Print ISBN: 978-93-90149-86-5, eBook ISBN: 978-93-90149-87-2

Case Study: A Roadmap for Developing Capacity in Plant Biotechnology Field Research

John W. Medendorp[1], Jane Payumo[2*], Cholani Weebaddee[2], Kelly Zarka[2], Karen Hokanson[3], Phil Wharton[4] and Dave Douches[2]

DOI: 10.9734/bpi/ctas/v1/12143D

ABSTRACT

This case study analyzes learning gains from a five-year capacity development effort for a biotechnology project focused on the development, testing, and preparation for the general release of a genetically engineered potato under national biotechnology regulatory regimes in two Asian countries. This study contributes to two gaps in the literature 1) the application of experiential learning to biotechnology, and 2) training for biotechnology in developing countries. The case study methodology was applied to data collected using statistical comparisons (mean and standard deviation) between the pre-and post-project period to determine the impact of the HICD intervention on the Country A and Country B core teams. Due to non-normal data determined after the Shapiro-Wilk test, a non-parametric equivalent of the *t*-test, the Wilcoxon rank-sum test called Mann-Whitney U-test, was employed to determine statistically significant differences between the pre-and post-fellowship datasets. Significant learning gains were made in most areas of biosafety practice using experiential learning methods. Where gains were not made, it was due to a breakdown in the application of experiential methods. Training in biosafety, especially in poorly regulated or unregulated contexts, is best benefited by a systematic experiential learning process, adequate base knowledge, time-extensive training in standard operating procedures accompanied by mentoring and coaching, frequent formative evaluation, and simulated trials under local conditions where trainees can experience the full process of biosafety operating standards under the constraints of their contexts.

Keywords: Biotechnology education; capacity development; biosafety training.

1. INTRODUCTION

Genetically engineered (GE) plants hold great promise for improving crop yields, reducing toxic chemical usage, and preventing pre-and post-harvest losses. In a world where food is still in increasingly short supply and where vulnerable members of our human race are exposed to hunger and its destructive effects, including death, we would be unwise to turn away from the potential that GE crops represent. GE crops have the proven potential to reduce the damaging effects of pathogens and pests, improve the crops ability to survive and thrive in sub-optimal conditions, reduce the use of chemical inputs that are damaging to the environment and human health, and thereby improve family incomes, health, and nutrition [1,2,3]. For these reasons, development agencies and philanthropic organizations, such as the US Agency for International Development (USAID) and the Bill and Melinda Gates Foundation, have invested in bringing these promising new technologies to the developing countries where they offer some of the most benefits, and building the capacity of the research communities in these countries to understand and utilize the technology to its greatest potential. Some of the crops and traits that have been or are being developed using biotechnology specifically for developing countries include banana, cassava, corn, cowpea, banana, eggplant, potato,

---

[1] *Purdue University, College of Agriculture, USA.*
[2] *Michigan State University, College of Agriculture and Natural Resources, USA.*
[3] *University of Minnesota, College of Food, Agriculture and Natural Resource Sciences, USA.*
[4] *University of Idaho, College of Agricultural and Life Sciences, USA.*
**Corresponding author: E-mail: payumoja@msu.edu*

rice with disease resistance, insect resistance, drought tolerance, or improved nutritional quality [4]. Most of these projects have a significant human and institutional capacity development component to enable the conduct of research in-country, particularly to conduct critical field trials in the crop-growing environment of the country.

Although there is strong scientific evidence in support of the potential benefits, there are safety concerns and there remains entrenched opposition to GE crops, especially in Europe (governments and activists) and North America (activists) [5,6,7]. GE crops have been grown in the United States and other countries for more than twenty years without a single documented incidence of harmful effects to humans or the environment. In 2018, the 23rd year of continuous global biotech crop adoption, a total of 70 countries adopted biotech crops through cultivation and importation; Twenty-six countries, of which 21 were developing countries, planted 191.7 million hectares of biotech crops [4]. These crops have all passed through the regulatory systems and have met the requirements for safety approvals in the countries where they are grown or used for food or feed, at which point they are considered no longer regulated (or ‘deregulated’) according to the regulatory systems in most countries. Safety arises from being able to identify, measure and manage potential risks, which is the purpose of the national regulatory systems. These regulatory regimes are required to ensure the proper development and use of GE crops and minimize the potential risks [8]. Therefore, it is incumbent upon all practitioners of biotechnology to ensure that regulatory requirements are properly met until it can be determined by the national regulatory authority that GE crops, with sufficient management, pose little or no risk to either human health or the environment, especially where the regulatory systems are newly developed, inexperienced, and often driven by political motivations and misguided policies [9,10,11]. For these projects, it is an important goal to develop the capacity of the research community not only to properly conduct the research but also to understand and meet all the necessary regulatory requirements.

This publication details the experiences of a five-year biotechnology project to develop and test a three resistance (R) gene late blight-resistant potato. Our capacity development theory of change builds on the extensive research foundation of experiential learning. We review the literature, describe our initial theory of change, present the case study on our capacity development efforts in Country A, in conjunction with an institute devoted to the study of biogenetic resources agricultural resources, and biotechnology, and country B, in conjunction with a sub-center of the national agricultural research institute focused on tuber crops. We conclude with lessons learned, and adaptations to the approach over the five years.

2. LITERATURE REVIEW ON EXPERIENTIAL LEARNING

2.1 Kolb’s Experiential Learning Theory

A recent concise description of experiential learning is the process of "learning through reflection on doing" [12]. Experiential learning is aligned with the two pedagogical principles of constructivist learning theory: that learning should be authentic, active, and student-centered, and that it must also be facilitated through social negotiation [13]. Experiential learning builds metacognitive skills and can be goal-oriented and assessed [14].

David Kolb is credited for theorizing experiential learning, building upon the works of Dewey, Lewin, and Piaget. Kolb’s Experiential Learning Theory [15] has the following educational principles as its foundation: 1) Learning is conceived best as a process instead of a product; 2) Learning involves relearning of prior beliefs and ideas on a topic so they can be drawn out, tested, examined, and integrated into new concepts; 3) Learning is driven by conflicts, dissonance, and disagreement; 4) Learning is a holistic process of adaptation to the world that involves thinking, feeling, perceiving, and behaving; 5) Learning results from synergistic transactions of the learner assimilating new experiences into existing concepts and accommodating existing concepts into new experiences, and 6) Learning is the process of creating knowledge.

The central tenet of ELT is that knowledge results from experiences that have been grasped and transformed [15]. ELT puts forth two dialectically related modes of grasping experience: Concrete

Experience (CE) and Abstract Conceptualization (AC); and two dialectically related modes of transforming experience: Reflective Observation (RO) and Active Experimentation (AE) [12,16]. The result of these two dimensions of learning and transformation is four different elementary forms of knowledge: divergent knowledge (CE and RO), assimilative knowledge (RO and AC), accommodative knowledge (CE and AE), and convergent knowledge (AC and AE).

The process of experiential learning is cyclical and requires an initial focus of the learner, followed by interaction with the phenomenon being studied, reflecting on the experience, developing generalizations, and then testing those generalizations [14]. The context in which experiential learning occurs is defined by four dimensions: the level, the duration, the intended outcome, and the setting [17]. It is important to note that simply providing experiences does not constitute learning and that reflection on action is necessary [14,15,18].

2.2 Applying ELT to Agricultural Education

Knobloch [19] summarized the four tenets of experiential learning as they relate to agricultural education as learning through real-life contexts [18], learning by doing [as cited in 19], learning through projects [20], and learning through solving problems [21].

Baker, Robinson, and Kolb [14] further clarified the inherent connections between experiential learning and a comprehensive (i.e., the three-component) agricultural education model. The three-component model [16] is understood as 1. classroom/laboratory instruction, which is contextual, inquiry-based, and where learning is achieved through an interactive classroom and laboratory; 2. Supervised Agricultural Experience (SAE), which is experiential, service, and/or work-based learning, and 3. Future Farmers of America (FFA), which means premier leadership, personal growth, and career success, through the National Postsecondary Agricultural Student Organization (PAS) or the National Young Farmer Educational Association (NYFEA). The three components of agricultural education fit well into the experiential learning cycle, in that the classroom/laboratory instruction is related to the abstract, SAE is the converging aspect and FFA is the concrete and reflective aspects of experiential learning [14,22].

Pennington et al. [23] evaluated the effectiveness of the agricultural visual communications experiential learning curriculum developed by the University of Arkansas and integrated into secondary agricultural programs throughout the state. Eleven schools participated in the study with 106 students represented. Analysis of student test scores revealed a significant effect between pre-, post-, and/or delayed-post scores for each curriculum unit, suggesting positive effects of experiential learning on knowledge acquisition.

Baker and Robinson [24] examined the effects of two contrasting pedagogies (i.e., experiential learning and direct instruction) on students' retention of agricultural knowledge over time. A six-week deferred post-test was administered to assess long-term retention of the subject matter. The results indicated that initially, students who were taught both experientially and through direct instruction experienced a statistically significant increase in analytical scores, with the direct instruction treatment group outperforming the experiential learning treatment group. However, that increase was not statistically significant and was followed by a statistically significant decrease in analytical scores six weeks following instruction. Implications for instructors are to pace their lessons more slowly to increase understanding and mastery of the content learned.

Additional studies have been conducted to investigate the impact of specific aspects of experiential learning on student knowledge acquisition in agricultural education. First, Baker, Brown, Blackburn, and Robinson [25] utilized an experimental design to determine the effects of order of abstraction and type of reflection on student knowledge acquisition. Students were assigned randomly to one of four treatment combinations in the completely randomized 2x2 design which included either abstraction before or directly after an experience, and either reflection-in-action or reflection-on-action. The findings indicate that order of abstraction does not have a statistically significant effect on knowledge acquisition scores, but that reflection-in-action did have a statistically significant effect on increasing students' knowledge of concepts. It is recommended that agricultural education teachers focus on effective strategies of reflection-in-action to help students develop deeper and more enduring learning from their experiences.

Similar to the above research, the study by DiBenedatto, Blythe, and Meyers [26] sought to determine the effect of reflection-in and reflection-on-action regarding content knowledge acquisition, the effect the order of abstraction had on content knowledge acquisition, and if any interaction existed between the type of reflection and order of abstraction on content knowledge scores of secondary agriscience students. Utilizing a 2 x 2 randomized experimental design, this study was conducted in a secondary agriscience classroom. The order of abstraction and type of reflection was found to be significant in the development of discussion skills. Teachers are recommended to design effective concrete experiences for their students to engage, reflect, conceptualize, and experiment.

Finally, Smith and Rayfield [27] investigated the effect of cognitive sequencing of instruction in the dimension of grasping information through ELT in a quasi-experimental study that involved 121 students in agricultural science courses from four Texas high schools. Two units of STEM-enhanced instruction were developed, each with two separate sequences; one with concepts presented beginning with a concrete experience and moving to an abstract conceptualization and the other in the opposite sequence. Findings indicated significant interactions on both units of instruction between student preference for grasping information and cognitive sequence of instruction.

2.3 Initial Theory of Change

The United Nations in Measuring Capacity [28] defines capacity as the ‘ability of individuals, organizations, and societies to perform functions, solve problems and set and achieve objectives in a sustainable manner’. Changes in capacity are easier to monitor and evaluate if the capacity development approach is comparatively focused, integrated into the project, and technically specialized such as for modern biotechnology. Capacity development, however, has its unique challenges. Many of this capacity relates to soft skills that are intangible such as leadership, ability to build consensus, and/or ability to learn and adapt; these are hard to measure and can be subjective. Capacity development in modern biotechnology research can be evaluated through different levels: individual, organizational and wider systems, which can be difficult. Although this is true for other types of the intervention strategy, there are various influences at play at organizations and their ability to implement wider organizational and external actions may not necessarily be linked to the capacity intervention. Citing attribution is one important challenge [29,30].

The project’s HICD activities were designed to support LBR potato research and regulation and to determine how the HICD intervention and their contribution to change involved the design of a simple theory of change (TOC) for HICD and a linear, tracking-forward approach. (See Image 1).

2.4 Case Study of Developing and Deploying Late Blight-resistant GE Potato with 3 Resistant Genes

Late blight continues to devastate potato cultivation around the world. A handful of potato breeding programs have been successful in developing resistant lines through conventional as well as through genetic engineering approaches. Previous projects have introduced potato lines engineered with a single gene resistant to late blight. However, given that the pathogen can evolve to breakdown resistance much faster in plants with single-gene resistance, multi-gene constructs are currently being used to genetically engineer more durable late blight resistance into potato lines. Therefore, our case study for developing capacity for plant biotechnology field studies focused on training core teams in two partner countries, at different stages in the development of their regulatory regimes, to import genetically engineered potato plants from the US and conduct confined field trials to determine the performance of these plants in comparison to locally grown potatoes. A confined field trial, or CFT, is standard terminology used to describe a field trial for research with regulated GE plants, which is conducted with confinement measures in place to ensure the plant material is controlled at all times during the trial and does not remain in the environment after the trial is complete [31]. Country B has already approved an insect-resistant GE food crop for general use, and Country A recently approved a drought-tolerant GE food crop. Both countries also had previous experience in field testing a genetically engineered single R-gene potato line resistant to the late blight disease through a USAID-funded project. However, for this new project involving the 3 R-gene potatoes, the HICD team particularly focused on documenting the capacity development efforts and processes as they apply to ELT of agricultural biotechnology education.

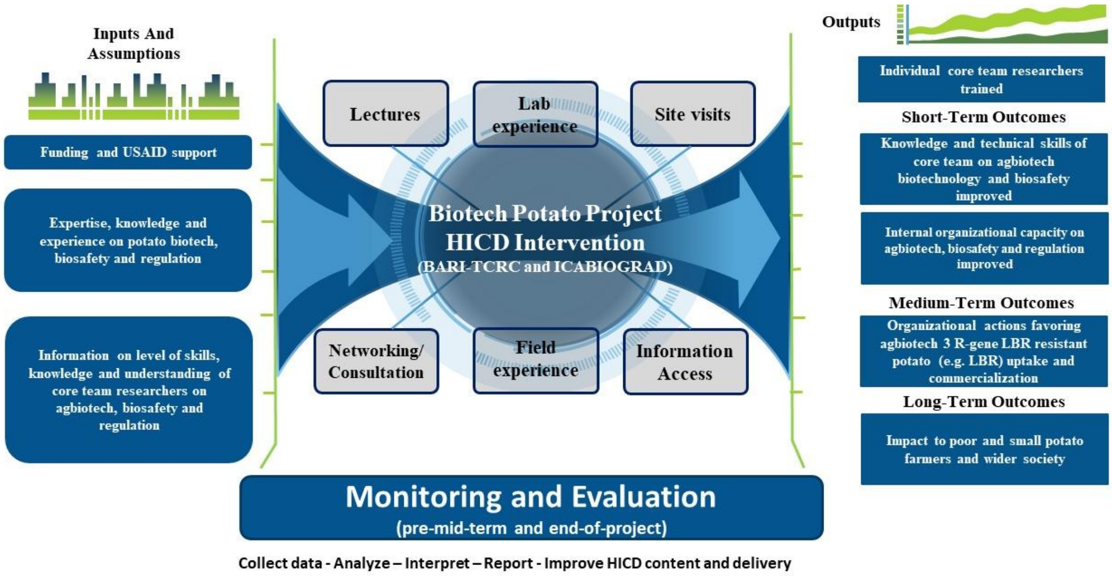


Image 1. Initial TOC of the Biotech Potato Project (2015-2020)

At the onset of the project, our HICD focus was on Objectives and Key Results (OKRs). Therefore, the first step was to understand the existing knowledge of the core teams that were selected to work on the project before designing any capacity-building programs. First, informational sessions were held with previous project implementors that worked with our partners on the single R-gene potato project. Then, survey instruments carefully developed to include a question on OKRs for the project helped test the existing knowledge of the team on biotechnology research and regulation for implementing the project activities with deliverables in mind. Based on the information gathered from the surveys, an onboarding project workshop was conducted for the core teams in Country A, as a cost-effective approach to meeting project participants. The workshop content was developed to provide information on the project, its objectives, and key expected deliverables from the core teams.

As the second step in the HICD plan, the core teams were invited to US-based implementing institution for 1-5 months (depending on the training needs of the team members) during the growing season to provide an opportunity for them to observe how researchers develop and field test genetically engineered late blight resistant potato following the biosafety regulations in the United States. Upon arrival, the teams took a second survey that included questions on the skills required for delivering the expected outcomes of the project. The survey included sections on tissue culture propagation, molecular analyses, pathology techniques, and plant breeding aspects to determine knowledge of the core teams in these specific areas important for receiving, maintaining, and field-testing GE potato lines. Based on the survey responses, individual training components were developed for the team members responsible for each of the biotechnology, pathology, and plant breeding aspects of the project. The method of training for these areas consisted of modeling behavior, and then observing participants exercising the behavior. At the end of each week of training, the participants were brought together to reflect on what they learned and realize where this training is applicable upon return to their institutions. The core teams also had events that allowed them to compare and contrast facilities available at their institutions to deliver project outcomes. The teams also had a week of training on biosafety regulations with the Regulatory Team lead of the project. The training concluded for the core teams with a second skills survey that summarized what they had learned during the training. Although the period of training varied between core scientists, our goal was to ensure that all of the core team members were introduced to a set of skills that were necessary to implement project activities.

A set of follow-up activities were requested to be completed by each of the members of the core scientific teams upon return to showcase their capabilities for carrying out project activities. However, with the teams returning to their institutional and personal responsibilities, along with communication difficulties faced in the remote areas where project activities were to be implemented, the HICD activities of the project had to take a new turn. Strictly adhering to our goal of documenting the local capacity for receiving, maintaining, and field trialing the 3 R-gene potato lines, the HICD and Technical Teams worked together to develop a manual for evaluating the skills of the trained team in implementing project activities in-country and demonstrating their capabilities. As such, the teams were requested to complete activities listed in the training manual (details of which are discussed elsewhere) using a non-genetically engineered potato line sent to the project partners from Michigan State University. Upon receiving the plants, the teams were requested that they treat the plants as if they had received the 3 R-gene potato lines in-country. The manual was divided into 4 separate sections with step-by-step instructions to be followed by the teams on laboratory best practices (including videos), tissue culture techniques, pathology techniques, and molecular methods to ensure the acclimated greenhouse plants are of the expected genotype. Each of these sections included built-in checklists, surveys, and reporting strategies with photographs that allowed the project team to determine the skill level of the core scientific teams. The completion of the activities in the manual allowed the teams to harvest potato minitubers for conducting confined field trials (CFTs).

Upon completing the activities in the training manual, several in-country training workshops and visits were conducted by the Pathology and Regulatory Team leads of the project to train the core teams on conducting confined field trials. Once again, the training utilized the basic strategy of ELT – modeling behavior, engaging participants in behavior, and observing participants exercise the behavior. Because the minitubers were not ready in-country for the CFTs, MSU provided the minitubers as planting material for the CFTs to be initiated. However, the understanding is that these activities will take place in-country when the 3 R-gene product arrives.

While this training helped the project achieve its HICD goals of developing a skilled core team to deliver OKRs, there were several times that project objectives had to be altered to achieve the key results. For example, the skill level of the core team in one country for the tissue culture component indicated that the project should bring in additional trained individuals in tissue culture to achieve project deliverables. Indeed, this is the nature of OKRs, where there needs to be constant evaluation of objectives of the project and activities that help reach the key results associated with those objectives. If the objectives and activities designed do not meet the key results, then, we must change these objectives and activities to get to the key results. It is this flexibility that allowed the project to reach its HICD goals.

2.5 Monitoring and Evaluation (M&E) Methodology: Mapping of Inputs to Outcomes

The question remained, however, how best to monitor and evaluate these activities to ensure for ourselves and also demonstrate to others that capacity was being developed. Building on Kolb's six principles of experiential learning, the HICD intervention by the Biotech Potato Project involved two capacity-building processes gap filling and integrated capacity development that influenced the M&E design. The Biotech Potato Project aims to fill a knowledge gap on agricultural biotechnology research and regulation, thereby enabling project partners to make progress towards a broader set of outputs and outcomes. The project also aims to provide training activities that are integral to the 3 R-gene late blight resistant potato biotech research and its deregulation. Using the TOC for Biotech Potato Project, the evaluation of impact, hence, focused on evaluating the overarching question: "*How does the HICD intervention provided by the Biotech Potato Partnership project impact the skills and competencies on potato biotech research and regulation of individual and organizational partners*?"

Two M&E methods were employed to measure changes in individual and organizational capacity: output measures (process evaluation) and outcome evaluation to evaluate the HICD activities and intervention impact. These methods were used to help the following evaluation questions: 1) process

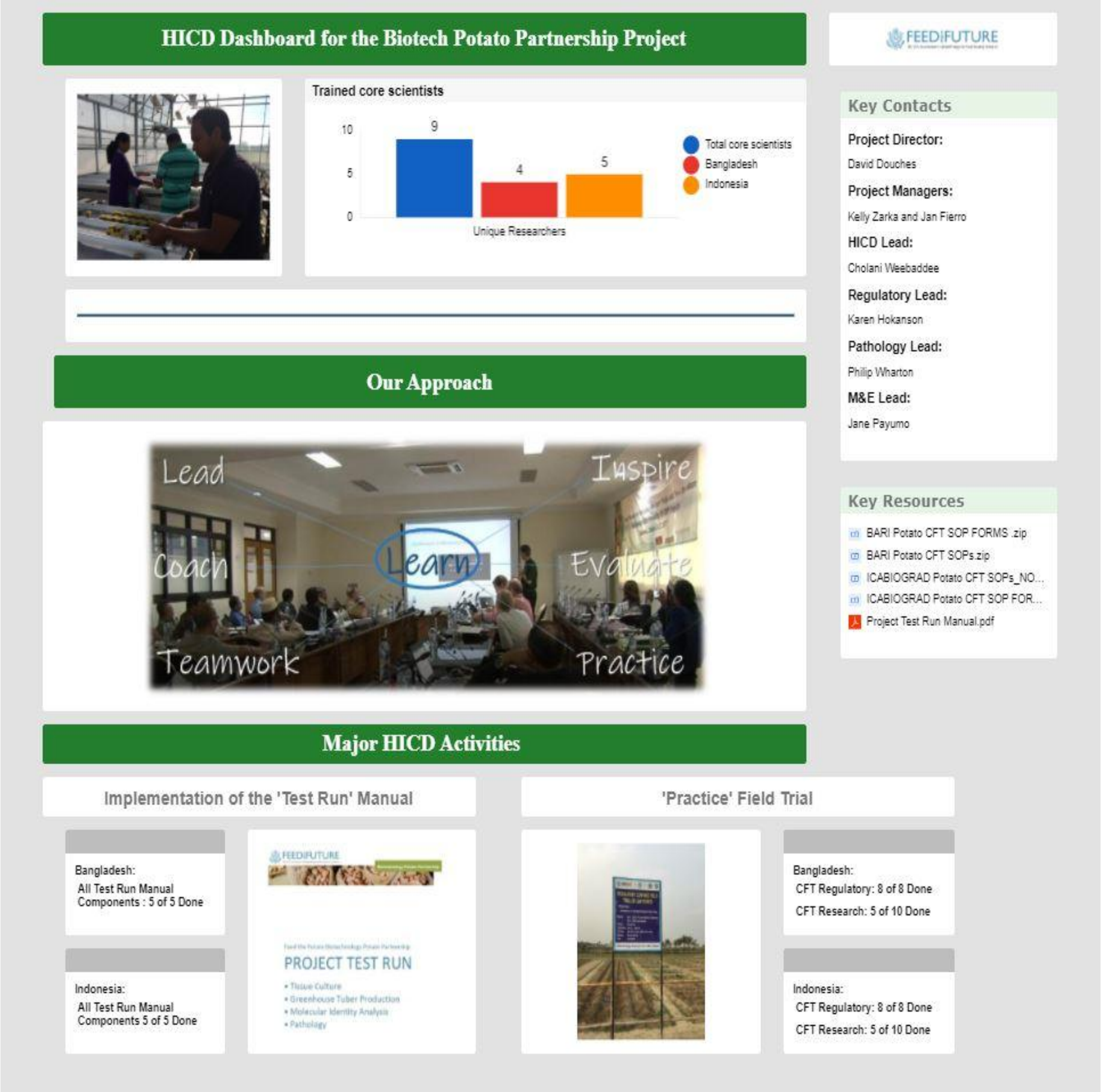
– Are the HICD intervention activities implemented as planned? and 2) outcome – Are all the HICD interventions achieving their objectives that support the Biotech Potato Project's goals? Through output measures, the outputs of the program's activities (e.g. how many in-country core team scientists were trained were quantified. Outcome evaluation, on the other hand, was used to determine if the program was able to achieve desired changes in knowledge, skills, and competencies) because of the HICD intervention. Evaluation instruments (pre-or baseline, mid-, and end-of-project follow-up) were designed to measure short- and medium-term outcomes. The assessment of success to project objectives is based on these two methods on a carefully designed combination of qualitative and quantitative indicators. For better monitoring and reporting of the progress to HICD goals and objectives, these indicators were set up in a project management software, Smartsheet. Graphical snapshots and an HICD portal and dashboard built in Smartsheet (image 1) were also generated for time-series reporting and analysis, and dissemination to the Project Management Team, USAID, and various audiences.

Outcome evaluation focused on the following areas: microbiology and pathology, tissue culture, seed production, and regulatory compliance. Thus, for example, in the case of the tissue culture, one of the points of valuation was whether GE materials were properly labeled and segregated to avoid the mixing of samples and eliminate the possibility of GE material being used unintentionally. These areas were selected because they were core procedures in the development of the resistant potato and vital for project success. Each of these areas of the evaluation was built out using the standard techniques that had been made part of the capacity development process. A simple rating of ranking was developed to identify the capacity of the individuals and the organizations against each of the different areas. Specifically, the skills and competencies were measured using a five-point scale (1 = poor, Far below minimum requirements hence no capability and 5 = excellent, Far above requirements). The Likert scale was a 6-point item for microbiology and pathology skills; a 5-point item for tissue culture skills; a 10-point item for seed production; and an eight-point item for regulatory compliance. The Project Technical Team leads (Molecular Biotechnology, Pathology, and Regulatory) were asked to evaluate the capability of the partners in various areas. The team was asked to evaluate three stages (pre-, mid, and end-of-year project) to show through changes in scores how individual and organizational capacity has changed. All pre-and mid-term assessments were conducted and reported here. The final evaluation for these areas, including mid-term assessment for regulatory, is scheduled before the project transfers the 3 R-gene late blight resistant potato events to both institutions. The change in specific areas will also be further investigated to assess to what extent they are the results of a particular HICD intervention by the project and validate attribution.

The outcome of the HICD intervention or the change in skills and competencies of the core team scientists for the tuber crops sub-center in Country B and the biogenetics and biotechnology institute in Country A was determined by comparing the baseline value against the mid-project assessment value for each of the skills and competencies. Scores were analyzed making statistical comparisons (mean and standard deviation) between the pre-and post-fellowship to determine the impact of the HICD intervention on the Country A and Country B core team. Due to non-normal data determined after the Shapiro-Wilk test, a non-parametric equivalent of t-test,

Wilcoxon rank-sum test called Mann-Whitney *U*-test was employed to determine statistically significant differences between the pre-and post-fellowship datasets. The research question was: Does the median rank of Likert scores for skills and competencies for microbiology and pathology, tissue culture, seed production, and regulatory compliance differ from before the HICD intervention and after the intervention?

All the statistical analyses and visualization were performed using the Real Statistics Resource Pack in Excel [32]. Counterfactuals were not established to compare effects of the baseline data and mid-term assessment for the effects of the HICD intervention since the partners in Country A and Country B are not receiving any capacity support from other groups on potato biotech research; this also provides additional justification on the use of the tracking change forwards approach.



HICD Dashboard for the Biotech Potato Partnership Project

Trained core scientists

Key Contacts

Project Director:
David Douches
Project Managers:
Kelly Zarka and Jan Fierro
HICD Lead:
Cholani Weebaddee
Regulatory Lead:
Karen Hokanson
Pathology Lead:
Philip Wharton
M&E Lead:
Jane Payumo

Key Resources

- BARI Potato CFT SOP FORMS .zip
- BARI Potato CFT SOPs.zip
- ICABIOGRAD Potato CFT SOPs_NO...
- ICABIOGRAD Potato CFT SOP FOR...
- Project Test Run Manual.pdf

Our Approach

Major HICD Activities

Implementation of the 'Test Run' Manual

Bangladesh:
All Test Run Manual Components : 5 of 5 Done

Indonesia:
All Test Run Manual Components 5 of 5 Done

'Practice' Field Trial

Bangladesh:
CFT Regulatory: 8 of 8 Done
CFT Research: 5 of 10 Done

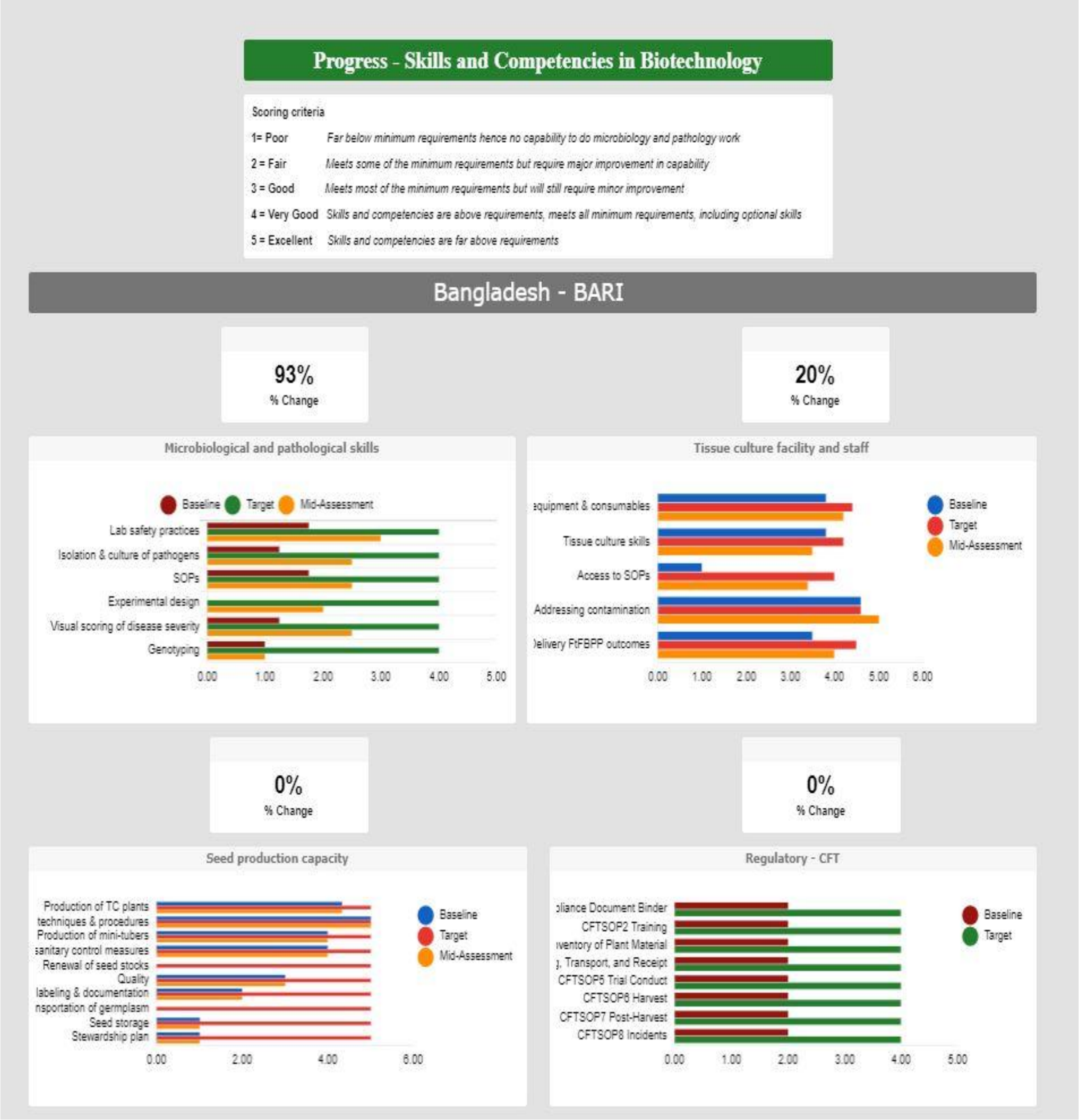
Indonesia:
CFT Regulatory: 8 of 8 Done
CFT Research: 5 of 10 Done

Image 2. HICD Dashboard Portal

2.6 Initial Impact Findings and Integrating the Collaboration-Learning-Adopting (CLA) Approach

Nine core scientists benefited from the project's HICD interventions. In line with Kolb's six principles, they all benefited from the following: lectures, lab, and field experiences, site visits, information access, and networking and consultation activities with US experts. These activities were implemented from Year 2 to Year 4 of the project. The primary outcome of these activities was the perceived change in skills and competencies in microbiology and pathology, tissue culture, seed production, and regulatory aspects of biotechnology.

As shown in Table 1, the skills and competencies of core teams of Country A and Country B, which have been randomly assigned the labels "Team A" and "Team B" to avoid identifying individuals, both improved after the HICD intervention and were found statistically significant ($p < 0.05$). Specifically, the microbiology and pathology skills for the Country B core team improved while the microbiology and pathology skills, tissue culture, and seed production skills improved for the Country A core team. The statistically significant evidence supports the rejection of the null hypothesis that there was no change in skills and competencies in microbiology and pathology for Country B; and microbiology and pathology, tissue culture, and seed production for Country A after the HICD intervention and mid-term of the project. The skills and competencies for tissue culture and seed production after HICD intervention were not found statistically significant for Country B, which supports the null hypothesis that there was no change in skills and competencies for these two areas.



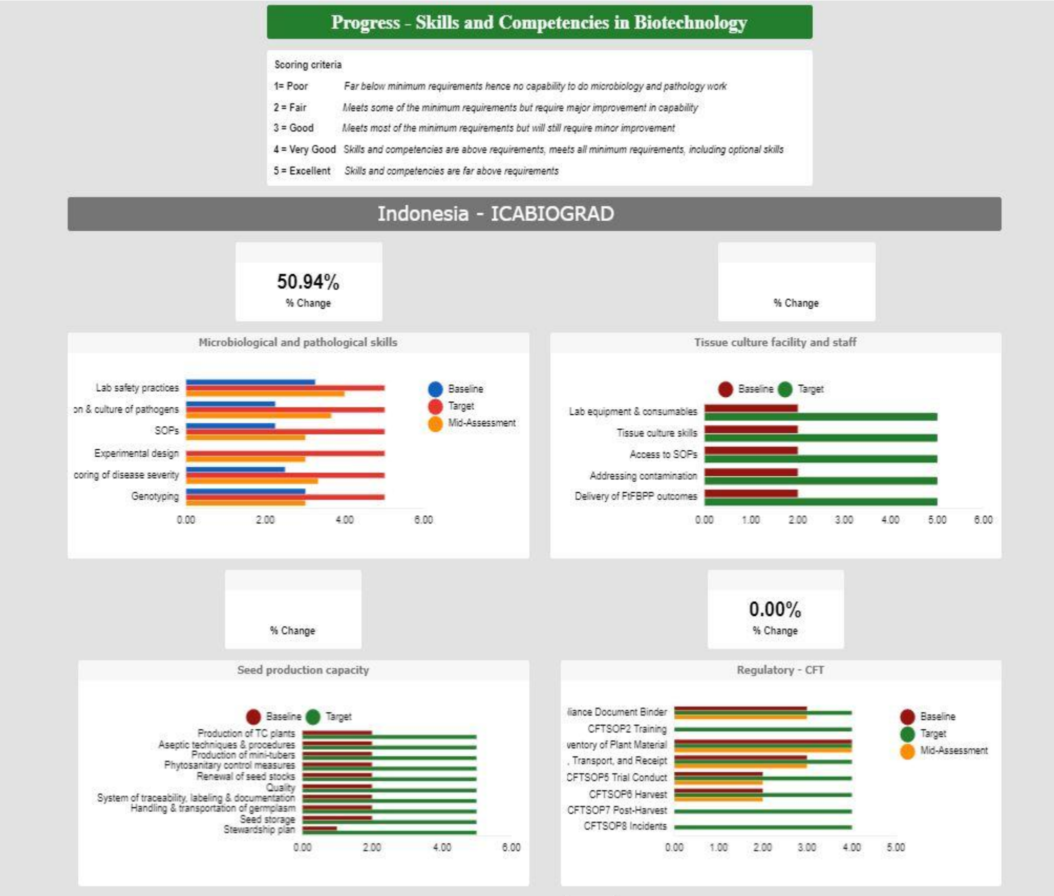
Progress - Skills and Competencies in Biotechnology

Scoring criteria

1= Poor	*Far below minimum requirements hence no capability to do microbiology and pathology work*
2 = Fair	*Meets some of the minimum requirements but require major improvement in capability*
3 = Good	*Meets most of the minimum requirements but will still require minor improvement*
4 = Very Good	*Skills and competencies are above requirements, meets all minimum requirements, including optional skills*
5 = Excellent	*Skills and competencies are far above requirements*

Bangladesh - BARI

Image 3. HICD Dashboard View 2



Scoring criteria
1= Poor *Far below minimum requirements hence no capability to do microbiology and pathology work*
2 = Fair *Meets some of the minimum requirements but require major improvement in capability*
3 = Good *Meets most of the minimum requirements but will still require minor improvement*
4 = Very Good *Skills and competencies are above requirements, meets all minimum requirements, including optional skills*
5 = Excellent *Skills and competencies are far above requirements*

Image 4. HICD Dashboard View 3

Table 1. Impact parameters for biotech potato partnership HICD Intervention: Changes in skills and competencies of Country A and Country B core teams

Skills and Competencies	Pre (Baseline) Mean (SD)	Mid-Term Assessment Mean (SD)	P-value[s]
Core Team Country A			
Microbiology and Pathology	2.00(1.52)	5.00(0.00)	2.02E-15***
Tissue Culture	2.00(1.52)	5.00(0.00)	1.21456E-13***
Seed Production	1.90(0.32)	5.00(0.00)	5.41254E-06***
Regulatory	2.00 (0.00)	N/A	
Core Team Country B			
Microbiology and Pathology	1.45 (1.33)	2.50(0.80)	0.009***
Tissue Culture	3.26 (1.63)	4.00(1.13)	0.18
Seed Production	3.20 (1.40)	3.20(1.39)	0.81
Regulatory	2.00 (0.00)	N/A	

[a] *All P-values were derived from two-tailed Mann-Whitney U-test: * P <0.05 ** P <0.01 *** A P < 0.001*

Overall, the mid-term results imply that the HICD capacity development and training were not enough and not impactful for Team A. Careful review, collaboration, a reflection of learning from the HICD intervention, and the need to adjust with the delays in the transfer of the 3 R-gene late blight resistant potato in-country resulted in the revisiting and reiteration of content for all areas, design of new capacity development and training materials, and delivery of additional HICD intervention to prepare both Team A and Team B for confined field testing (CFT) and other research-related activities.

A detailed GE Technology Capacity Evaluation Manual was designed as a follow-up and supplemental reference for the in-country core team's training and capacity development activities at MSU. The manual consists of two components 1) In-country Technical Capacity Evaluation (TCE) and 2) In-count Field Capacity Evaluation (FCE). The manual was developed so the in-country core technical teams could self-report and document their capacity. Specifically, the TCE is made up of five areas that cover instructions and development of standard operation procedures (SOP's) unique to the countries' resources, for each component. The areas include safe laboratory practices, handling new GE plant material, tissue culture, micropropagation, greenhouse tuber production, and basic molecular biology and pathology activities that support the research and regulation of biotech potato materials. The project used an importation of non-GE potato as a surrogate for an actual GE potato. In addition to the protocols, the manual provides step-by-step instructions on activities that need to be conducted in the form of a checklist. As shown in Image 2, both the core team of Country A and Country B finished all the components of the TCE manual. The second component of the manual, the FCE was designed and implemented to provide a practice-regulated confined field trial to train and build the capacity of Country A and Country B core team in conducting field trials under confined conditions that meet regulatory guidelines. The practice field trials, again using an imported non-GE potato, along with simulating field conditions, tested the efficiency of field research and regulatory compliance during the CFT of the LBR biotech potato. This was complemented with research study plans and development and training on standard operating procedures (SOPs) for CFT regulatory compliance. The study plan included information on the plant materials, field sites, experimental design, agronomic practices, data collection and analysis, and records that need to be maintained. The CFT SOPs provided step-by-step instructions for various tasks typically involved in CFT regulatory compliance at the institutional and individual researcher levels, with form-based record-keeping for key aspects or regulatory compliance identification and inventory of plant materials, transportation, shipping and receipt of materials, planting and trial conduct, the harvest of materials and post-harvest management of field trial sites for LBR biotech potato, and reporting of incidents and corrective actions [25]. As shown in Image 2, both Team A and Team B were able to implement the CFT Regulatory practice (8/8/ steps). They did not, however, fully complete the CFT Research component with only five out of 10 steps completed. The field trial design and data collection were not executed exactly as planned and will be monitored more closely for the actual CFT for the biotech LBR potato.

Outcome evaluation is not yet completed for the Biotech Potato Project but the mid-term evaluation results and how the project used the results indicate that capacity development and training for modern biotechnology research and regulation is not a one-off intervention but an iterative process of design-application-learning-adjustment. Guided by mid-term evaluation results and the CLA approach, the Biotech Potato Project now captures this iterative process in its modified TOC (Image 3). There is now a greater recognition that HICD for biotechnology research is a long-term effort that needs to be embedded in broader, endogenous change processes that are owned by those involved, that is context-specific focused on a changing mindset, values, skills, and competencies. Approaching HICD through this process lens makes for a rigorous and systematic way of supporting it, without using a blueprint, and improves the consistency, coherence, and impact of HICD intervention.

3. ANALYSIS AND DISCUSSION

In assessing the value of the assumptions and practices applied in the conduct of this training, it is helpful to return to Kolb's six principles as an analytical framework. The six principles help us understand both the successes and the deficiencies of the approach described above.

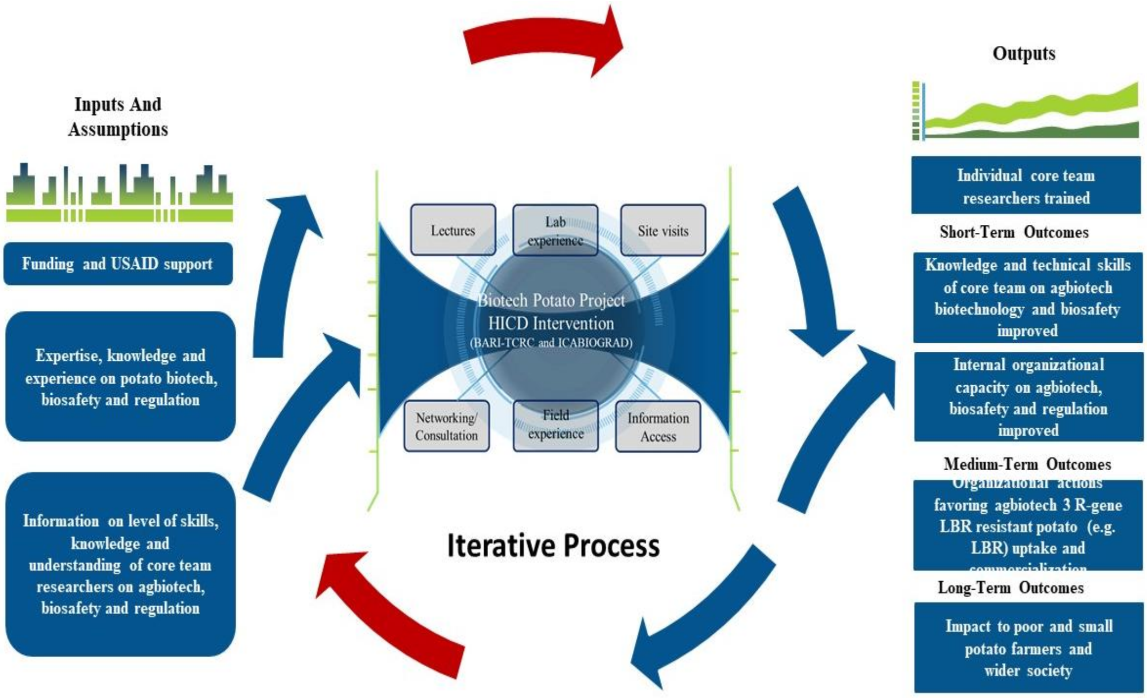


Image 5. Revised theory of change

3.1 Learning is Conceived Best As a Process Rather than a Product

From the outset of the project, there was an assumption, as the initial theory of change indicates, that the learning would be a process rather than a single intervention. Reinforcing learning concepts through repetition and built-in redundancy is an important part of the learning process [33,34,35,36]. Early capacity development efforts were designed to be a combination of abstract (lecture) learning and experiential (lab and field) learning extended over five months. This was to be followed by the leadership of project activities with oversight and ongoing coaching and learning. Early indications showed, however, that prior learning might not be as extensive or as profound as expected. In response to these early signs, supporting educational materials were generated to make the instruction provide additional support for the trainees, especially after they had departed. In addition, frequent oversight visits (at least once per quarter) were scheduled in which evaluations took place to measure progress.

In the face of continued difficulty in the implementation of key tasks, it was decided to add a demonstration trial, using non-GE material as a substitute for the GE material, to refine the skills and continue to emphasize key learning points to the participants. This was done for both groups A and B. This required some close coaching, especially in the area of pathology. In the end, progress was made for both groups through the implementation of the demonstration trial.

3.2 Learning Involves Relearning Prior Beliefs and Ideas on a Topic so they Can be Drawn out, Tested, Examined, and Integrated into New Concepts

Connecting new learnings to prior beliefs and ideas can be a challenge, especially where there are multiple cultures in play [37,38]. Yet, building on prior beliefs and ideas is a core component of the constructivist foundation on which Kolb's experiential learning was built [39,40,41]. This challenge was faced with both groups A and B, in that they each came to the task with different prior beliefs and ideas derived from their unique scientific backgrounds and cultural contexts. In the case of group B in particular, it was clear at several points in the training process that prior experience and knowledge were not adequate for an effective constructivist approach to learning and that learning in some instances needed to be scaled back to the point where there were prior experiences sufficient to serve as “scaffolding” for the new learning [42,43]. Although a pretest was done to serve as a baseline for learning, there was little thought given to the possibility that the international trainees might have come from deficient training systems or that they may have not been selected based on their qualifications. In this case, a selection requirement should have been put in place and a qualifying test of some kind should have been put in place before candidates were accepted for the training. In the end, it must be conceded that some of the trainees lacked sufficient base knowledge to successfully scaffold learning.

3.3 Learning is Driven by Conflicts, Dissonance, and Disagreement

In constructivist approaches to learning, the learning is often compared to building a structure, borrowing from construction such metaphors as “foundation,” “base,” and “scaffolding.” Unlike construction, however, where blueprints provide a precise path forward, learning is often messy and imprecise. Cognitive dissonance theory, first developed by the Stanford Psychologist, Leon Festinger [44], hypothesized that changes in attitude and behavior could be catalyzed through conflict and disagreement. Festinger’s theories were taken up into education and experimentally tested and confirmed [45,46,47,48] Situations of provoked cognitive dissonance improved learning. Growth in learning can be provoked by creating dissonance between our assumptions and reality, forcing a process of rethinking how we interpret and understand reality [49].

Appropriately, perhaps the times of greatest progress in the learning cycle were those in which there were clear and open conflicts as to what was correct and appropriate. One clear example of this was while working with Team B during the demonstration efficacy trial that had been designed as a learning experience for the team. During that particular growing season, it was unusually dry and the team was having trouble infesting the trial with the targeted pathogen, *Phytophthora infestans* (*P.infestans.*), which, due to the dryness of the season, was not occurring naturally as had been hoped. To salvage the trial, it was decided to inoculate the trial to catalyze and spread the infestation. Although this was but a demonstration trial, it was understood by the implementing team that this situation allowed acquiring new skills that would undoubtedly be required in the future, namely, culturing *P.infestans.* for the production of inoculant and the safe application of inoculant in a field trial. Group B resisted the instruction for fear of infesting other nearby trials. An initial hurdle had to be overcome when Group B was unable to successfully culture spores of locally collected *P.infestans.* for inoculum production. The implementing team brought in a specialist from a nearby university to assist with the culturing of the spores and successful cultures were established. Despite the extensive experience of the pathologist giving oversight to the trial, it was only when the conflict reached the point of a near impasse that Group B agreed to inoculate the trial according to instruction. The trial was successfully inoculated, and nearby fields were not infected. The conflict provided an opportunity for Group A to acquire new skills and new assumptions about the safety of implementing inoculation in field trials in confined spaces.

3.4 Learning is a Holistic Process of Adaptation to the World that Involves Thinking, Feeling, Perceiving, and Behaving

The most effective aspect of experiential learning is the integration of learning into a real-world setting. As such, it requires the participation of all the dimensions of human experience, from cognitive comprehension to tactile skills, to sensing and feeling [25,26]. This is in line with the way that memory works. According to neuroscientist John Medina [50], memory is stored in various parts of the brain not as a whole, but as a function of the sense involved, so for example, retrieval of memory for scent is from a different location in the brain than retrieval of memory for color, or light, or emotions, or tactile aspects of the memory. Memory gets more firmly grounded when several of the dimensions of consciousness are engaged simultaneously. For that reason, experiential learning generates greater recall because the memory is rooted in more dimensions of consciousness than purely cognitive experiences meaning that there are more memory pegs on which the memory hangs increasing the chances that there will be recall [51,52].

Table 2. List of interventions in biotechnology capacity development

Group	Type of Intervention	Location of Intervention	Experiential Learning Principle Applied	Level of Mastery Observed/Comments
A	5-month training including: - Lectures - Lab work - Coaching - Mentoring - Social engagement - Evaluation - Fieldwork	US Research University	1-6	Factual, conceptual, procedural, although results were uneven. Some scientists grasped more than others.
B	3-week training including: - Lectures - Lab work - Coaching - Mentoring - Social engagement - Evaluation - Fieldwork	US Research University	1-6	Factual, conceptual, procedural, and some metacognitive. This group entered the training with significantly more experience and knowledge of bio-safety procedures than group A.
A B	Workshops on research and biosafety, project goals.	Team B host country	1, 2, 6	Factual, conceptual. Several two- to three-day workshops provided a significant amount of information for the trainees on the safe conduct of biotech tissue culture production, seed multiplication, and field trials. During the later workshops, SOPs were co-created.
A B	Supplemental training materials including - Training videos - Written materials	Virtual	1,	Factual, conceptual. Extensive “how-to” materials that could be reviewed at any time.
A B	Virtual mentoring	Virtual	1-6	Factual, conceptual, procedural, metacognitive. Regular virtual calls were held with the teams to chart the progress of the assignments.

Group	Type of Intervention	Location of Intervention	Experiential Learning Principle Applied	Level of Mastery Observed/Comments
A B	GE Technology Capacity Evaluation Manual -Technical Capacity Evaluation (TCE) with Non-GE Potato and regular evaluations	Virtual/Host countries	1-6	Factual, conceptual, procedural, metacognitive. Assignments were given and the teams carried them out in the regular conduct of their work duties. Oversight and evaluation were given through regular virtual calls and at least once a quarter, a site visit was conducted to do an on-site evaluation.
A B	GE Technology Capacity Evaluation Manual -Field Capacity Evaluation (FCE) with Non-GE Potato - Lab work - Fieldwork	Host countries	1-6	Factual, conceptual, procedural, metacognitive. Simulated trials using non-GE material were conducted to allow each team to go through the process of the field trial, including filling out the required SOPs and collecting data, in a no-risk environment
B	Biotechnology field trails	Host country	1-6	Factual, conceptual, procedural, metacognitive. As of this writing, an actual GE field trial is taking place in the host country of Group B using GE material. Once again, the Group is going through the entire process of the field trial, including filling out the required SOPs and collecting data under close supervision.

Efforts were made to give each of the trainees a spectrum of experiences from purely cognitive mastery of basic information, to hands-on experience, so that the full panoply of dimensions were engaged. This included not only classroom experiences, in which the trainees received instruction in the principles of conducting field trials with GE material, but also lab experiences, participation in the actual field trials, multi-media training materials, direct one-on-one coaching and mentoring, and a demonstration trial intended to not only evaluate the level of comprehension of previous experiences but also their ability to integrate these learning acquisitions into an integrated demonstration of the learning acquired.

3.5 Learning Results from Synergistic Transactions of the Learner Assimilating New Experiences into Existing Concepts and Accommodating Existing Concepts into New Experiences

Integrating new learning into existing concepts is essential for new learning to take root [14,53]. Unless these linkages are made in the mind of the learner, the chances that new learning will be successfully grounded to be retained are remote. In line with Hunsaker's findings, we also incorporated regular mentoring sessions to work with the trainees in connecting their new learning experiences to prior experiences. In a follow-up to the initial intensive training, there were evaluations at regular intervals and frequent coaching. Even with these intentional efforts, however, for some of the trainees, the linkages were not successfully made.

3.6 Learning is the Process of Creating Knowledge

Bloom's taxonomy [54], as revised by Krathwohl and Anderson [55] structures the complexity of learning from the most basic to the most complex. This process of learning takes us through the various levels of comprehension which are identified as factual, conceptual, procedural, and metacognitive [55]. The goal of mastery of knowledge is to bring the learner to the point of metacognition, which Krathwohl and Anderson define as "strategic knowledge, knowledge about cognitive tasks, including appropriate contextual and conditional knowledge, as well as self-knowledge" (p. 46). In our context it would mean that the trainees had so absorbed and mastered the training that they would have the capacity to take that knowledge and apply it in new situations, creating new understanding in the process. Our evaluations show that all through our adjusted models allowed us to achieve mastery at the factual, conceptual, and procedural levels, metacognition continues to elude the team, meaning that their comprehension was not as complete as we might have liked. We use, again, the example of inoculation as a case in point. Confronted with an unrehearsed circumstance (inability to culture *P.infestans.*, and an unusually dry growing season), Team A was uncertain how to adapt their acquired knowledge to the new circumstances. As a result, coaching had to be brought in, continued mentoring had to be applied, and even confrontation had to be used to achieve the needed levels of understanding.

4. CONCLUSION

Conducting biotechnology field trials with actual GE material is a high-risk endeavor, especially when it is essential to obtain high-quality research results as efficiently as possible while maintaining strict control of regulated GE plant materials according to national and international regulations and requirements. It is incumbent upon the implementer to ensure that sufficient learning takes place that host country practitioners will be at the highest level of learning according to Bloom's taxonomy, that is, the creative stage, able to encounter new and unexpected circumstances and able to respond appropriately because sufficient grasp of the principles and the base knowledge have been gained to allow for the creative application of the principles to new contexts. We owe it to ourselves and all of the scientific community as well as producers and consumers.

Recognizing that obligation is what led not only to our original theory of change but also the changes made to that theory based on the experiences we encountered. As a result of our assumptions, at several points in the training process, we were required to adapt our plans to ensure satisfactory outcomes. In the course of the collaborate, learn, and adapt cycle, we were able to identify several lessons learned which we share here.

Base requisite knowledge: For projects, trainees, and institutions to benefit from experiential learning, there has to be a threshold of base knowledge present in the trainees. Some form of pre-test or qualifying exam should be part of the experiential learning process for there to be a sufficient base on which to scaffold new knowledge. In our case, we had to dismiss two of the ten trainees for lack of adequate base knowledge. The time, effort, and cost of their training, in the end, were lost since the trainees were never able to integrate new knowledge into their existing base knowledge.

Prolonged training as well as mentoring and coaching: Our original timelines were too short. Although the five-month training was extensive and very valuable for our trainees, in the end, it was clear that we should have planned on a longer and more rigorous process. Even using the best of experiential learning techniques, a learning process of two to three years should be assumed to inculcate fully the principles needed for the safe and effective conduct of GE trials as well as the ability to successfully face and overcome unexpected obstacles. In addition, we found the need to have ongoing mentoring and coaching programs in place that allow for continual oversight. Even though the last stages of the live GE trial, there were still points that needed reinforcement and repetition.

Frequent evaluation: One of the more effective adaptive practices that we established by way of necessity in the conduct of this training was the introduction of evaluations. This provided two important components of the experiential learning process. First, it allowed for frequent formative evaluation, giving us insight into how well the trainees had grasped the concepts that we had shared. This was especially important because we were working across cultures and languages.

Simulated trials: We would highly recommend at least one simulated confined field trial using non-GE materials in a no-risk environment during the initial implementation of a biotechnology project. Most of the deep learning took place in the course of these trials and it was surprising to see and learn what important misunderstandings remained after the extensive training had been undertaken. Some of these issues would have made moot the trial results or would have produced a high risk for non-compliance to regulations had it been at the time a trial with the actual GE plants. We now consider a simulated trial to be a core component of effective plant biotechnology field research training and the implementation of biotechnology projects.

ACKNOWLEDGEMENTS

This work was supported by the United States Agency for International Development under Cooperative Agreement Award No. AID-OAA-A-15-00056, "Feed the Future Biotechnology Partnership."

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Brookes G, Barfoot P. Farm income and production impacts of using GM crop technology 1996-2016. GM Crops & Food. 2018;9(2):59-89.
DOI: 10.1080/21645698.2018.1464866
2. Gartland KMA, Gartland J. Contributions of biotechnology to meeting future food and environmental security needs. The EuroBiotech Journal. 2018;2(1):2-9.
DOI: 10.2478/ebtj-2018-0002
3. Roa N. Chandrasekhara. Biotechnology for Farmers Welfare and Poverty Reduction: Technologies, Impact and Policy Framework, Agricultural Economics Research Review. 2017;30.

DOI: 10.5958/0974-0279.2017.00038.6
4. ISAAA Brief 54. Global Status of Commercialized Biotech/GM Crops: 2018. International Service for the Acquisition of Ag-biotech Applications; 2019.
5. Blancke S, Van Breusegem F, De Jaeger G, Braeckman J, Van Montagu M. The Need to Understand GMO Opposition: Reply to Couée. Trends in Plant Science. 2016;21(2):92. DOI: 10.1016/j.tplants.2015.12.001
6. Couée I. Hidden Attraction: Empirical rationality in GMO opposition. Trends in Plant Science. 2016;21(2):91. DOI: 10.1016/j.tplants.2015.12.002
7. Lynas, M. (2018). Seeds of science: why we got it so wrong on GMOs (Vol. 34). Bloomsbury Publishing. DOI: 10.5040/9781472946966
8. Mbabazi R, Koch M, Maredia KM, Guenthner J. Crop Biotechnology and Product Stewardship. GM Crops & Food. 2020;12(1):106-114. DOI.org/10.1080/21645698.2020.1822133
9. Adenle AA, Morris EJ, Murphy DJ, Phillips PWB, Trigos E, Kearns P. et al. Rationalizing governance of genetically modified products in developing countries. Nature Biotechnology. 2018;36:137-139. DOI: 10.1038/nbt.4069
10. Hokanson K, Ellstrand N, Raybould A. The integration of science and policy in regulatory decision-making: observations on scientific expert panels deliberating crops in centers of diversity. Frontiers in Plant Science. 2018;9:1157. DOI: 10.3389/fpls.2018.01157.
11. Paarlberg R. “Let them eat precaution: why crops are being over-regulated in the developing world”, in Let Them Eat Precaution: How Politics is Undermining the Genetic Revolution in Agriculture, ed J Entine (Washington, DC: The AEI Press). 2006;92-112.
12. Felicia, P. (Ed.). (2011). *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches: Multidisciplinary approaches*. iGi Global.
13. Splan R, Porr S, Broyles T. Undergraduate Research in Agriculture: Constructivism and the Scholarship of Discovery. Journal of Agricultural Education. 2011;52(4): 56–64. DOI: 10.5032/jae.2011.04056
14. Baker M, Robinson S, Kolb D. (2012). Aligning Kolb’s Experiential Learning Theory with a Comprehensive Agricultural Education Model. Journal of Agricultural Education. 2012;53(4):1–16. DOI: 10.5032/jae.2012.04001
15. Kolb DA. Experiential learning: Experience as the source of learning and development. Upper Saddle River, NJ: Prentice Hall; 1984.
16. Kolb, A. Y., & Kolb, D. A. (2009). The learning way: Meta-cognitive aspects of experiential learning. *Simulation & gaming*, *40*(3), 297-327. DOI: 10.1177/1046878108325713
17. Roberts G. A Philosophical Examination of Experiential Learning Theory for Agricultural Educators. Journal of Agricultural Education. 2006;47(1):17–29. DOI: 10.5032/jae.2006.01017
18. Dewey, J., & Authentic, I. E. L. (1938). *Experiential learning*. New Jersey: Pentice Hall.
19. Knobloch NA. Is Experiential Learning Authentic? Journal of Agricultural Education. 2003;44(4):22–34. DOI: 10.5032/jae.2003.04022.
20. Stimson, R. W. (1919). Vocational agricultural education by home projects. New York, NY: Macmillian.
21. Lancelot, W. H. (1944). Permanent learning: A study of educational techniques. New York, NY: John Wiley & Sons.
22. FFA. (2019, January 14). Retrieved from https://www.ffa.org/agricultural-education/.
23. Pennington K, Calico C, Edgar LD, Edgar DW, Johnson DM. Knowledge and Perceptions of Visual Communications Curriculum in Arkansas Secondary Agricultural Classrooms: A Closer Look at Experiential Learning Integrations. Journal of Agricultural Education. 2015;56(2):27–42. DOI: 10.5032/jae.2015.02027

24. Baker M, Robinson JS. The Effect of Two Different Pedagogical Delivery Methods on Students' Retention of Knowledge Over Time. Journal of Agricultural Education. 2018;59(1):100–118. DOI: 10.5032/jae.2018.01100
25. Baker MA, Brown NR, Blackburn JJ, Robinson JS. Determining the Effects that the Order of Abstraction and Type of Reflection have on Content Knowledge When Teaching Experientially: An Exploratory Experiment. Journal of Agricultural Education. 2014;55(2):106–119. DOI: 10.5032/jae.2014.02106
26. DiBenedatto C, Blythe J, Meyers B. Effects of the Order of Abstraction and Type of Reflection on Content Knowledge when Teaching Experientially in a High School Classroom. Journal of Agricultural Education. 2017;58(2):67–82. DOI: 10.5032/jae.2017.02067
27. Smith K, Rayfield J. A Quasi-Experimental Examination: Cognitive Sequencing of Instruction Using Experiential Learning Theory for STEM Concepts in Agricultural Education. Journal of Agricultural Education. 2017;58(4):175–191. DOI: 10.5032/jae.2017.04175
28. UNDP. Research and Publications: UNDP." UNDP Web site; 2010. Accessed January 30, 2020. Available:http://content-ext.undp.org/aplaws_publications/2679640/UNDP_Measuring_Capacity_July_ 2010.pdf.
29. Mayne, John. Addressing Attribution through Contribution Analysis Using Performance Measures Sensibly. The Canadian Journal of Program Evaluation. 2011;16(1):1-24.
30. Hailey John, Rick James. NGO Capacity Building: The Challenge of Impact Assessment. Oxford; 2003.
31. Halsey M. Integrated confinement system for genetically engineered plants: A comprehensive approach to biosafety for confined field trials. PBS Brief 9. International Food Policy Research Institute, Washington, D.C; 2007.
32. Zaiontz, Charles. Real Statistics Using Excel; 2020. Accessed January 31, 2020. Available:http://www.real-statistics.com/.
33. Luh YH, Stefanou SE. Learning-by-doing and the sources of productivity growth: A dynamic model with application to US agriculture. Journal of Productivity Analysis. 1993;4(4):353-370.
34. Trninic D. Instruction, repetition, discovery: Restoring the historical educational role of practice. Instructional Science. 2018;46(1):133-153.
35. Wogan M, Waters RH. The role of repetition in learning. The American journal of psychology; 1959.
36. Zhan L, Guo D, Chen G, Yang J. Effects of repetition learning on associative recognition over time: role of the hippocampus and prefrontal cortex. Frontiers in human neuroscience. 2018;12:277.
37. Hutchison CB. Cultural constructivism: the confluence of cognition, knowledge creation, multiculturalism, and teaching. Intercultural Education. 2006;17(3):301-310. DOI: 10.1080/14675980600841694
38. Kurteš S, Larina T, Ozyumenko V. Constructivist approach to intercultural communication teaching and learning. In Edulearn17 Proceedings. 2017;591-597. IATED.
39. Daniels H. Vygotsky and pedagogy. Routledge; 2016.
40. Osborne JF. Beyond constructivism. Science Education. 1996;80(1):53-82. DOI: 10.1002/(SICI)1098-237X(199601)80:1<53::AID-SCE4>3.0.CO;2-1
41. Vygotsky LS. The collected works of LS Vygotsky: Scientific legacy. Springer Science & Business Media; 2012.
42. Hogan, K. E., & Pressley, M. E. (1997). Scaffolding student learning: Instructional approaches and issues. Brookline Books.
43. Trif, L. (2015). Training models of social constructivism. Teaching based on developing a scaffold. Procedia-Social and Behavioral Sciences, 180, 978-983.
44. Festinger, L. (1957). A theory of cognitive dissonance. Evanstone, IL: Row, Peterson.
45. Allan M. Frontier crossings: Cultural dissonance, intercultural learning, and the multicultural personality. Journal of Research in International Education. 2003;2(1):83-110. DOI: 10.1177/1475240903021005

46. Cano F. Consonance and dissonance in students' learning experience. Learning and Instruction. 2005;15(3):201-223.
DOI: 10.1016/j.learninstruc.2005.04.003
47. Simonson MR. Attitude change and achievement: Dissonance theory in education. The Journal of Educational Research. 1977;70(3):163-169.
DOI: 10.1080/00220671.1977.10884976
48. Vermunt JD, Verloop N. Dissonance in students' regulation of learning processes. European Journal of Psychology of Education. 2000;15(1):75.
DOI: 10.1007/BF03173168
49. Houdé O. 3-system Theory of the Cognitive Brain: A Post-Piagetian Approach to Cognitive Development. Routledge; 2019.
50. Medina J. Brain rules: 12 principles for surviving and thriving at work, home, and school. ReadHowYouWant.com; 2011.
51. Quak M, London RE, Talsma D. A multisensory perspective of working memory. Frontiers in human neuroscience. 2015;9:197.
DOI: 10.3389/fnhum.2015.00197
52. Talsma D. Predictive coding and multisensory integration: an attentional account of the multisensory mind. Frontiers in Integrative Neuroscience. 2015;9:19.
DOI: 10.3389/fnint.2015.00019
53. Hunsaker PL. Debriefing: The key to effective experiential learning. In Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL conference. 1978;5.
54. Bloom BS. Taxonomy of educational objectives. Vol. 1: Cognitive domain. New York: McKay. 1956;20-24.
55. Krathwohl DR, Anderson LW. A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. LonGEan; 2009.

© Copyright (2021): Author(s). The licensee is the publisher (B P International).