ChemRoots

A Science Engagement Project

Business Plan

cchange
DST-NRF Centre of Excellence in Catalysis

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Ley summary

The c*hemRoots project will develop and distribute curriculum-aligned support material, in the form of a series of teaching resource kits for grade 8-12 science teachers, throughout South Africa. The material is intended to support science teachers in teaching key chemistry concepts using hands-on practical activities, while focussing on conceptual understanding. National distribution of the material will take place through training workshops in collaboration with the provincial education departments, local science centres, and existing organisations working in the science education field. A series of short courses will be designed to provide longer-term teacher support beyond the timeline of this project. The project is a DST-NRF Centre of Excellence in Catalysis c*change initiative, supported and guided by the Department of Chemical Engineering, the Faculty of Engineering and the Built Environment, and the Schools Development Unit at the University of Cape Town.

Who is c*change?

c*change is a DST-NRF Centre of Excellence in Catalysis, and is hosted within the Department of Chemical Engineering of the University of Cape Town (www.cchange.ac.za). Amongst the first six centres established by the Department of Science and Technology (DST) and the National Research Foundation (NRF) in 2005/06, c*change was devised as a virtual centre. While hosted at the University of Cape Town, 25-30 researchers at 14 research groups and 11 national Higher Education Institutions collaborate in three research programmes, namely synthesis gas conversion, paraffin activation, and olefin functionalization, with a strong focus on the South African chemical industry.

The main mandate of c*change is to train highly qualified MSc and PhD graduates by conducting fundamental research of an international standard. Currently c*change supports approximately 50-55 postgraduate students and 15 post-doctoral fellows, of which 50% are female, over 80% are South African (over 90% are African) and approximately 80% are black, through bursaries and running cost contributions. The total annual budget of R8.9m obtained from the DST is supported by an additional R6m, solicited through various funding streams secured by individual c*change researchers.

Table of Contents

Project Overview 1
The need for teacher support 2
Material development 2
Piloting of the material 3
Project timeline 3
Manufacturing 4
Distribution 4
Reach beyond the project timeline 4
Copyright considerations 5
Space requirements 5
Objectives 6
Mission 6
Market analysis 7
Financial plan 8
Budget 9
Conclusion 10

Project Overview

It is one of the key strategic goals of the University of Cape Town (UCT) to actively work towards a transformed society and workforce in South Africa, both in the private sector as well as within the University. Regarding candidates for an academic career, the university is in direct competition with the private sector over a given number of graduates in each field of study. Many graduates, especially those from previously disadvantaged backgrounds, still do not see the academic career track as a viable option, and branch off into the private sector. Multiple interventions are designed to counter these developments, ranging from dedicated early stage support and mentoring strategies, to direct financial incentives. The Faculty of Engineering and the Built Environment is spearheading such an activity with its 'Growing the Future Generation of Academics' project. While extremely valuable and without alternative, all these processes are limited by an extremely poor performance at matric level.

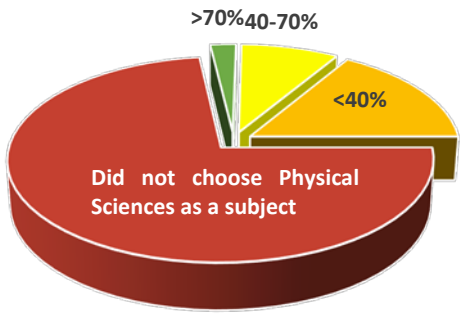

Figure 1: Performance of matriculants in the 2016 Physical Sciences examination

Physical Sciences is a gatekeeping subject for admission to tertiary level science and engineering programmes. In 2016 only 192 618 (27%) out of a total of 717 371 South African matriculants wrote the Physical Sciences examination. Of these, 39.2% (76 044 students) achieved a 40% pass and only 8.2% (15 795 students) obtained the minimum threshold of 70% for guaranteed admission to the Faculty of Science and the Department of Chemical Engineering at the UCT. Thus, only 2.2% of 2016 cohort of matriculants actually qualified for guaranteed admission.

A closer look at the chemistry examination results (see Figure 2[1]) confirms that students perform poorly in nearly all chemistry topics.

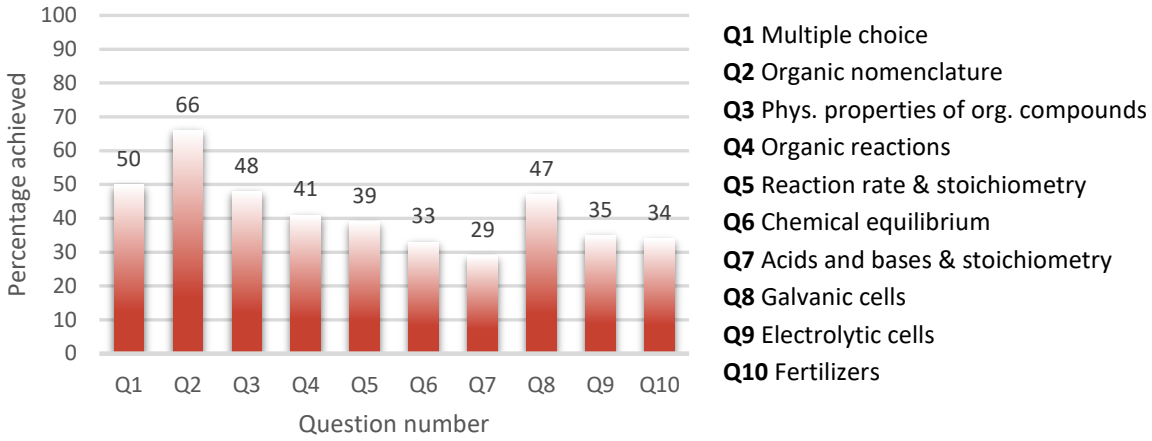

Figure 2: National average percentage achieved per question and topic in the 2016 chemistry examination

[1] DBE. (2017). National Senior Certificate examination 2016: Diagnostic report. Pretoria, South Africa.

The need for teacher support

Although many factors play a role in poor learner performance at school level, one issue that has been identified is the teachers' lack of content knowledge and methods of teaching the content effectively[2]. The DST-NRF Centre of Excellence in Catalysis, c*change, has identified this gap in the past and has acted upon it. A curriculum change in 2006 introduced new topics to the Physical Sciences curriculum. c*change, with financial support from SASOL, developed a 'Chemical Industry Resource Pack', providing teachers with content and context to teach the new topics. Posters, animations and videos of practical activities were also provided. A major strength of this project was the distribution of the resource packs through workshops where teachers had the opportunity to engage with the materials and learn how to best integrate it into current teaching practices.

The Chemical Industries Resource Pack project was concluded in 2012, although continued interest was signalled by teachers. In 2016, under the lead of Dr Nico Fischer, the idea of c*hemRoots was developed. In contrast to providing teachers with content on new topics, this current project will provide educative curriculum materials, which focus on using practical work as a teaching strategy to promote conceptual understanding of key topics in chemistry. Educative curriculum material, materials that not only provide teaching resources, but also provide content and pedagogy support, have been found to be effective in supporting practicing teachers[3]. This type of teacher support material is available in developed countries, but little is aligned to, or available, for the current South African curriculum.

Figure 3: Workshop with 35 teachers at the University of Johannesburg held on the 6th of September 2017.

Figure 4: c*hemRoots prototype kit

Material development

In the form of a c*change funded post-doctoral research project, a proof of concept and a pilot product was developed in collaboration with high school teachers in the Western Cape, Gauteng and the North-West Province. Workshops were held where the kit, containing teaching aids for one specific curriculum relevant topic, namely acid-base chemistry, was tested and discussed. This kit is not just a box containing chemicals for specific experiments, but rather a collection of resources which allow teachers to illustrate

[2] Spaull, N. (2013). South Africa's education crisis. *Report for the Centre for Development and Enterprise (CDE). Johannesburg*.

[3] Schneider, R. M., & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education*, *13*(3), 221-245.

theoretical concepts using hands-on practical activities (see Figure 4). It must be noted that these activities are not intended to replace formal chemical practical investigations required by the curriculum, but rather provide alternative teaching strategies to more effectively teach fundamental concepts. Various suggestions on how to apply the materials in different teaching environments are demonstrated in the respective roll-out workshops. A teachers' guide, which elaborates on the content covered and describes appropriate teaching strategies, will also be provided.

Piloting of the material

The draft material will be tested in a variety of teaching contexts before it is finalised, to ensure useful and context-appropriate resources. The School Development Unit (SDU) at the University of Cape Town has a long history of working in various educational settings, especially in township[4] contexts, and the development and piloting of the material will take place in close collaboration with the SDU.

Project timeline

The three-year project plan is depicted in Figure 5.

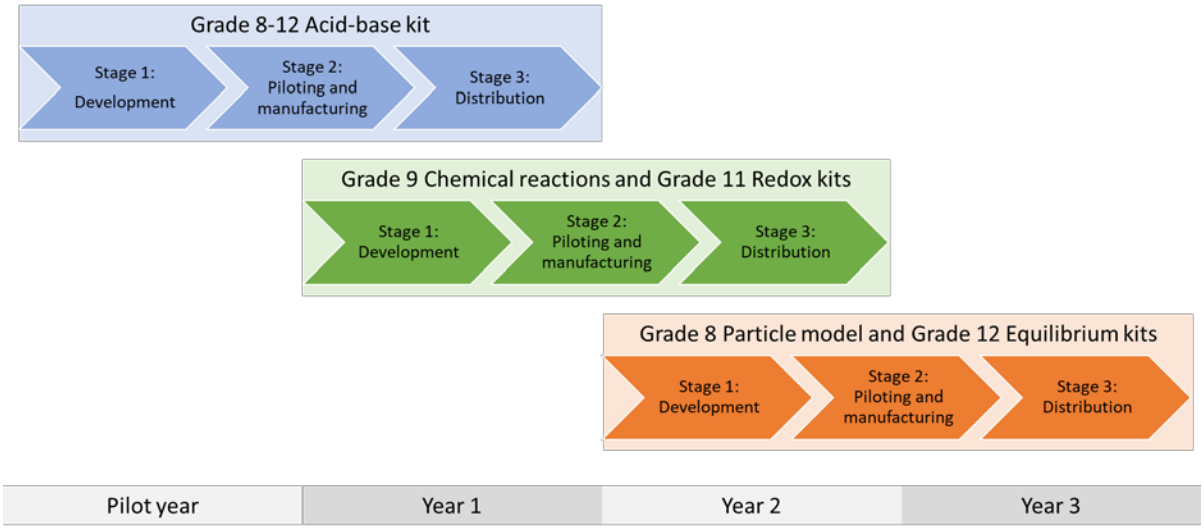

Figure 5: Three-year timeline for c*hemRoots project, including the c*change funded post-doctoral research project in 2017

In Year 1, the prototype acid-base kit, which was developed during the post-doctoral project in the pilot year, will be finalised, manufactured and distributed throughout the country. Parallel to this, two further kits on new topics will be developed and piloted. During Year 2, the second and third kits will be finalised, manufactured and distributed, while the fourth and fifth kits will be developed. Year 3 will see the finalisation, manufacturing and distribution of the two final kits, and the conclusion of the project. Over the course of the project five kits will therefore be developed and distributed throughout South Africa. It is envisaged that 5000 kits for each topic will be manufactured, totalling 25 000 c*hemRoots kits over the three-year period.

[4] A township is an urban settlement area characterised by high unemployment and low levels of infrastructure. 'Township' has similar connotation to 'inner city' in first world settings; however, townships are not situated in city centres, but rather on the outskirts of cities.

Manufacturing

The kits will be assembled at the Department of Chemical Engineering with the support of undergraduate students. A further possibility is to establish collaborations with high schools surrounding the University of Cape Town and offer a community service project. Many high schools near the university have a community service requirement as part of the Life Orientation curriculum in grades 8 to 10. The project team could introduce a small group of high school learners to the purpose and reach of the project, show them the facilities at the University of Cape Town, and in return get support in the production process. Since the contents of the kits do not include specialised chemicals or sensitive equipment, no special safety precautions are required for this work.

Distribution

The success of any project which involves the supply of teaching support material is dependent on the level of engagement the teachers have with the material at the point of distribution. The distribution of the c*hemRoots kits will be done through face-to-face workshops where teachers will have the opportunity to engage with the material, and discuss its use in the classroom.

The workshops will be arranged in close collaboration with the provincial education departments, science centres, and other organisations involved in science education. Since c*change has been involved in the development and distribution of teacher resources in the past, existing relationships with such role players will be utilised. A 'train-the-trainer' approach will also be used when engaging with education department officials, lead teachers and facilitators at science centres, equipping them to conduct further training workshops with teachers.

The roll-out workshops in the first project year will provide opportunity for teacher input into new resources still under development. The new material will then be distributed in workshops in subsequent years, aiming to reach the same teachers to achieve continuity and continued engagement with the same individuals over time. This will strengthen the relationship between UCT and teachers from the various provinces, and lay the foundation for a community of teachers.

Reach beyond the project timeline

It is the explicit idea of c*hemRoots that teachers continue to engage with the materials after the roll-out workshops, and even develop new applications beyond the ones supplied. A web platform for teachers to share these developments will be utilised to establish and support a community of professionals that can continue to operate beyond the timeline of the project.

To ensure the longer-term sustainability of the project, topic specific short courses will be developed in collaboration with the SDU. The intention is that a teacher will be able to attend several courses over an extended period. Teacher support will therefore not be once-off, but continuous, building a relationship between teachers and the training team. The development of short courses is aimed at becoming part of the compulsory Continuous Professional Teacher Development (CPTD) programme as specified by the South African Council of Educators (SACE). Since 2016 teachers must earn 150 CPTD credits over a period of 3 years as part of their personal professional development plan. This programme is new and there are not many service providers in this space yet. There is thus a gap in the market for quality professional development initiatives which are aimed specifically at supporting teachers in the classroom.

Copyright considerations

All written material in the kits will be published under a Creative Commons licence (CC-BY-SA) allowing teachers to modify and reproduce the material for non-commercial educational purposes. Blueprints to the kits will be made available through social media and through a dedicated web presence. The project aims to develop a community of science teachers who has been exposed to teaching strategies using practical work, and who would be encouraged to develop the materials further, or even create and share their own material.

Space requirements

The initial developments of the materials will be carried out in the laboratories of the Catalysis Institute and the Department of Chemical Engineering at the University of Cape Town. This extensive network of professionals, supplemented by the content experts in c*change, will be utilized to ensure conceptual accuracy of the content. Additional support regarding space as well as administration will be provided by the Faculty of Engineering and the Built Environment.

Objectives

The overall objective for the c*hemRoots Project is to produce and distribute curriculum-aligned chemistry teaching kits on five different topics to high school science teachers in all nine provinces in South Africa. This will involve:

I. **Development** of curriculum-aligned teacher support material, in the form of a series of teaching kits, which includes practical activities and accompanying teaching strategies to teach fundamental concepts in the chemistry curriculum.
II. **Piloting** of the draft material with practicing science teachers in various teaching contexts, especially in the township environment, through the network of the Schools Development Unit at UCT to ensure a useful and appropriate product.
III. **Manufacturing and distribution** of the kits to teachers in all nine provinces through national roll-out workshops where teachers will engage with the material.
IV. Development of a **community** of science teachers in South Africa by developing a web platform where teachers can exchange ideas, new applications and experiences and ask questions related to the use of the kits.
V. Development of **short courses** based on the kits, through collaboration with the UCT Schools Development Unit, to extend the use of the material beyond the project timeline.

Mission

It is the c*hemRoots Project's mission to develop and actively distribute curriculum-aligned resource materials which allow high school science teachers to more effectively teach fundamental concepts in chemistry. It is our belief that more effective teaching will positively influence the number of students choosing Physical Sciences as a subject in grade 10 and improve performance in the final examination in grade 12. Increased performance at school level translates into more students who are eligible for access into engineering and science programmes at tertiary level. A better conceptual preparation at school level also increases success at university, which results in a healthier foundation from which universities and the private sector can grow both a highly-trained workforce, and a new generation of academics.

Market analysis

There are many organisations, universities and other stakeholders who provide a variety of services to improve education in South Africa. Many of these services are aimed at learners, especially matriculants, to improve performance in the high-stake exit examination.

Some organisations, for example the network of Science Centres in South Africa, also aim to improve learners' interest in science. A notable example is Nkazimulo Applied Sciences with their ChemStart kit. The kit aims to raise learners' interest in science by providing chemicals, equipment and instructions for 52 experiments that learners can do at home.

Fewer products and services are available for teachers, and even fewer include face-to-face interactions with teachers as part of the distribution strategy. The RADMASTE Centre at the University of the Witwatersrand had been providing teacher resource materials and teacher workshops for many years, but recently closed. Their Microscience Kits are well-known in South Africa and abroad. These kits are cost-effective and useful, but are micro-size, and often perceived to be difficult to manipulate due to their size.

Other role players include the MyLab Physical Sciences laboratory unit. The unit includes equipment and chemicals for curriculum-aligned experiments and is accompanied by a teacher manual and training videos and a short training course. Although the units are high quality and very useful, the pricing structure is often beyond the reach of the average school in South Africa.

The Siemens Foundation also design and distribute extensive teacher resource kits (the Experimento series). These include a large collection of experiments and all the equipment and chemicals needed for it. The kits are distributed through an intensive teacher training course, but the experiments are not all aligned to the South African curriculum, and therefore of limited use.

There is thus a gap in the market for affordable, easy to replenish, curriculum-aligned teacher resources which focus on practical work, and are accompanied by a training course to support teachers in the implementation of the material.

Financial plan

The financial plan discussed in the following encompasses all costs for the c*hemRoots project, building on the development of the first teachers' resource kit on acid-base chemistry conducted in 2017 as part of the c*change funded post-doctoral project.

Three different cost positions contribute to much of the total budget, namely staffing, development and production, and finally distribution and training costs. Through the support from the Faculty of Engineering and the Built Environment as well as the Schools Development Unit at the University of Cape Town, **no overhead** in form of laboratory and office space, administrative assistance, electricity, telephone, internet, and library facilities contributes to the overall costs.

The **staffing contribution** consists of one new entry level Research Officer position (approximately 80% of the cost). Although soft funded, i.e. not financed by the General Operating Budget from the University, but via external sources, the position is fully aligned to University's pay policy, and is also managed via the same channels. The balance cost is a 10% contribution to the salary of Dr Nico Fischer, the principal investigator in the initiating post-doctoral project, who will remain in this role in c*hemRoots. The remaining 10% includes about R197 000 over the full duration of the project assigned to an ad-hoc staff member assisting in the production of the boxes.

A second major cost contribution are the **development and production costs**. These are dominated by the actual costs for the containers and materials, with the actual development costs and fees for storage for the produced boxes before distribution only contributing 5-10%. It must be noted that in the present financial plan and budget, retail costs are assumed for the plastic containers as well as the teaching materials that make up the kit, with the former representing approximately 50% of the costs. Even without the identification of a sponsoring entity, which produces such plastic containers, the sheer number of required containers (a total of 25 000 over three years) warrants the assumption that the costs per unit will be lower than the here underlying retail costs.

Finally, the **distribution of the developed materials** in form of teachers' workshops (a minimum of nine per year), travel of project members to the workshops, and sending the materials from the production site to the workshop venue. The latter contributes approximately 50% to the costs. This is another possibility for a dedicated external funder to get involved in the c*hemRoots Project. It is envisaged that costs for venue hire will be kept to a minimum. The extensive network of Higher Education Institutions of c*change, as well as the established relationships with schools, science centres and provincial education departments, will be utilized.

Budget

	Total	Year 1	Year 2	Year 3
Staff costs [a]	**R2 479 623**	R771 291	R825 281	R883 051
Development costs	**R100 000**	R50 000	R50 000	
Production of boxes [b]	**R3 930 000**	R790 000	R1 570 000	R1 570 000
Storage of boxes	**R54 000**	R18 000	R18 000	R18 000
Workshop and delivery costs	**R565 000**	R165 000	R200 000	R200 000
Travel [c]	**R183 600**	R57 600	R61 200	R64 800
Development of web presence and branding	**R64 000**	R 60 000		
Maintenance of web presence			R2 000	R2 000
Subtotal	**R7 376 223**	R1 911 891	R2 726 481	R2 737 851
VAT	**R1 032 671**	R267 665	R381707	R383 299
Total	**R8 408 894**	R2 179 556	R3 108 188	R3 121 150

[a] One staff member on entry level Research Officer, 10% of Senior Research Officer and 25-30% of PASS staff in pay class 5.
[b] Production of 5000 boxes in Year 1 and 10000 each in Year 2 and Year 3.
[c] National travel to nine workshops per year including ground transport and accommodation.

Conclusion

The c*hemRoots project aims to develop and distribute a total of 25 000 kits, on five different chemistry topics, over a period of three years, to science teachers throughout South Africa. The resource materials will support teachers in teaching key chemistry concepts using hands-on practical activities while focussing on conceptual understanding.

Through the strong support of c*change and its partners, the Department of Chemical Engineering and the Faculty of Engineering and the Built Environment, as well as the Schools Development Unit at the University of Cape Town, that the project has the potential to impact the teaching of chemistry on a national level. The existing network allows to engage with teachers with very different social backgrounds during the development of the materials as well as for the subsequent distribution.

The establishment of a web platform where teachers can engage will create a community of professionals who can support each other beyond the scope of the project. Furthermore, accredited short courses will guarantee the use of the material beyond the timeline of the project and will contribute to the professional development of science teachers in South Africa.

We believe that an increased conceptual understanding of teachers will translate into an increased interest by learners and subsequently to improved performance at school level. This translates into more students who are eligible for access into engineering and science programmes at tertiary level. A better conceptual preparation at school level also increases success at university, which results in a healthier foundation from which universities and the private sector can grow both a highly-trained workforce, and a new generation of academics.

Workshop at NWU 19/08/2017

Bicarbonate + vinegar
UJ 06/09/2017

Working with indicators
UJ 06/09/2017

Group photo at UJ 06/09/2017

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