Chapter

Activities Pivotal for the Sustainability of Newly Established Technology Transfer Offices: A Case Study of Publicly Financed South African Universities

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Abstract

The activities with potential to sustain new technology transfer offices (TTOs) within the publicly financed South African universities (PFSAU) and elsewhere are poorly examined. The current chapter thus aims to lay out a series of simple strategic activities which the referred universities can execute to ensure the sustainability of their newly formed TTOs. Data were collected via strategic conversations with intellectual property (IP) experts, and active academic researchers from PFSAU. The activities considered vital for the sustainability of newly formed TTOs in this study encompass extensive training of TTOs staff, IP awareness within and outside the universities, compliance with relevant legislations, learning from well-established TTOs, establishment of IP and innovation policy as well as IP and innovation modules, collaboration with formal and informal sectors outside the universities, execution of applied and industry-driven research by academics and finally, protection and commercialisation of IP. Overall, efficacious executions and implementations of these activities as discussed in the present study will not only contribute towards the sustainability of newly established TTOs within PFSAU but also aid in achieving some of this universities' shared goals such as community engagement, research with economic impact, teaching and learning. However, some of the referred activities can be achieved either over a short or medium periods, but together are crucial stepping stones to continual achievements of long-term goals of TTOs in PFSAU.

Keywords: intellectual properties, innovation, South Africa, technology transfer office

1. Introduction

Intellectual property (IP) is the application of the mind by any individual to develop or invent something new and original, either an innovative technology or invention that can be legally protected from being exploited by people

without the owner's/inventor's consent [1–3]. This protection can be in terms of a particular country's legislation or a foreign law. The World Intellectual Property Organization [2] describes an innovative technology as a means of creating something novel that improves a product, process or service. Furthermore, it defines an invention as new research results that can both solve a problem and be exploited commercially. According to Kalanje [4], innovative technologies and inventions generally stand a better chance of successfully reaching the marketplace if IP is used strategically.

Various types of IP that can be used to legally protect the innovative technologies and inventions include patents, copy rights, designs, trademarks, geographical indications, trade secrets/know-how and plant breeder's rights [5–8]. By copyright, the author of the present paper refers to a bundle of rights granted automatically (in South Africa) by law to creators of the original work [9]. However, the work must be fixed in a tangible medium (i.e. copies and phonorecords) for protection under this IP. Typical examples of materials that can be copyrighted encompass artistic, dramatic, literary and musical works, sound recordings, broadcasts and films [10, 11]. Unlike copyright, registered designs are granted as a form of formal IP and are classified as either aesthetic or functional [12]. According to the National Intellectual Property Management Office [6], aesthetic designs protect the visual attractiveness of a product, and functional designs protect features of an article that are necessitated by the function the article is to perform. These designs must be new and original, and not common in the state of the art at the time of registration or protection. It should be stated that a sole product may be registered as both a functional and aesthetic design. With regard to trademarks, their primary functions are to distinguish different sources of products or providers of services from each other, but they may also have other connotations [13, 14]. A trademark can take many forms including amongst others, words, pictures or even smells [15]. Geographical indications are forms of IP that identify the geographical origin of a product where a given quality, reputation or other characteristic of such product is essentially attributable to its geographical origin [16]. Generally, geographical indications are protected by means of sui generis systems or via conventional IP rights, mainly as a form of trademark. A trade secret is any confidential and commercially valuable information that provides a company with a competitive advantage, such as customer lists, methods of production, marketing strategies, pricing information and chemical formulae [17]. Protection of these secrets may extend indefinitely, lasting as long as the subject matter of the trade secret is commercially valuable and is kept confidential. In contrast, a patent is the legal right of an inventor to exclude others from making or using an invention, and this right is customarily limited in time to 20 years from the priority date in most countries [18]. To qualify for patent protection, inventions must be new, nonobvious and commercially applicable.

Intellectual properties are becoming increasingly important tools for sustainable development in developing countries [19]. Most developing countries that are found in various regions of Africa such as Namibia [20], Nigeria [21], Kenya [22], Mozambique [23], Uganda [24], Tanzania [25] and Egypt [26] amongst the others have developed IP policies to foster economic and social development. South Africa is not excluded and the IP Rights from Publicly Financed Research and Development Act, Act 51 of 2008 (IPR Act), was established by the government to encourage these developments. The objectives of this Act are to encourage the identification, protection, utilisation and commercialisation of all IP emanating from publicly financed research and development, for the benefit of the people of the Republic.

As part of an effort to achieve these, the South African government has recently established technology transfer offices (TTOs) in various publicly financed universities and other state-owned enterprises to carry out the above-stated objectives. The government provides the start-up finance for a certain number of years (3 years for start) to ensure the establishment of these offices, and thereafter, it is the responsibility of the host institution to sustain the referred office. It should be stated that the performance of university TTOs in South Africa and elsewhere has been studied, and a wide range of Data Envelopment Analysis metrics including TTO revenue, number of IP/invention disclosures, number of patent applications, patents granted, licences signed, start-up companies formed and new commercial products, employment and productivity growth of start-up partners amid others have been selected to assess the performance and success of TTOs based at the universities [27, 28]. However, studies looking at the strategic activities with potential to contribute towards achieving these metrics which are curial to the sustainability of newly formed TTOs within the publicly financed South African universities (PFSAU) are lacking. It is fundamental that continual effective strategic activities that encourage the innovative ideas and disclosures of actionable IP be put in place to ensure that these offices achieve the objectives of IPR and become self-supporting.

The present study is thus aimed at investigating some of these strategic activities. Importantly, the stated Data Envelopment Analysis approach highlighted earlier is regarded as the most suitable and acceptable way of measuring university-based TTO efficiency. However, such approach is not applicable to newly established TTOs, as the offices need to engage in strategic activities that will in a long run enable them to build a strong IP/invention and commercialisation portfolio to allow the application of such approach. Therefore, the strategic activities can be considered performance measurement necessary to determine whether newly established TTO is on the right track to achieve their goals or not.

2. Research methods

Information presented in this chapter was gathered using strategic conversation with IP experts and active academic researchers in PFSAU who are knowledgeable about IP and technology transfers. Furthermore, the author also extracted copious notes through listening to strategic conversations amongst local and international IP experts who presented at World Intellectual Property Organisation Summer school, held at the University of the Western Cape (Cape Town, South Africa, 27 November to 08 December 2017), under the theme 'Advanced Intellectual Property and Transfer of Technology'. According to Kyprianou et al. [29], strategic conversations are any naturally occurring, as opposed to scripted or interview-based, interactions (including talk and non-verbal cues) amongst the targeted population. Godfrey and Hill [30] wrote that strategic conversation data are distinct from archival and interview data and are likely to generate insights into otherwise unobservable and neglected aspects of strategy because conversations are (1) unscripted, naturally occurring and fluid and (2) include multiple voices and perspectives. Generally, all the personnel from whom the authors obtained information via strategic conversation are referred in this study as 'participants', except in few cases were they are specified (i.e. academic researchers in PFSAU). Overall, content analysis was used to analyse data gathered. According to Krippendorff [31], this type of analysis provides new insights, increases a researcher's understanding of a particular phenomenon and informs practical actions. Simple descriptive statistics, namely percentage, were used were necessary.

3. Results

The present study documented the following activities with potential to sustain newly established TTOs within PFSAU;

3.1 Extensive training of technology transfer offices staff

An extensive training of staff from newly established TTOs via workshops and short courses was perceived by all participants as critical to ensure that the office functions swiftly and efficiently. Furthermore, they reported that the success of any strategic activity depends upon motivated, knowledgeable as well as empowered staff. However, they stressed that relevant workshops and courses that are in line with the office's strategic goals should be prioritised. Some of the participants were also of the view that newly established TTO staff must not attend all technology transfer or IP-related courses/workshops. This was based on the fact that the duties of TTO staff are both university-based and outside-university based. For instance, they asserted that the staff must educate the researchers and students within the university about the various technology transfer issues including IP protection and commercialisation, and also search and approach/visit potential funders for IP commercialisation outside the university.

3.2 Intellectual property awareness within and outside the universities

Intellectual property awareness was stated by the vast majority (n = 16, 80%) of participants as one of the critical factors that might encourage the researchers and students within the university and formal and informal sectors outside the university to disclose IP and innovative ideas with potential for commercialisation to newly formed TTOs within PFSAU. Based on the researcher's understanding of participants' descriptions of these sectors, informal sectors in this study refer to community members including those who are involved in the informal trading of creations and innovative products. The formal sector includes institutions outside the university which are known or more likely to develop products with potential IP for commercialisation or composed of individuals with ideas that might lead to the identification of these IP. According to participants, IP campaigns and awareness amid both formal and informal sectors outside the university are crucial, because the sustainability of newly established TTO within PFSAU cannot wholly rely on IP disclosure from academics within the university. Similar campaigns and awareness were also mentioned by participants (n = 16, 80%) as imperative amongst researchers in the universities. About 57.2% (n = 9) of these participants specifically those from PFSAU stated that very few of their academic co-workers know about the IP protection and commercialisation; thus, IP awareness in this regard is fundamental. Workshops (n = 16, 80%) and media outlets (n = 8, 40%) such as prints-outs in the form of posters, pocket manuals and flyers, and Internet specifically social networks such as Facebook and radio were generally perceived by interviewees as important innovative ways of increasing awareness of IP.

3.3 Intellectual property and innovation policy

Only seven participants (35%) regarded the development of IP and innovation policy as essential key strategic activity for the sustainability of newly established TTOs within PFSAU. They stated that the primary aim of this policy should be to promote a culture of innovation, IP protection and commercialisation within

the universities, and in both formal and informal sectors outside the universities, while protecting IP rights. For instance, most of the participants (n = 4, 20%) stressed the need for IP and innovation policy to endorse execution of applied and industry-driven research as well as innovations amongst the researchers within the universities and in both these sectors. The rest of the interviewees (15%, n = 3) reported that for this policy to contribute towards the sustainability of newly established TTOs, it must encourage the strategic collaboration between local and/or international business and these offices. Furthermore, they pointed out that such policy must specify the terms and conditions for funding of collaborative research or innovative programmes, including the ownership of IP or innovative idea.

3.4 Compliance with relevant legislations

Extensive knowledge of various IP and innovative laws as well their compliance by newly established TTO's staff was highlighted by some participants (n = 20) as essential to the office's sustainability. This will, according to some of these participants, assist the newly established TTOs within PFSAU to avoid the financial penalties and damages to the office's reputation allied to infringement. Furthermore, they were of the view that staff from this office must keep track of any legislation or regulation changes and appraise how they may affect the office's various operational areas.

3.5 Learning from well-established technology transfer offices

One participant reported that staff from newly established TTOs within PFSAU should consult with well-established TTOs to get advice and to observe their activities. This participant was of the view that the latter offices are now able to do the following: (i) eliminate projects and processes that do not work and (ii) identify potential or real problems and search for new working strategies or approaches to solve them. Subsequently, newly formed TTOs within PFSAU can benefit by learning from experienced TTOs.

3.6 Intellectual property and innovation modules

This activity was highlighted by one participant who stated that an introduction of compulsory IP and innovation modules within the South African higher institutions of learning and elementary schools would be one of the key activities to sustain the newly formed TTOs within PFSAU. According to this participant, IP and innovation education can support and capacitate students and learners in becoming IP creators or inventors.

3.7 Collaboration with formal and informal sectors outside the universities

As one of the imperative strategic action to sustain newly formed TTOs within PFSAU, an overwhelming majority (n = 16, 80%) of participants recommended establishment of alliance between these offices and informal as well as formal sectors (as defined in this study). This collaboration was viewed as having great potential to produce economically viable and beneficial innovations, which would contribute meaningfully to sustaining the newly formed TTOs within PFSAU as more IP and innovative ideas from both personnel within the universities and outside will be disclosed to offices. Therefore, participants suggested the identification of people possessing innovative ideas or who are involved in innovative

business (formal or informal) outside the universities by newly formed TTO staff and collaborate with them.

3.8 Execution of applied and industry-driven research by academics

As expected, an execution of applied and industry-driven researches or projects was disclosed by all participants as a vital activity to sustain newly formed TTOs within PFSAU. Participants emphasised the need for researchers and academics within these universities to avoid conducting research that is basic or does not consider the identification and protection of IP with potential for commercialisation. According to the participants, this can be achieved by conducting IP and innovative awareness focusing exclusively on the significance of conducting research/project with potential IP for commercialisation. However, in addition to this, they suggested the initiations of activities with an objective to coerce academics to execute research projects that might lead to the identification of IP with potential for commercialisation. In this regard, the vast majority (n = 14, 70%) of these participants emphasised the need for a clear innovation and IP policy underlining the attractive and adequate incentives for researchers who disclosed the IPs with potential for commercialisation to TTOs. They stressed the need for this policy when taking into consideration the long duration of obtaining a patent as opposed to the benefit of publishing research work (including those with potential IP for commercialisation) in the journals accredited by the South African Department of Higher Education and Learning. Such benefits according to participants include generous financial remuneration (depending on the institution) and contribution to job promotion. Another strategic action suggested (n = 8, 40%) to coerce researchers within PFSAU to conduct research with commercial impact is to formalise a compulsory extensive patent and novelty search prior to the initiation of research projects. Therefore, the research proposal templates of all faculties within the universities should be amended to include novelty and potential IP section. Research proposals without this section should not be approved by the relevant committee.

3.9 Intellectual property protection and commercialisation

As anticipated, the protection and commercialisation of IP and innovative materials was mentioned by all participants as a compulsory or 'must do' activity to ensure the sustainability of newly established TTOs within PFSAU. However, for this to be a success, it was emphasised that either some of the earlier mentioned strategic activities or the combinations of these activities should be implemented successfully. These activities included collaboration with formal and informal sectors outside the universities, compliance with relevant legislations, execution of applied and industry-driven research by academics, extensive training of TTO staff, IP and innovation policy, IP and innovation modules, IP awareness within and outside the universities, and learning from well-established TTOs.

4. Discussion and perspectives

Strategic planning is critical to the success of any newly established office, and TTOs are not an exception, chiefly because this kind of a planning indicates where an institution wants to go and how it will get there [32, 33]. However, prior initiations of strategic plans of any office within the institutions, clear goals and associated strategic objectives for the office must be a priority written [34, 35]. Subsequently, strategic objectives must outline an office's intended activities

designed to achieve inscribed strategies and, ultimately, goals. With reference to PFSAU, their common goals include, enhancing teaching and learning, research and community engagement/public services. Consequently, it is acceptable to state that the establishment of TTO within the above-stated universities must directly contribute to some of these goals.

As highlighted earlier, in South Africa, the primary and common goal of TTOs within the PFSAU is to identify IP and thereafter protect and commercialise it for the benefit of the people of the republic as mandated by the IP Rights from Publicly Financed Research and Development Act, Act 51 of 2008 [6]. Therefore, continual accomplishment of these goals will automatically aid in the sustainability of newly established TTOs. However, such attainment will in turn depend on the execution of effective strategic activities. Participants in the present study mentioned the following as some of the key strategic activities that South African publicly financed universities can use as tools to achieve the aforesaid goals and ultimately the sustainability of their newly formed TTOs: (i) collaboration with formal and informal sectors outside the universities, (ii) compliance with relevant legislations, (iii) execution of applied and industry-driven research by academics, (iv) extensive training of TTOs staff, (v) IP and innovation policy, (vi) IP and innovative modules, (vii) IP awareness within and outside the universities and (viii) learning from well-established TTOs. These activities were considered by participants as vital determinants of newly based university TTO productivity and sustainability. Therefore, it can be said that the sustainability of this kind of TTOs relies on short or medium strategic activities (or both activities) that build on each other's accomplishments, to ensure long-term goals of the offices and continued progress.

4.1 Extensive training of technology transfer office staff

An extensive training of newly established TTO staff via relevant workshops and short courses to ensure efficient functioning of the office as stated by participants in this study is partially supported by various studies [36–39]. These studies demonstrated the effectiveness of staff empowerment at work place via relevant workshops or courses. In support of finding from the current study, Perera et al. [40] revealed that lack of relevant skills, knowledge and experience amongst most officers who are responsible for the development of research, commercialisation and marketing in a Government Research Organizations of Sri Lanka hindered an effective technology transfer and commercialisation process. A similar finding was noted in Ghana [41] and elsewhere [42, 43]. Indeed, Van Looy et al. [44] found that there is a positive association between university technology transfer efficiency, knowledge and relevant experience of TTO staff. Therefore, extensive training of staff via workshops as well as short courses might be crucial as it can capacitate the workforce with appropriate professional skills and knowledge, especially since there are no formal educational qualifications for technology transfer. Meanwhile, TTO staff are expected to have a variety of educational backgrounds useful in carrying out the office's goals, and in this regard, initiatives such as workshops and short courses as reported in this study are key to achieving this. These initiatives should however encompass skills focusing on flexibility of dealing with academic staff and students, because the successful transfer of technology (i.e. IP protection and commercialisation) within the universities depends in large part on the IP disclosures to TTOs by these personnel. Sibanda [45] observed that key ingredients for successful technology transfer within the South African public research institutions stem from an effective and trustworthy relationship between TTO staff and the inventors, based on the ability of the first personnel to engage with the latter and demonstrate

empathy with their challenges, as well as being able to proactively assist them to extract the maximum value from their research.

However, it is very crucial to emphasise that not all newly established TTO staff within PFSAU require training. For instance, newly appointed vast experienced employees with relevant skill set, networks and depth of knowledge usually have worked long enough to understand technology transfer culture and thus can add instant value to the office. Hiring such people can therefore also help cut down on training cost, as the focus can only be on mandatory training. Generally, to ensure swift proper functioning of newly established TTOs (including effective technology transfer management) and ultimately its sustainability, first priority should be given to highly experienced professionals in the field of technology transfer when recruiting staff for newly established TTOs within PFSAU. Importantly, for inexperienced employees who need to be capacitated with appropriate professional skills and knowledge, there must be a balance between course/workshop attendance and day-to-day activities of the office. Accordingly, the relevancy of each course/workshop to be attended by such employees must be determined against the office's principal strategic goals prior approval and financing. This however, should not be misconstrued, because there are some courses/workshops that are not directly contributing to the office's strategic goals, but can assist the staff to better execute and rapidly understand matters that are directly linked to the office's mandate. Therefore, a sound motivation should be given for attending such courses/workshops.

4.2 Intellectual property awareness within and outside the universities

The success of the IP system depends very much on the public's level of awareness [46]. According to Doerte [47], this kind of awareness generally influences and changes public opinion and behaviour on an issue, because it serves as an educational tool to assist people to better understand a particular issue or topic and ultimately develop an interest. As such, it is not surprising that a sizable number of participants in the present study mentioned IP awareness amongst academics and students within the university and other people not affiliated to the universities (referred in this study as formal and informal sectors) but who are involved in innovative creations as a potential activity to contribute to the sustainability of newly established TTO within PFSAU. In support of this view, Tartari et al. [48] found that researchers who are aware of the significance of research commercialisation are more likely to be involved in IP protection and collaborative projects with industries. Likewise, a study by Risaburo et al. [49] revealed that Indian academic institution patent application increased drastically after the institutions became aware of the importance of protecting IP and dissemination of knowledge through patents.

On the other hand, Alessandrini et al. [50] who interviewed personnel dedicated to technology transfer at PFSAU found that low levels of IP awareness (including of the benefits of protecting and commercialising research) amongst researchers have contributed to the low number of actionable IP/invention disclosures and the low conversion of patents to commercial products or licences. These authors also revealed that top management within the universities is vital for success of newly established TTOs and consequently suggested that a top-down approach would be most beneficial by promoting awareness of IP amongst the executives. Certainly, the top management holds the power to set tone, and thus they play a principal role in whether the institution will actively engage in IP protection and commercialisation or not. Therefore, IP awareness by newly established TTO staff within the PFSAU must not only follow bottom-up approach (i.e. conducting IP awareness amongst academics and students) as suggested by participants in this study, but

should also adopt top-down approach (i.e. conducting IP awareness amongst councils and management). The latter approach should be the first because once the university top executives are aware of the value of IP protection and commercialisation to the institution and South Africa at large, it will be instrumental in spreading the message across the executives (i.e. faculty deans and heads of departments), who will in turn inform the researchers.

The recommendations made by participants in the present study regarding execution of IP awareness amid formal and informal sectors as one of the strategic activities to sustain newly established TTOs have merit. For instance, Szogs [51] who studied a collaboration between the University of Dar es Salaam's College of Engineering and Technology (Tanzania) and informal and informal sectors regarding the transfer of technology found that some of the inventions created by students in the colleges were initially developed by informal and formal sectors. The research by Kawooya [52] revealed active interactions in Automotive Engineering (i.e. sharing of innovations, solutions to problems and product designs as well as models) between the personnel from formal university research institution and informal-sector in Kampala (Uganda). In South Africa, most commercialised geographical indications and pharmaceutical products [44, 53–60] invented/developed by academic researchers were either inspired by traditional knowledge in informal sectors or developed with the help of people in this sector. It therefore makes sense that participants in the current study perceive IP awareness amid academics and students within the university and informal sectors as having potential to ensure that newly formed TTOs receive commercialisable IP and innovative disclosures from people affiliated to the university and those who are not. This is crucial especially since the IP Rights from Publicly Financed Research and Development Act, No. 51 of 2008 only oblige the South African university staff (i.e. academics, researchers and supports) and students to disclose innovative and IP ideas they created using institution's resources to TTOs [61], without coercing them to execute projects that might lead to the identifications of these ideas. In other words, academics within the PFSAU are not compelled to conduct projects that might lead to the identification of the referred ideas. Therefore, educating both informal and formal sectors about IP as well as innovations including allied benefits, in addition to people affiliated to the university, is more likely to increase IP disclosure to the university's newly established TTO. However, for this to happen, staff from this office must during IP awareness advice people to work with them as far as IP protection and commercialisation are concerned.

Although there is logic in conducting IP awareness in the formal and informal sectors as one of the strategic activity to sustain newly established TTOs as discussed above, it should however be noted that establishing beneficial partnership with these sectors will not be an easy task and cost-free. This is especially true when looking at the strategic activities such as workshops, media outlets including Internet (via the development of Website spreading the word about the importance of IP protections and commercialisations), radio and print-outs such as poster, pocket manual and flyers, disclosed by interviewees as part of IP awareness. For instance, print-outs reporting on IP and innovation to be distributed to people should be written in both local and English dialects, to accommodate people (especially in the informal sector) who cannot read and understand the latter language. Similarly, to cover a larger number of audiences in informal and formal sectors using radio broadcast will require IP information to be communicated in various languages to accommodate diverse South African ethnic groups, and this will be very costly for newly established TTOs. It will therefore be more practical and cost-effective for these offices to firstly focus on informal and formal sectors located near the universities. In this regard, the use of local community radio station and

print-outs to convey IP information will be less expensive. In addition, the newly established TTO staff can identify potential people or groups within informal and formal sectors and arrange with them to provide a short talk on matters of IP.

Though not mentioned by participants in this study, initiation of IP and innovation competitions with attractive prices and rewards for the winners could also increase awareness and eventually IP portfolio within newly established TTOs. This initiative is not a new suggestion and has proved to be beneficial in encouraging innovation and commercialisable inventions [62–64]. Such initiatives as mentioned by participants in this study could therefore inspire academics, people in both formal and informal sectors, to disclose potentially commercialisable inventions and innovative ideas to newly established TTOs. However, there must be terms and conditions, whereby winners of prize/s in such competitions must have, at least, disclosed a single IP or innovative idea that meets the legal requirements for protection by these offices. The criterion for determining the winners can be outlined by TTO personnel. This will in the long-run create a strong rapport between this personnel and inventors within the universities, as well as informal and formal sectors, and will in due course encourage them to voluntarily disclose their ideas that are worth protecting to the office.

4.3 Intellectual property and innovation policy

The significance of a relevant and sound policy in sustaining and assisting an institution to achieve its role cannot be overemphasised [65, 66]. Some participants in the current study suggested the development of IP and innovation policy as one of the crucial key strategic activity for the sustainability of newly established TTOs within PFSAU. Similar findings were IP policy were less valued by academics in these institutions as fundamental to transfer technology and commercialise research output was reported in Botswana [67]. According to the participants in the present study, IP and innovation policy must promote the following: (1) the execution of applied and industry-driven research as well as innovations amongst the researchers within the universities and in both formal and informal sectors, (2) encourage the strategic collaboration between local and/or international business and newly established TTOs, and (3) it must specify the terms and conditions for funding of collaborative research including the ownership of IP.

The latter need careful attention; Bansia and Karunanidhi [68] found that most academics affiliated to a PFSAU strongly disagreed with the provision of IP Rights from Publicly Financed Research and Development Act, Act 51 of 2008, regarding the ownership of IP, that if a researcher has conducted research with publicly financed funding, the ownership of the IP produced from such research resides with the institution the researcher is affiliated to. Comparable finding was reported by Ramika [69]. Thus, a very generous financial reward via IP and innovation policy will go a long way in encouraging academics within the universities and personnel in informal and formal sectors to disclose IP for possible protection to newly established TTOs. It is worth mentioning that IP and innovation policy that encourage the strategic collaboration between local and/or international business and this offices, as reported in this study, is supported by other studies [70, 71] which demonstrated that such partnership is key to the successful transfer of technology from universities to industry/market. Nevertheless, for sustainable newly established TTO-business partnerships, effective engagement mechanisms beneficial to both parties must be enacted.

However, participants' recommendations that IP and innovation policy must promote the execution of applied and industry-driven research as well as innovations amongst the researchers within the universities and in both formal and

informal sectors will be very complex and time-consuming for newly established TTOs. For instance, such policy must provide a climate beneficial for industry-driven research and innovations by advocating extensive training and opportunities for increasing skills and marketplace awareness amongst researchers/innovators, to guide research/innovation direction on industry requirements [72]. Therefore, the referred policy can be effective and beneficial activity in several years. This is especially true, when taking into account the diversity of IP and an innovation with potential value for commercialisation that might arise from the academic staff.

Importantly, the academic staff should be involved in policy development as they will be implementing it on almost daily basis. In this regard, newly established TTO IP and innovative policy draft must be made available to them for comments and approval. Same policy draft must be accessible to the public within informal and formal sectors for inputs. The involvement of all potential partners with newly established TTOs in institutional policy development will advocate a sense of ownership, less dissatisfaction and greater obligation to implementation. This will ultimately build trust and strong rapport between the TTO staff and potential partners in IP protection and the drive to commercialisation. However, the success of the referred policy must be reviewed and revised more often in line with newly established TTO strategic goals, to permit the office to respond and deal with unexpected changes in industrial structures.

4.4 Compliance with relevant legislations

Studies showed that legal compliance with relevant legislations and regulations is one of the cornerstones for the sustainability and success of any office [73–75], and as such newly established TTOs are not exception. The increased need for TTO staff to be aware of the latest developments in various IP law and related regulations cannot be over-emphasised [76]. This is because IP rights (including legal compliance) and infringement are generally thorny issues in the technology transfer process [77, 78].

In the present study, some participants stated that newly established TTO staff must be knowledgeable about various IP and innovative laws and ensure that they comply with them to avoid the financial penalties and damages to the office's reputation allied to infringement. Certainly, as far as technology transfer processes are concerned, TTO staff are key human resources in carrying out all compliance activities on behalf of the PFSAU. Furthermore, they are also responsible for the improvement or amendment of the institutional policies relating to the management and commercialisation of IP. Therefore, it is very fundamental for newly established TTO staff to identify legislations and regulations (locally and internationally) that apply to the office and assess how each affect the day-to-day work of the office. This must be continual activity to ensure that the office also meets its legal obligations in various operational areas to mitigate its risks. It is therefore suggested that newly established TTOs within PFSAU must either have a highly experienced legal expert to handle and/or oversee legal matters or must work closely with the university's legal office and seek advice or clarity prior to committing/signing any deal or agreement, especially those that are legally binding. The latter will cut cost of using external legal consultants for some services.

4.5 Learning from well-established technology transfer offices

While TTOs are still new in some PFSAU, there are universities and science councils formally carrying out technology transfer activities which are considered well-established, having been in operation for a number of years [79]. These are

institutions that learned effectively from their own failures and from the failures of others over time [80] and have likely commercialised more IP and facilitated numerous patents and licence agreements. One participant in the current study stated that staff from newly established TTOs should consult with employees of well-established TTOs to get advice on the running of the office including the strategic activities. In the same view, Friedman and Silberman [81] observed that the length of time a TTO has existed can measure any learning or experience effects within it and that established networks as well as relationships created over time, which are vital in the success of TTO, come with experience. Similarly, Weckowska [82] has shown that the university TTOs learn through experimentation and failure and by sharing these experiences with other TTOs, thereby improving the technology transfer process. Therefore, the newly formed TTO within PFSAU can be efficient by benchmarking its own performance against well-established TTOs and seeking advices where necessary in order to set up a roadmap for improvement. Although this might contribute to the survival and adaptation of newly established TTO as imperative information for learning, it does not mean that employees from this office 'must do things similarly to well-established TTOs' even if prior rights/consent are attained. Case studies have shown that universities' TTOs vary in size, resource allocated and scope of their technical specialisation [83–85]. As such, if not cautious, newly formed TTOs may adopt strategic actions that are not compatible with the configuration of their resources and academic environment, all which according to Lafuente and Berbegal-Mirabent [86] translate into ineffective changes in the TTOs' technology transfer operations and, consequently, poor productivity results.

Accordingly, excursions to well-established TTOs for advice by newly formed TTOs staff as reported in this study must be viewed primarily as a vehicle to assist in observing actions from divergent perspectives and subsequently to develop novel and original ideas/activities that can addresses their goals. It is therefore recommended that as part of learning from experienced TTOs, staff from newly established TTOs should ask questions related to the short and long-term challenges that are likely to be faced by the office, the failure of some of the projects including the root cause of failure and mitigation measures used. This will assist the staff from newly established TTOs to avoid similar challenges from occurring, and/or to know which effective solution to apply when they come across such hitches, and subsequently allow the introduction of changes that enhance productivity levels.

4.6 Intellectual property and innovation modules

Education in every sense is one of the fundamental factors of development [87], because it raises people's productivity and creativity and promotes entrepreneurship as well as technological advances. However, only one participant in this study stated that an introduction of compulsory IP and innovation modules within the South African higher institutions of learning and elementary schools would be one of the key strategic activities with potential to sustain newly established TTOs based on the universities. University researchers in Pakistan also highlighted the need of IP property rights in the educational system of this country for effective IP and commercialisation [88]. Comparable finding was noted in Brazil [89] and Australia [90]. Indeed, as reported by European Union Intellectual Property Office [91], IP education has great potential to capacitate learners/academic staff with skills and competences that would enable them to become familiar with IP, understand its potential to generate income and economic growth and lead them to respect IP rights, whether their own or those of others. A study conducted by the National Union of Students [92] found that most students in Higher Education and Further Education institutions of the

United Kingdom who had studied designs, design rights and trade marks in their current course recognised the importance of IP education as a key to exploit ideas commercially and want IP issues to be included from the early stages of their course. The same organisation has also shown evidence that IP teaching earlier in students' education motivates their greater interest in technology transfer issues.

While an introduction of compulsory IP and innovation modules within the South African elementary schools has potential to instil innovation culture amongst learners, its contribution towards the sustainability of newly established TTOs based in the universities will only materialise over years when learners go to tertiary institution wherein they are expected to develop a comprehensive understanding of the IP which will motivate them to become inventors or innovators in their respective fields of study. Similarly, the contribution of compulsory IP and innovation modules within the South African higher institutions will only benefit newly established TTOs in a long run. For instance, the development of module curriculum (and its accreditation) might take longer, as it must be tailored to particular needs of students in different disciplines across the university, covering theoretical teachings and practical approaches through real life case studies. However, once programme is up and running, students will be able to rapidly and prematurely recognise and explore their own creative ideas/IP worthy of legal protection and commercialisation and disclose them to TTOs.

4.7 Execution of applied and industry-driven research by academics

All participants in this study suggested an execution of applied and industry-driven researches by academics as imperative activity to sustain newly established TTOs within PFSAU. This finding does not strike as surprising since augmentation of research-related revenues is one of the goals embraced by many universities [93]. In agreement with participants of the current study, Asuako [41] also emphasised the need for academics within the Ghanaian government owned Universities to undertake industry-oriented research to successfully transfer technology and ultimately support the needs of society. Researchers in South Africa [69] and Norway [94] also accentuated this. Interestingly, Mansfield [95] found that 11 and 9% of new products and processes, respectively, in 76 United States firms were initially from academic research. Similarly, Tijssen [96] who questioned inventors in the Netherlands reported that 20% of patented technologies that became innovations were based on publicly funded research executed by academics. With particular reference to the present study, execution of applied and industry-driven research by academics will indeed contribute towards the sustainability of newly established TTOs within PFSAU. However, for some TTOs located in the universities dominated by scientists who carry out research of a basic nature, the referred sustainability will be achieved over a period of time. This is because supporting these scientists to think creatively and conduct novel industry-driven researches is a complex process that cannot be achieved in a short period of time and will depend on the nature of the project.

One fundamental factor that discourages academic researchers to conduct industry-driven researches mentioned by participants in this study is the lack of IP and research commercialisation awareness. It is worth stating that encouraging academics to execute applied and industry-driven researches via IP awareness alone has shortcomings, as newly established TTO staff have very little influence on the quality and type of researches conducted by academics. When asked about actions to take if IP awareness fail, most of the participants highlighted the need for initiations of activities with an objective to both encourage and coerce academics to conduct research with potential IP for commercialisation. They disclosed that a universities' policy reflecting better benefits (i.e. generous financial remuneration and

contribution to job promotion) of protecting and commercialising research work compared to the benefits offered by publishing in the accredited journals will go a long way in encouraging academics to both initiate and actively participate in IP projects with potential for commercialisation and ultimately disclose them to newly established TTOs. Indeed, studies [85, 97] showed that researchers' retaliation to take part in technology transfer activities within institutions of higher learning is a weak system of incentives.

Another strategic activity reported by participants for encouraging academics to conduct industry-driven research is to do an extensive patent and novelty search prior initiation of projects. The significance of this action towards increasing the probability of implementing projects with commercial value cannot be overemphasised [97–99] and will certainly assist the academics as well as students to avoid the likelihoods of duplicating research projects. However, for this to work, researchers should keep up-to-date with the latest developments in their respective professional fields to ensure that their researches are new and original. One way to achieve this is for newly established TTOs to encourage/initiate joint research projects to foster university-to-industry technology transfer. In addition, some participants recommended the amendments of the research proposal templates of all faculties within the universities to include novelty and potential IP section. Subsequently, suggested disapproval of research proposals without information relating to this section. In this regard, it makes sense that newly established TTO staff must form part of the university's research proposal-approval committee (perhaps at departmental level) and assess projects with potential IP for commercialisation. This will afford TTO staff an opportunity to provide advices to researchers on how the office can assist in commercialising their researches and to guards against activities that might affect the legal requirements of protecting potential IP from such projects.

Although not stated by the participants in this study, staff from newly established TTOs within PFSAU should write industry-driven proposals in collaboration with appropriate academics/researchers and apply for funding. Subsequently, funded research projects encompass the following: (1) aim and objectives and (2) expected outcomes with potential to address newly established TTOs objectives. The terms and conditions of the project must be allocated to interested postgraduate students. This approach will increase the probability of discovering protectable IP with potential for commercialisation and most importantly afford newly established TTO staff more influence on the research areas or projects conducted by university employees and students. Also, an establishment of a multidisciplinary journal run by these offices that accepts the manuscripts reporting on protected innovations and inventions (amongst others) in all fields of study recognised by the South African Department of Higher Education will contribute significantly in generating money (i.e. via publication fees) for newly established TTOs. In addition, the journal policy should compel the authors whose manuscripts are accepted for publications to transfer the copyright to the journal. This will give the TTOs an exclusive monopoly over all the accepted articles or published articles, including the right to trade as collection of articles or book based on a series of papers. Newly established TTOs in PFSAU can furthermore capitalise financially from the government funding initiatives (such as Technology Innovation Agency Seed Funding, amid others) which are mainly administered by the office to fund the academic projects with 'potential' IP for commercialisation. In this regard, TTO personnel with the consent of funders can amend institutional IP and innovation policy to compel funding recipients to at least write and publish an article in accredited journals in case commercialisable IP was not attained as expected. Subsequently, a considerable proportion of financial reimbursement for publication offered by the government should go to newly established TTOs.

4.8 Protection and commercialisation

As anticipated, the protection and commercialisation of IP and innovative ideas was mentioned by all participants as a compulsory activity to ensure the sustainability of newly established TTOs within PFSAU. This finding was expected for a sole obvious reason that TTOs within these institutions were established with the primary aim of protecting IP and commercialising it for the benefit of people of the republic [6]. There is a growing body of research [98, 100, 101] indicating that the universities' commercialisation performance depends partly on the abilities of their respective TTOs to facilitate exploitation of academic inventions in commercial applications. However, the investigator of the present study shares similar sentiments with his participants that the successful protection and/or commercialisation of IP/innovative creations by newly established TTOs within PFSAU will depend on the positive outcomes of the earlier listed and discussed strategic activities. In other words, these offices stand a better chance of identifying protectable IPs/innovations and successfully commercialise them if these activities are effectively applied. Each of the referred activity has different benefits with potential to launch the office forward towards achieving its principal mandate, which include the introduction of IPs/innovations in markets and thereafter generate income and job creations.

5. Conclusions and perspective

This study concludes that the sustainability of newly established TTOs within PFSAU requires integrated incessant strategic activities, subjected to continual monitoring to ensure their effectiveness. The success of each strategic activity can be easily monitored quarterly and annually by its impact towards contributions to the offices' objectives and ultimately universities' strategic goals. Overall, efficacious implementations of strategic activities proposed in the current study will not only contribute towards the sustainability of newly established TTOs within PFSAU, but will also aid in achieving some of these universities' shared goals such as community engagements, research with economic impact, teaching and learning. For instance, IP awareness as discussed in this study as well as introduction of compulsory IP course within the universities will contribute towards achieving the institutions' teaching and learning goal. Collaboration with informal and formal sectors (as defined in this study) outside the universities as earlier discussed is directly linked to the institution's mission of engaging with the public/community, and lastly, the execution of applied and industry-driven research by academics will contribute to the university's goals of conducting research projects with economic impact. Therefore, all the proposed strategic activities in this study if implemented successfully can be used as an effective tool to sustain newly established university-based TTOs and direct them towards accomplishing the overall goals of the university. However, it should be emphasised that some of the strategic activities documented in this study can be achieved over short, medium or long-term periods, but together they can be utilised as stepping stones to continually achieve the overall goals of newly established TTOs within the publicly financed South African universities.

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References

[1] Pouris A, Pouris A. Patents and economic development in South Africa: Managing intellectual property rights. South African Journal of Science. 2011;**107**:11-12

[2] World Intellectual Property Organization. 2017. Available from: http://www.wipo.int/edocs/pubdocs/en/intproperty/450/wipo_pub_450.pdf [Accessed: 03 August 2018]

[3] Companies and Intellectual Property Commission. 2017. Available from: http://www.cipc.co.za/index.php/trade-marks-patents-designs-copyright/what-ip/ [Accessed: 01 August 2018]

[4] Kalanje CM. Role of Intellectual Property in Innovation and New Product Development. 2018. Available from: http://www.wipo.int/sme/en/documents/ip_innovation_development_fulltext.html [Accessed: 27 July 2018]

[5] Knudso W. An Introduction to Patents, Brands, Trade Secrets Trademarks, and Intellectual Property Rights Issues. Michgain State University: Product Centre of Agriculture and National Resources; 2006

[6] National Intellectual Property Management Office. A Guide to Intellectual Properties for Researchers. Pretoria: The Innovation Hub; 2013

[7] Dagne TW. Place-based intellectual property strategies for traditional and local agricultural products: Acting locally to participate globally in a rights-based approach. Drake Journal of Agricultural Law. 2013;**17**:3-4

[8] De Beer J, Armstrong C, Oguamanam C, Schonwetter T. Innovation and Intellectual Property Collaborative Dynamics in Africa. University of Cape Town, South Africa: UCT Press; 2013

[9] Society of Composers, Authors and Music Publishers of Canada. 2017. Available from: http://www.socan.ca/files/pdf/Copyright%20101%20Eng.pdf [Accessed: 28 July 2018]

[10] Southern African Research and Innovation Management Association. A Guide to Intellectual Properties for Researchers. Pretoria: CSIR Campus; 2013

[11] Bollier D, Bradford G, Racine L, Sohn GB. So What—About Copyright? What Artists Need to Know about Copyright and Trademarks: For Filmmakers, Visual Artists, and Writers. United States of America: LuLu Enterprises; 2013

[12] Organisation for Economic Co-operation and Development. Enquiries into Intellectual Property's Economic Impact Chapter 1. Synthesis Report. Paris, France: Directorate for Science, Technology and Innovation Committee on Digital Economy Policy; 2015

[13] Qinghu A. Well-known marks and China's system of well-known mark protection. Official Journal of the International Trademark Association. 2005;**95**:706-772

[14] Kudrjavceva J. Issues surrounding registration of colour trademarks [MSc dissertation]. University of Latvia; 2012

[15] Jackson L. Solicitor with the Commercial and ICT Unit of Leman Solicitors. 2012. Available from: http://www.leman.ie/ [Accessed: 24 July 2018]

[16] World Intellectual Property Organization. Geographical Indications: An Introduction. 2012. Available from: http://www.wipo.int/edocs/pubdocs/en/geographical/952/wipo_pub_952.pdf [Accessed: 29 July 2018]

[17] Yeh BT. Protection of Trade Secrets: Overview of Current Law and Legislation. Congressional Research Services; 2016

[18] Hall BE. Contribution to the New Palgrave: A Dictionary of Economics. 2nd ed. 2007. Available from: https://eml.berkeley.edu/~bhhall/papers/BHH06_Patents_Palgrave.pdf [Accessed: 28 July 2018]

[19] Fink CM, Maskus KE. Why we study intellectual property rights and what we have learned. In: Fink CM, Maskus KE, editors. Intellectual Property and Development. Lessons from Recent Economic Research. Washington, D.C.: The World Bank; 2002. pp. 1-15

[20] Mengistie G, Halm N, Kaakunga RA. Intellectual Property Audit Report of Namibia. Multi-Stakeholders Workshop: Validation of the National Intellectual Property Strategy for Namibia. Windhoek: Nampower Convention Centre; 2016

[21] Nwokocha U. Nigerian intellectual property: Overview of developments and practice. Journal of Intellectual Property. 2016;**6**:110-116

[22] Nzomo V. Laws Governing Intellectual Property (IP) in Kenya. 2011. Available from: https://ipkenya.wordpress.com/2011/09/09/laws-governing-intellectual-property-ip-in-kenya/ [Accessed: 28 July 2018]

[23] USAID. An Assessment of Mozambique's Intellectual Property System. Nathan Associates Inc., United States Agency for International Development; 2009

[24] Spennemann C. Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Textbooks. United Nation; 2010

[25] Lugwisa AH. Intellectual Property Rights in Tanzania. 2017. Available from: http://yakubuchambers.com/wp-content/uploads/2016/07/a-paper-on-intellectual-property-in-Tanzania.-3.pdf [Accessed: 03 August 2018]

[26] US-Egypt Business Council. Intellectual Property Rights in Egypt. 2017. Available from: http://www.usegyptcouncil.org/wp-content/uploads/2010/08/USEBC-Intellectual-Property-White-Paper-Oct-15.pdf [Accessed: 01 August 2018]

[27] Kim J, Anderson J, Daim J. Assessing university technology transfer: A measure of efficiency patterns. International Journal of Innovation and Technology Management. 2008;**5**:495-526

[28] Tseng A, Raudensky M. Performance evaluations of technology transfer offices of major US research universities ampere. Journal of Technology Management and Innovation. 2014;**9**:93-102

[29] Kyprianou C, Graebner ME, Rindova V. Strategic conversations: Methods for data collection and analysis. In: Elsbach K, Kramer R, editors. The Handbook of Qualitative Organizational Research. Routledge; 2016. pp. 272-285

[30] Godfrey PC, Hill CWL. The problem of unobservables in strategic management research. Strategic Management Journal. 1995;**16**:519-533

[31] Krippendorff K. Content Analysis an Introduction to its Methodology. London, United Kingdom: Sage Publications Ltd; 2004

[32] Gates LP. Strategic Planning with Critical Success Factors and Future Scenarios: An Integrated Strategic Planning Framework. Technical Reports. Carnegie Mellon University; 2010

[33] Pirraglia W. Why is Strategic Planning Important to a Business? 2017.

Available from: http://smallbusiness.chron.com/strategic-planning-important-business-2671.html [Accessed: 22 July 2018]

[34] Chartered Institute of Purchasing and Supply and US Organization the National Institute of Governmental Purchasing. Public Procurement Practice: Strategic Procurement Planning. 2012. Available from: https://www.nigp.org/ [Accessed: 20 July 2018]

[35] Holmes AT. How to Facilitate the Strategic Planning Process. 2018. Available from: http://www.drtyroneholmes.com/uploads/2/0/3/4/20346297/how_to_facilitate_the_strategic_planning_process_-_final.pdf [Accessed: 03 August 2018]

[36] Mahmudi RK, Kargaran JM. The effect of in-service training on empowerment of staff at the University of Tabriz. International Journal of Humanities and Cultural Studies. 2001;**1**:1-7

[37] European Commission. Improving Knowledge Transfer between Research Institutions and Industry across Europe. Belgium; 2007

[38] Maxfield RC, Flumerfelt S. The empowering principal: Leadership behaviours needed by effective principals as identified by emerging leaders and principals. International Journal of Teacher Leadership. 2009;**2**:39-48

[39] Voegtlin C, Boehm S, Bruch H. How to empower employees: Using training to enhance work units' collective empowerment. International Journal of Manpower. 2015;**36**:354-373

[40] Perera HSC, Darshana M, Liyanage C. A Case Study of Technology Transfer Process in a Government Research Organization in Sri Lanka. Technical Reports. Department of Management of Technology, University of Moratuwa Sri Lanka; 2015

[41] Asuako EL. Constraints of industrialization and technology transfer in Ghana [MSc dissertation]. Ghana: Kwame Nkrumah University of Science and Technology; 2015

[42] Swamidass PM, Vulasa V. Why university inventions rarely produce income? Bottlenecks in university technology transfer. The Journal of Technology Transfer. 2009;**34**:343-363

[43] Jorgensen B. Out of the lab and into the market: Universities and businesses struggle with technology transfer issues. Electronic Business. 2005;**31**:13

[44] Van Looy B, Landoni P, Callaert J, Van Pottelsberghe B, Apsalis E, Debackere K. Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. Research Policy. 2011;**40**:553-564

[45] Sibanda M. Intellectual property, commercialisation and institutional arrangements at South African public research institutions. In: The Economics of Intellectual Property in South Africa. Geneva, Switzerland: World Intellectual Property Organization (WIPO) 1013(E); 2009

[46] Ahmed S, Varun PK. Awareness regarding intellectual property rights a survey amongst the P.G. and Ph.D. students of Babasaheb Bhimrao Ambedkar University, Lucknow. International Journal of Law. 2017;**4**:184-190

[47] Doerte P. Media Campaigns—Posters and Flyers (WD). 2017. Available from: https://www.sswm.info/ [Accessed: 01 August 2018]

[48] Tartari V, Perkmann M, Salter A. In good company: The influence of peers on industry engagement by

academic scientists. Research Policy. 2004;**43**:1189-1203

[49] Risaburo N, Kiang CS, Ganguli P, Nithad K, Nishio K, Tansinsin LG, et al. Technology Transfer, Intellectual Property and Effective University-Industry Partnerships: The Experience of China, India, Japan, Philippines, the Republic of Korea, Singapore and Thailand. Geneva: World Intellectual Property Organization; 2018

[50] Alessandrini M, Klose K, Pepper MS. University entrepreneurship in South Africa: Developments in technology transfer practices. Innovation: Management, Policy and Practice. 2013;**15**:205-214

[51] Szogs A. Technology Transfer and Technological Capability Building in Informal Firms in Tanzania. CIRCLE, Lund University; 2010

[52] Kawooya D. Informal–formal sector interactions in automotive engineering, Kampala. In: De Beer J, Armstrong C, Oguamanam C, Schonwetter, T (Editors). Innovation and Intellectual Property: Collaborative Dynamics in Africa. UCT Press, University of Cape Town, Cape Town; 2014

[53] Levy D. Continuities and changes in Ndebele beadwork: C. 1883 [MA dissertation]. Johannesburg: University of the Witvatersrand; 1990

[54] Van Wyk B-E. A broad review of commercially important southern African medicinal plants. Journal of Ethnopharmacology. 2008;**119**:342-355

[55] Maharaj VJ, Fouche G, Senabe J, Nthambeleni R, Kotze F. Agro-processing opportunities identified through a novel mosquito repellent from a medicinal plant. In: Proceedings of the 2nd CSIR Biennial Conference on Science Real and Relevant; Pretoria, South Africa; 2008. Available from: http://hdl.handle.net [Accessed: 26 July 2018]

[56] Singh Y. Systematics of Hypoxis (Hypoxidaceae) in southern Africa [PhD thesis]. Pretoria: University of Pretoria; 2009

[57] Van Wyk B-E. The potential of South African plants in the development of new food and beverage products. South African Journal of Botany. 2011;**77**:857-868

[58] Van Wyk B-E. The potential of South African plants in the development of new medicinal products. South African Journal of Botany. 2011;**7**:812-829

[59] Aboyade OM, Styger G, Gibson D, Hughes G. Sutherlandia frutescens: The meeting of science and traditional knowledge. Journal of Alternative and Complementary Medicine. 2014;**20**:71-76

[60] Department of Science and Technology. Intellectual Property and Technology Transfer at Publicly Funded Research Institutions: Inaugural Baseline Study: 2008-2014. 2017. Available from: http://www.sarima.co.za/wp-content/uploads/2017/05/SA-IPTT_BASELINE-SURVEY-REPORT-2017.pdf [Accessed: 12 August 2018]

[61] Department of Science and Technology. Intellectual Property Rights from Publicly Financed Research and Development Act, No. 51 of 2008. Department of Science and Technology, Government Printer, Pretoria; 2017

[62] Mokter H, Ilkka K. Competition-based innovation the case of the x prize foundation. Journal of Organization Design. 2014;**3**:46-52

[63] Moser P, Nicholas T. Prizes, publicity and patents: Non-monetary awards as a mechanism to encourage

innovation. The Journal of Industrial Economics. 2003;**61**:763-788

[64] The Knowledge Round Table. Using Innovation Competitions to Motivate Students. 2018. Available from: https://www.theknowledgeroundtable.com/using-innovation-competitions-to-motivate-students/ [Accessed: 25 August 2018]

[65] Conti A, Gaule P. Is the US outperforming Europe in university technology licensing? A new perspective on the European paradox. Research Policy. 2011;**40**:123-135

[66] Department of Agriculture. Policy on Agriculture in Sustainable Development a Discussion Document. 2018. Available from: http://www.nda.agric.za/docs/Policy/SustainableDev.pdf 8th [Accessed: 20 July 2018]

[67] Njoku OA. Perspectives on intellectual property from Botswana's publicly funded researchers. In: De Beer J, Armstrong C, Oguamanam C, Schonwetter T, editors. Innovation and Intellectual Property: Collaborative Dynamics in Africa. University of Cape Town, Cape Town: UCT Press; 2018

[68] Bansia R, Karunanidhi R. Intellectual property from publicly financed research and intellectual property registration by universities: A case study of a university in South Africa. Procedia—Social and Behavioral Sciences. 2015;**181**:185-196

[69] Ramika B. Commercialization of university innovation in South Africa [PhD thesis]. KwaZulu Natal: Durban University of Technology; 2016

[70] Van Zyl A, Amadi-Echendu A, Bothma TJD. Nine drivers of knowledge transfer between universities and industry R&D partners in South Africa. South African Journal of Information Management. 2007;**9**:1-22

[71] Chávez JR. University Industry Technology Transfer in Canada (online). 2010. Available from: http://rnee.umich.mx/index.php/RNEE/article/view/61 [Accessed: 17 July 2018]

[72] Baxter R. Innovation and Inventors Interest. New York: Free Press; 2011

[73] Benedek P. Compliance management—A new response to legal and business challenges. Acta Polytechnica Hungarica. 2012;**9**:135-148

[74] Losiewicz-Dniestrzanska E. Monitoring of compliance risk in the bank. Procedia Economics and Finance. 2015;**26**:800-805

[75] Vadastreanu AM, Maier D, Maier A. Is the success possible in compliance with ethics and deontology in business? Procedia Economics and Finance. 2015;**26**:1068-1073

[76] Maskus KE. Encouraging International Technology Transfer. UNCTAD/ICTSD Issue Paper No. 7 (Geneva: UNCTAD/ICTSD). Geneva, Switzerland: International Centre for Trade and Sustainable Development (ICTSD); 2004

[77] Sikoyo GM, Nyukuri E, Wakhungu JW. Intellectual Property Protection in Africa: Status of Laws, Research and Policy Analysis in Ghana, Kenya, Nigeria, South Africa and Uganda. Nairobi, Kenya: ACTS Press; 2006

[78] Song X, Balamuralikrishna R. JOTS v27n1—The Process and Curriculum of Technology Transfer. 2018. Available from: https://scholar.lib.vt.edu/ejournals/JOTS/Winter-Spring-2001/song.html [Accessed: 01 August 2018]

[79] Wolson RA. The role of technology transfers offices in building the South African biotechnology sector: An assessment of policies, practices and

impact. The Journal of Technology Transfer. 2007;**32**:343-365

[80] Madsen PM, Desai V. Failing to learn? The effects of failure and success on organizational learning in the global orbital launch vehicle industry. Academy of Management. 2010;**53**:3451-3476

[81] Friedman J, Silberman J. University technology transfer: Do incentives, management, and location matter? The Journal of Technology Transfer. 2003;**28**:17-30

[82] Weckowska DM. Learning in university technology transfer offices: Transactions focused and relations-focused approaches to commercialization of academic research. Technovation. 2015;**41**:62-74

[83] Sellenthin MO. Technology transfer offices and university patenting in Sweden and Germany. The Journal of Technology Transfer. 2009;**34**:603-620

[84] DRS P, Vidal VS, Zen AC, Barros HM. Management of Intellectual Property in Brazilian Universities: A Multiple Case Study. Rua Washington Luiz: Federal University of Rio Grande do Sul (EA/UFRGS); 2013

[85] Vinig T, Lips D. Measuring the performance of university technology transfer using meta data approach: The case of Dutch universities. The Journal of Technology Transfer. 2015;**40**:1034-1049

[86] Lafuente E, Berbegal-Mirabent J. Assessing the performance of technology transfer offices: An analysis of the relevance of TTO's outcome configuration and aspiration performance. Paper presented at the 4th Workshop on Efficiency in Education, Politecnico di Milano; October 20-21 2016. In: Proceedings of the 4th Workshop on Efficiency in Education; 2016. pp. 1-24

[87] Ozturk I. The Role of Education in Economic Development: A Theoretical Perspective. 2008. Available from: https://ssrn.com/abstract=1137541 or http://dx.doi.org/10.2139/ssrn.1137541 [Accessed: 3 August 2018]

[88] Hina K, Batool S, Khalique M, Iqbal Z. Intellectual property rights in education of Pakistan: Review of constitution, current status and expectations. The Dialogue. 2017;**12**:136-147

[89] Gimenez AMN, Bonacelli MBM, Carneiro AM. The challenges of teaching and training in intellectual property. Journal of Technology Management and Innovation. 2012;**7**:176-188

[90] Monotti A. Maximising the benefits from intellectual property in universities: Awareness of our rights and obligations. Australian Universities Review. 2000:23-31

[91] European Union Intellectual Property Office. Intellectual property and Education in Europe: Study on IP Education in School Curricula in the EU Member States with Additional International Comparisons. Alicante, Spain: Office for Harmonization in the Internal Market; 2015

[92] National Union of Students. Student Attitudes Towards Intellectual Property National Union of Students. London, UK; 2012

[93] Warshaw JB, Hearn JC. Leveraging university research to serve economic development: An analysis of policy dynamics in and across three U.S. states. Journal of Higher Education Policy and Management. 2014;**36**:196-211

[94] Rasmussen E, Rice MP. A framework for government support mechanisms aimed at enhancing university technology transfer: The Norwegian case. International

Journal of Technology Transfer and Commercialization. 2012;**11**:1-25

[95] Mansfield E. Academic research and industrial innovation. Research Policy. 1991;**20**:1-12

[96] Tijssen RJ. Science dependence of technologies: Evidence from inventions and their inventors. Research Policy. 2002;**31**:509-526

[97] Markman G, Gianiodisa P, Phan P, Balkin D. Innovation speed: Transferring university technology to market. Research Policy. 2005;**34**:1058-1075

[98] Graf SG. Improving patent quality through identification of relevant prior art: Approaches to increase information flow to the patent office. Lewis and Clark Law Review. 2005;**495**:502-504

[99] Loizides F, Diallo B, Pollard A, Mavri A. Increasing the Discovery and Use of Non-Patent Literature (NPL): Scientific Publications in Patent Examination. IOS Press; 2017. DOI: 10.3233/978-1-61499-769-6-211 [Accessed: 13 July 2018]

[100] Alexander AT, Martin DP. Intermediaries for open innovation: A competence-based comparison of knowledge transfer offices practices. Technological Forecasting and Social Change. 2013;**80**:38-49

[101] Siegel DS, Waldman DA, Atwater LE, Link AN. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. Journal of Engineering and Technology Management. 2004;**21**:115-142