfeldt & Khutoryanskaya, 2015) This requires the students to research the relevant methodology, undertake a H&S assessment, and analyze and evaluate their obtained data. Students submit an outline proposal to their virtual client to be signed off before undertaking any laboratory work. In the laboratory the students are not directly supervised; staff are only present for H&S reasons.

In the next step the students typically look at the required physical testing of the tablets given, as required for the Certificate of Conformity. Again the students research the methodology, and undertake a H&S assessment prior to submitting their outline proposal to their client. On receipt of approval from their virtual client, the students independently undertake the laboratory work to gather their data. As the relevant forms follow a very similar structure to the first sets of analysis, the students have the opportunity to demonstrate learning from the feedback received from the first submission.

Finally, the students summarize all their data in the Certificate of Conformity. At the end of the academic year, the students have the chance to meet their client to hand in their Certificate of Conformity personally. Meeting their client is a nice addition to the practical as the students take it very seriously and act professionally.

For the students to succeed in this practical class they must actively integrate knowledge from Years 1 and 2 together with principal study skills. The aim is to encourage the students to actively integrate knowledge and as a result this practical class targets a number of learning outcomes besides teaching the actual physical science skills such as setting up, performing laboratory experiments and analyzing the data. These learning outcomes include: to engage with quality assurance and relevant procedures; study and research relevant protocols; to perform a H&S assessment; to work to high standards; to make decisions; to develop an understanding of technical limitations; understand precision and accuracy; how to behave professionally; and insight into alternative career paths. In summary, it is not surprising that the focus is firmly directed towards integration of knowledge and teamwork.

Evaluation and assessment

The 'Integrated Practical' is officially associated with one module in Part 2 and contributes 30% to the overall module mark. The module itself contributes ¼ to the overall Part 2 grade. While the 'Integrated Practical' draws on elements of all modules in Part 2, it is formally positioned within one module as part of our governance structure.

In the past, students were assessed using traditional wet laboratory classes, which lacked real integration. The assessment focused on practical work as described by a laboratory manual and traditional laboratory write-up. The latter determined mostly the final mark. Typical marks were high with averages of 72% (average of four years of student cohorts).

This novel 'Integrated Practical' assesses a number of skills as indicated by the numerous learning outcomes as previously stated. Students are not 'only' assessed on their ability to perform experiments and write up their results. They are additionally assessed on their research skills, H&S evaluation, professional behaviour and crucially the ability to integrate knowledge. Students will not be able to achieve high marks if they fail to actively show vertical and horizontal integration. In addition, the 'Integrated Practical' follows a re-iterative process, where forms of assessment are replicated under different topics. Students are encouraged to learn from the feedback and integrate any new knowledge obtained.

Feedback is a crucial instrument to actively monitor and encourage integration. It is important that feedback is timely and of high quality in order to support the next steps. We have developed a series of marking schemes, which gives rapid feedback to the students for any work they submit to their virtual client. These marking schemes can be administered online, if the facilitator wishes, and provide the students with quantitative and qualitative feedback. The marking schemes are based on the re-iterative process of the 'Integrated Practical' and provide feed-back and feed-forward opportunities.

The marking schemes themselves are a series of marking rubrics comprising assessment criteria and performance indicators (see Table 1 as an example). The marker simply indicates the performance level and can provide brief individual feedback against every descriptor. This allows the facilitator to provide meaningful and efficient feedback to students.

Students are also required to use peer assessment to judge each other's teamwork skills. Teamwork is fully integrated into this practical and a crucial learning outcome. This prepares students for Part 3 and 4 of their degree and their future careers as health care professionals. The peer assessment marks contribute 10% to the overall mark of the 'Integrated Practical' to illustrate the importance of teamwork. Peer contributions were assessed using approaches traditionally applied in team-based learning (TBL). (Levine, 2012) Each team member is able to award 40 points (if they are in a five member team) and 50 points (if they are in a six member team) to their peers in order to rate their contribution to the teamwork. The students are able to distribute the points as they liked with only one rule that they are required to discriminate between their colleagues. This meant that it is not allowed to give all peers 10 points, they need to award at least one team member a higher and one team member a lower score than the average. Students are also required to reflect on their peers' performance on their feedback form.

Attendance itself is not assessed, however only the key laboratory working sessions are classed as compulsory sessions. However, interest at all workshops, feedback and drop-in sessions was generally high with more than 90% average attendance.

After the study gained ethical clearance from the School Ethics Committee, we invited students in the academic year 2016/17 to fill in a paper-based survey, to assess their interest in certain areas of their MPharm program, such as analytical and physical chemistry, team work and integration skills.

The survey was performed before and after the 'Integrated Practical'. Students were invited to judge the above mentioned categories on a 5-point Likert scale; strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). The survey was piloted and assessed for clarity by a small group of Part 3 students (10 students), which took part in the 'integrated practical' in the previous year. Both surveys had response rates of 44% (52 students) and 53% (63 students) respectively (student cohort 118 students). We were able to see a significant improvement in scores in all areas. Notably the learning outcome around team work achieved the best improvement in student satisfaction. However, it was great to see an upward trend in most areas, even in the subject related questions. Students clearly showed an increased interest and saw the relevance of science to their future profession after completing the practical. It was also pleasing to see that practically integrating their knowledge increased their confidence and understanding in the importance of integration of knowledge. While the confidence and enjoyment of teamwork was fairly high already before the practical class, it is great to see that students understood the importance of team work even more.

Table 1. Sample of marking schemes (rubrics) used to provide feed-back and feed-forward.

API analysis – Marking Scheme 'feedback point 1'							
Markers overall opinion on this assignment	Excellent work based on a thorough understanding of the problem posed, demonstrating clear and significant insight and well justified conclusions stemming from balanced argument **54**+: sophisticated, of highest professional standard **48**+: striking work demonstrated **42**+: excellent in all areas.	A good to very good work based on a sound to clear understanding of the problem posed to produce well-supported report ready for submission to virtual client. 3**6–41**	A competent to sound written report addressing the problem posed with standard sources. Some areas need improvement. **30–35**	A basic report, adequately written, but demonstrating only limited or superficial understanding of the problem posed. Report needs several corrections before submission to virtual client. **24–29**	Poorly written report showing little evidence of awareness of the issue. Report cannot go out to virtual client. **18–23**: some knowledge, but poorly presented. **12–17**: answered only in part, flawed. 6–**11**: deeply flawed or unacceptably brief **<6**: Irrelevant or unintelligible.	/60	COMMENTS
Experimental *Clear and detailed experimental section including all chemicals and amounts needed. Validation of experimental set-up included. Preparation of standard solutions included. Well referenced. Experimental description should be repeatable by any qualified person.*	Fulfils all the criteria on the left. No or very minimal help of supervisor needed. **14–20 marks**	Deficient in one area. Only minor corrections and/or help of supervisor needed. **12–13.5 marks**	Deficient in more than one area. Some corrections and or help of supervisor needed. **10–11.5 marks**	Deficient in more than one area Supervisor had to correct several parts of experimental description. Supervisor had to help with experimental setup. **8–9.5 marks**	Deficient in several areas. Significant corrections of supervisor needed. Resented experimental section not acceptable and repeatable. Inadequate. **< 7.5 marks**	/20	

(*Continued*)

Table 1. (Continued).

Background *Clear detailed background explaining the basis science of the experimental setup chosen. Well referenced. Including brief discussion of key facts and/or theories. Chemical equations included.* *Logical progression to the experimental setup chosen.*	Fulfils all the criteria (left). Demonstrates a full-mastery of the background material in the chosen area, logically integrating theory and evidence from wide range of relevant sources to address the research question posed. **10.5–15 marks**	Demonstrates a good understanding of the background material in the chosen area by integrating relevant information from a good selection of relevant sources to address the research question posed. **9–10 marks**	Demonstrates a sound understanding of the relevant background material in the chosen area through application of an adequate range of standard sources to address the research question posed. May have some gaps or minor misunderstanding/ errors **7.5–8.5 marks**	Demonstrates a limited understanding of background material in the chosen area through use of a few standard sources, which may not always be relevant to the research question posed. Likely to have significant gaps and or important areas of misunderstanding or errors. **6–7 marks**	Understanding of the relevant background material in the chosen area is not evident. Inadequate. **<5.5 marks**	/15
Risk Assessment Filled in completely and correct, including R/S phrases, Amount chemicals etc. Correct reference sources used. Understanding of risk assessment demonstrated.	Fulfils all the criteria on the left. No corrections of the supervisor necessary. **7–10 marks**	Deficient in one area. Only minor corrections of supervisor needed. Understanding of risk assessment has been demonstrated. **6–6.5 marks**	Deficient in more than one area. **5–5.5 marks**	Deficient in more than one area Supervisor had to correct several areas of risk assessment. **5–5.5 marks**	Deficient in several areas. Significant corrections of supervisor needed. Presented Risk assessment not acceptable for safe laboratory work. Inadequate. **< 4 marks**	/10
References *Appropriate sources used and correct acknowledged of source materials. References in consistent scientific style, preferable Vancouver style.*	Wide range of resource material; citations wholly accurate and in correct format, citations match those mentioned in main body of report. **7–10 marks**	Deficient in one area Variety of resource material referenced; citations are mostly correct. **6–6.5 marks**	Deficient in more than one area Limited range of resource material; citations show many errors. **5–5.5 marks**	Heavy reliance on very few standard sources. Citations do not follow an appropriate style or are incomplete. **5–5.5 marks**	Poor or incorrect use of materials. Inadequate. **< 4 marks**	/10

(*Continued*)

Table 1. (Continued).

Overall Format *Clear overall format. Professionally presented work. Can be given to virtual client without any changes. Well referenced. Guidelines followed. Signed and dated by all team members.*	Full fills all the criteria on the left. Report can be send to virtual client without alteration. **3.5–5 marks**	Deficient in one area **3 marks**	Deficient in more than one area **2.5 marks**	Presentation of report is just about acceptable to be send to virtual client. **2 marks**	Presentation of report is of too low standard to be send to virtual client. Inadequate. **<2 marks**	/5

Additional comments:

Discussion

The ‘Integrated Practical’ is designed to engage students in real-life scenarios, empowering their employability skills and to foster maximum integration of subject material and acquired skills from various modules throughout their degree program. Students are required to work for a client, which contacts the teams via video links and emails regularly. This acts as a strong trigger for our students which is an integral part of PBL and encourages them to approach the various tasks from a professional perspective,

It is certainly a highlight for the students when they meet their client and personally hand over their Certificate of Conformity. The Certificate of Conformity summarizes all their research they undertake throughout their 20-week practical class.

Students are highly motivated and generally enjoy this practical class. This is difficult to evidence, but we noticed a high attendance rate and very professional approach to their work, communication and attitude. Also, all teams submitted their coursework elements on time; late submission would have resulted in a penalty, according to standard University policy, but no penalty had to be applied to date.

We have run the ‘Integrated Practical’ for three consecutive years and evaluated the coursework grades students obtained. Students submit their work for the Conformity of Content testing (API analytical testing work) in two parts and the same for their testing of the physical properties. This essentially provides the students with four feedback/feed-forward points as these submissions are similar in structure (see Figure 1). In addition, students submit a piece of coursework relating to the therapeutic aspects of the drug they are working on and finally, the Certificate of Conformity; the latter does not contribute to the overall grade as it ‘only’ summarizes the analysis work, however it mirrors the professional output requested from this practical class.

Comparing marks for the same team throughout the year clearly shows an improvement of grades from coursework submission to coursework submission throughout the four submission points for the majority of teams. This means that feedback has clearly been taken into account and our mechanism of feed-forward is successful.

Mark distribution follows the typical Gaussian distribution curve and the average marks throughout the three years the course has run (2014–2017 as sample years) are 62.6%, 63.7% and 65.5% respectively. We believe that these marks are a realistic representation of the abilities of our students as they are in line with other assessments.

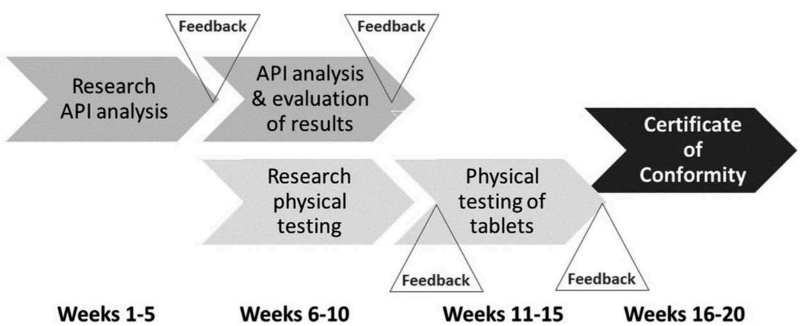

Figure 1. Illustration showing the four 5-week teaching blocks with feed-back (and feed-forward) points.

Previously, we saw a grade inflation in the marks students obtained in our traditional practical classes, which has not been replicated in this 'Integrated Practical' design. The marks also show that students apply the concept of integration well as they achieved overall good marks, which would not be possible without active integration of knowledge and skills learnt across Year 1 and Year 2. The integrated practical requires the students to actively apply skills and knowledge, which have been taught in previous years and/or modules as well as other subjects, in order to complete their tasks.

PBL is used as the main form of instruction to facilitate an active form of integration. (Fenwick, 2002; Winslade, 1994) The facilitator actively steps back and 'hides' behind the client. However, the facilitator can support the teams in their group work, especially in the development of their experimental design and processing their feedback. In return, this allows the facilitator to monitor team dynamics and intervene if necessary. The PBL approach is well known to actively encourage logical thinking and problem solving skill (Strohfeldt & Grant, 2010), which makes it an ideal medium to teach in an integrated manner.

This 'Integrated Practical' design is suitable for teaching large cohorts at University level. Our current cohorts consist of up to 150 students and the practical class is staffed by 1–2 faculty members who act as facilitators and provide feedback; the latter takes up the majority of the workload. The team is support by the typical compliment of technical staff, which provide support for the practical work in the laboratories. Health and Safety concerns in regards to the laboratory work, which is undertaken without a pre-prepared manual, can be addressed by the smart choice of the drugs to be assessed and the laboratory facilities available. Furthermore, each team submits a technical proposal to their client before entering the laboratory. This proposal is marked and feedback given, which also allows the facilitator to step in if any H&S concerns appear.

Peer assessment was welcomed by the students as they appreciated the individual recognition of their contributions. Often the peer assessment is used to scale a group mark. However, we have found that this process is not transparent for the students and as a result students do not feel recognized for their effort as an individual. Therefore, we decided to attribute 10% of the overall mark to the peer assessment itself. This means that the peer assessment mark as an individual component is highly visible to the students. Peer assessment marks averaged at 72% ranging from 40% to 97% showing a good and representative spread of marks. Students appreciated this option as it combined teamwork and the desire for individual recognition in a satisfactory way.

Students' perception of the integrated class was evaluated via the class surveys, which were undertaken at the beginning and at the end of the teaching year (see Table 2). The results clearly show that students understand the importance of the teamwork, as they stated they enjoyed it more (Table 2; agree increased from 67.3% to 76.2%) and believed more that it was relevant to their future career (Table 2; agree increased from 82.7% to 100%) while maintaining their confidence (Table 2; agree increased from 73.1% to 76.2%) after undertaken the 'integrated practical'. It was very pleasing to see that questions evaluating the relevance of science and the importance of integration gained significant in agreement (see Table 2). This nicely shows that the design of the 'integrated practical' fulfills its remit of integrating knowledge across the subjects and illustrating the relevance of science to the profession.

Table 2. Summary of pre- and post-practical survey. Numbers stated in the table refer to number of students ‘agreeing’ (Likert scale answers 4 and 5) versus students ‘disagreeing’ (Likert scale answers 1 and 2); cohort size 118 students.

		I am interested in analytical Chemistry	I believe analytical Chemistry is relevant to my future career	I am interested in the Physical properties of Drugs	I believe the Physical properties of Drugs is relevant to my future career	I believe integration of knowledge is important	I enjoy integrating knowledge	I believe learning in an integrated curriculum will benefit me in my future career	I enjoy working in teams	I am confident working in teams	I believe teamwork will be relevant to my future career
before	disagree	7	6	4	5	4	5	2	5	2	3
‘Integrated		**13.5%**	**11.5%**	**7.7%**	**9.6%**	**7.7%**	**9.6%**	**3.8%**	**9.6%**	**3.8%**	**5.8%**
Practical’	agree	25	2	39	40	44	36	38	35	38	43
		48%	**4%**	**75%**	**77%**	**85%**	**69.2%**	**73.1%**	**67.3%**	**73.1%**	**82.7%**
after	disagree	13	7	0	3	0	2	0	3	5	0
‘Integrated		**21%**	**11%**	**0%**	**5%**	**0%**	**3.2%**	**0.0%**	**4.8%**	**7.9%**	**0.0%**
Practical’	agree	37	39	55	54	59	48	62	48	48	63
		59%	**62%**	**87%**	**86%**	**94%**	**76.2%**	**98.4%**	**76.2%**	**76.2%**	**100.0%**

Table 3. Shows the marks achieved at each feedback point. Feedback point 1 and 2 belong to the API analysis, while feedback point 3 and 4 show the knowledge being applied to the physical testing.

	Feedback point 1	Feedback point 2	Feedback point 3	Feedback point 4	Peer assessment
Average	67.6	72.9	61.9	70.2	76.1
Min	46.67	47.27	46.45	33.85	40
Max	88.22	87.45	77.14	84.62	97.5

Integration forms the fundamental basis of this practical and is indicative in every aspect of the students' work. Students must actively integrate knowledge from Year 1 as they need this knowledge to develop their work plans. Further guidance was often given in accompanying modules to the students alongside the practical class. Therefore, timing of the delivery of teaching material and cross sign-posting by teaching staff is crucial. It is advisable to develop a skills map clearly outlining which skills or knowledge are required to feed into the 'Integrated Practical' and in which teaching session these are presented. It is therefore also crucial for the teaching staff to work as a team and emphasize good communication amongst staff, and between staff and students to achieve integration on such a large scale across and along teaching years and modules. Class surveys and grade profiles within the year (improvement of marks from submission point to submission point) clearly showed that students appreciated and actively engaged with the process of integrating their knowledge (see Tables 2 and 3).

While there are many beneficial aspects to the 'Integrated Practical' as described here, it also has potential limitations. The emphasis of the practical has shifted from a very experimental orientated practical, as you normally find in a laboratory practical setting, to a teaching exercise that emphasizes the planning and development of the experiments equally to the experimental work. Therefore, one could criticize that students obtain less hands-on experience compared to a traditional chemistry practical class, where students are provided with a laboratory manual, with the emphasis on the physical work in the laboratory. However, for us it is important that the students gain the full experience of planning, devising and undertaking experiments; therefore, the research around the analytical testing, understanding limits and devising Health and Safety protocols are important learning outcomes. Furthermore, it is important to place this practical in a formal setting, which is relevant to their potential future profession, in order to take advantage of the professional interest of the students and train their professional behavior.

Furthermore, students are exposed to only one drug/active pharmaceutical ingredient, which could be perceived as a limitation. By using the described PBL as our pedagogic approach, we emphasize the teaching of transferrable skills. We are therefore confident that the skills acquired can be applied to a wide range of scenarios preparing the students for life-long learning and continuous professional development.

Conclusion

The 'Integrated Practical' successfully exposes and guides students through the subject area of physical sciences, which is traditionally less popular with undergraduate Pharmacy students, with the 'assistance' of a virtual client. Applying integration as the pedagogic approach and using a client facing scenario certainly improved the interest in the subject area – the 'Integrated Practical' was well perceived by the students. The course nicely followed the four attributes for a successful integration as outlined in the introduction: authentic learning environment, encouraging students to explore further, promotion of higher level thinking and a cyclic learning process. (Ratka, 2012)

There is clear evidence that students understood the need for integration and that they actively learnt to integrate a wide range of knowledge. Improvements in marks throughout the practical at the various assessment points showed that their knowledge improved and that students applied their integration skills. The practical successfully guided the students in learning how to integrate knowledge and skills to the point that integration of knowledge learnt in different subject areas became the norm at the end of the practical class.

Students are often not keen on teamwork as they want to be recognized for their individual potential. However, good team-working skills are important to their future work as health care professionals and therefore it is an area which is emphasized in all healthcare related courses. We were able to see that our design of the 'Integrated Practical' fostered a positive attitude towards teamwork. Students learned to understand why working as a team was important and it naturally became the default working arrangement.

The design of the 'Integrated Practical' actively encourages the students to achieve a number of generic learning outcomes important to their future careers integrated in the subject knowledge learning. These learning outcomes and the integration must be carefully mapped out to be successful. However, if coordinated correctly, it can be a very powerful and engaging pedagogic approach. In our evaluation of the 'Integrated Practical' we could clearly see highly engaged students, who mastered how to actively learn to integrate skills and knowledge from within their whole degree to this point. The students displayed skills, which were clearly transferrable to a number of different scenarios and prepared the students well for their continuous professional development and life-long learning.

The pedagogic approach used can be applied and adapted to a wide range of scenarios and is not restricted to the physical sciences. It is important to actively support the students to learn how to integrate knowledge, but at the same time to accept the student is the owner of their own learning. It is important to visibly step back to allow the students to find their own pace while at the same time giving the students enough guidance to transition them to independent learners able to integrate knowledge.

Disclosure statement

No potential conflict of interest was reported by the author.

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