

Developments of Computing in Papua New Guinea in the Post-Independence Era

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Abstract

This article looks at the developments of computing in Papua New Guinea (PNG) in the post-independence era. More specifically, this article examines the development of national policies on Information and Communications Technology (ICT), digital technologies in PNG, and the development of computing education in PNG since 1975. The research findings reveal that PNG has made solid progress in computing, ICT, national ICT policies, digital technologies, and computing education at universities in the post-independence era. The proposed approach in this article might facilitate the research and development of computing, ICT, digital technologies, and big data analytics in PNG, and beyond.

Keywords

Computing, Digital Technologies, ICT, Computing Education, Papua New Guinea

1. Introduction

Papua New Guinea (PNG) has been an independent country since 1975 and is located in Oceania with rich natural resources including gold, copper, silver, natural gas, timber, oil, and fisheries [1]. It is a beautiful and diverse country with many traditions and cultures [2]. It has a population of about 10 million, ranked as the 94th largest country based on the census of 2022 [1].

Computing in general and information and communication technologies (ICT) in particular have been revolutionizing our lives, work styles, economy, and society for over two decades [3]. Computing and ICT have also become an everyday part of life, work, and social interaction in PNG [4]. The PNG government has recognized that ICT drives economic growth, strengthens governance,

changes the patterns of social and political interactions, and enhances public service delivery and performance [4]-[6]. Several research publications deserve attention for looking at the history of computing in PNG. Leh and Kennedy offered a glimpse of information technology (IT) culture and examined IT in PNG in the early 2000s from an educational perspective [2]. Stanley analyzed the development of ICT law and policy, and how to regulate the telecommunications sector in PNG [7] [8]. The department of ICT also traced its early history in PNG [9]. Kelegai and Middleton looked at IT education in PNG from a cultural, economic, and political perspective at that time [10]. Their research indicates that PNG IT professionals emphasize non-technical skills. Reijswoud recommended that free and open-source software has the potential to contribute to sustainable ICT development and should be used in all levels of education in PNG [3]. Daniel looked at enterprise information systems and e-government with their applications in PNG [11] [12]. His research can be considered as a part of computing development in PNG from a both technological and educational perspective. The PNG government has developed its national ICT Policies since its independence in 1975 and has made significant progress since 2018. Even though the research on computing developments in PNG has not yet drawn significant attention in academia and beyond. PNG is the second largest island nation after Australia in Oceania in terms of land mass and population. It is important to know what computing development is in PNG since its independence. Based on an extensive search online and available literature, the following questions are still significant for investigation into computing in PNG since 1975, with a focus on the past two decades.

- 1) What and how national policies have been developed on ICT, and digital technologies?
- 2) How have computing technologies been used in PNG?
- 3) How has computing education been developed in PNG?

As computing scientists and educators at the PNG University of Technology (PNGUOT), we have been in a unique position to address the above-mentioned research questions from a historical viewpoint in general and from an interdisciplinary perspective in particular. To address the first research question, we will look at the development of national policies on ICT and digital technologies in PNG. To address the second research question, we will explore computing technologies in PNG from a technical perspective. To address the third research question, we will examine the development of computing education at universities in PNG from technical, political, and social perspectives.

The rest of this article is organized as follows: Section 2 looks at the development of national ICT policies in PNG. Section 3 explores the digital technologies in PNG. Section 4 examines the development of computing education in PNG. The final section ends this article with a few concluding marks and the suggestions of future work.

It should be noted that acronyms and abbreviation definitions used in the article are listed in **Table 1** below.

Table 1. Acronyms used in the article.

Acronyms	Abbreviation's Definition
APEC	Asia-Pacific Economic Cooperation
DGP	Digital Government Plan
DICS	The Department of Information and Communication Services
DICT	Department of Information and Communications Technology
DPTS	The Department of Postal and Telecommunication Services
DSP	Development Strategic Plan
eSMACS	Electronic, social, mobile, analytics, cloud and security
G2B	Government to Business
G2C	Government to Citizens
G2G	Government to Government
ICT	Information and communication technologies
IT	Information technology
MTRS	Medium-term revenue strategy (in Kina Millions)
NICTA	The National Information and Communications Technology Authority
PNGTEL	The PNG Telecommunications Authority
PNG	Papua New Guinea
PNGUOT	PNG University of Technology

2. Development of National ICT Policies in PNG

National ICT policy is a set of public laws, regulations, and policies that regulate and develop the creation, use, storage, communication, presentation, export, and import of ICT and digital technologies, products, and services [10].

Governments are enablers, regulators, customers, and providers of ICT-based and digital technologies, goods, and services [4] [7]. The PNG government agencies and departments have accommodated various policy documents and the need to engage in ICT-related services and education mostly to support the targeted implementation plans on the PNG vision 2050. For example, the national broadband policy, encompassing the need for national broadband services for access to Internet and ICT services, covered ICT and digital skills and education as a part of the social-economic development [13].

The PNG government's computing operations were initially controlled by the central computing center called the National Computer Center. The Department of Information and Communication Services (DICS) was already created in PNG in 1973 [9].

After 1975, DICS was still responsible for national information services, communication policy, research and development [14], and provision of support services for the Minister of Information and Communication Service [7] [9]. The Department of Public Utilities was formed in 1975 to take over the functions and the responsibilities of the Department of Posts and Telegraphs, which was estab-

lished in 1855 and ceased operation on December 9, 1975 [7], and became the Department of Postal and Telecommunication Services (DPTS) [7] [9]. DPTS continued to function as a separate organization until it was incorporated as the Post and Telecommunication Corporation on October 1, 1982 [7] [9] [14]. the Post and Telecommunication Corporation was the sole telecommunications carrier [10] [14]. Later, it was divided and corporatized in 1996 because of the change of PNG government policy. The Telikom PNG Ltd was created responsible for telecommunications services [7], the Post PNG Ltd was created responsible for postal services, and the PNG Telecommunications Authority (PANGTEL) was created and later re-named as the National Information and Communications Technology Authority (NICTA), responsible for regulating, managing, and licensing of telecommunications and broadcasting in PNG [9] [14].

Telikom PNG provided the telecommunication services for profit. Telikom PNG was given exclusive rights up to 2007 to provide all forms of telecommunications services within PNG and between PNG and other countries [7] [15].

PANGTEL was established on January 1, 1997 to corporatize the Post and Telecommunication Corporation, which was divided into three organizations: two service delivery companies and one regulatory and licensing authority [7].

In 1994, the PNG Ministry of Information and Communication formed the Information Technology Board. Its members consisted of experts from many sections of the information industry. One of the Information Technology Board's tasks was to develop a national ICT policy for PNG [9]. The Department of Information and Communication Services was reduced to the Office of Information and Communication in 1997 [7]. A new National ICT Act (the Act) was approved by the PNG parliament in November 2009 [15]. The Act includes the National Information and Communication Technology Authority (NICTA) with regulatory responsibility for the ICT industry. That is, NICTA (<https://www.nicta.gov.pg/>) has replaced PANGTEL as a government agency responsible for the regulation and licensing of ICT in PNG since 2009 by drafting Guide to Class Licensing in 2010. In the past 14 years, Approved ICT Equipment Lists (1) and Technical Standards of NICTA has been approved by the government (9)

(<https://www.nicta.gov.pg/downloads/download-category/type-approval/>).

The PNG government recognized in early 2000 that ICT has transformed the rest of the world by providing opportunities for businesses, opening access to the global marketplace, delivering a wealth of information, enabling greater community engagement, and bridging the digital divide in the past decade [16]. The Ministry for Information and Communication Services was then reestablished in 2007 [9] [16]. The Department of Information and Communications Technology (DICT) was renamed in 2020 to provide national ICT policy and service delivery oversight and coordination [9]. Currently, DICT focuses on a digital-centric e-government to ensure that people can access government services through ICT and digital transformation [9] [17].

M.P. Thompson as the then Minister for information and community services tabled in parliament the progress of developing a national policy of PNG on computing and ICT from 1978 to 1992 [7]. In 2005, a National ICT Policy Framework was approved by the PNG Government which decided to formulate a national ICT policy [7]. In 2007, the PNG Government endorsed the national ICT policy, which introduced competition in mobile (phone) services commencing in 2007 [7]. Telikom had a monopoly with B-Mobile over mobile phone services prior to 2007. Digicel entered the mobile services market in 2007. Digicel replaced Telikom (Telikom-Mobile and B-Mobile) and became a new monopoly over mobile phone services within a few years [18]. For example, PNG had total mobile subscribers of 4.052 million in 2018. Of them, Digicel has about 3.8 million (96.7%), B-mobile has 190,000 subscribers (2.1%) and Telikom Mobile has 40,490 subscribers (1.2%) [19]. Based on the statistics, the average increase rate of total mobile subscribers is about 7%, therefore, the estimated total mobile subscribers in PNG would be more than 5 million in 2023 [19]. In other words, more than 50% of PNGeans have a mobile subscription. This is a big jump from 13.8% in 2008 [19].

The national ICT policy was revised and approved by the PNG Government in early 2008. This revised government policy aims to achieve competition in all sectors of the ICT industry through a staged approach starting in the mobile phone service sector [8].

Recently, propelled by the United Nations' global sustainable development goals [20], PNG expedited incorporating ICT and digital technology into their policy development and promoting ICT inclusions and supporting innovation in service delivery. PNG Government has drafted PNG Digital Government Plan (DGP) 2023-2027 to achieve the objectives of the PNG Vision 2050, launched in 2009, and the PNG Development Strategic Plan (DSP) 2010-2030, based on National ICT Roadmap 2018 and Digital Economy Agenda APEC 2018 [4] [21].

The PNG Vision 2050 creates a broad framework for developing PNG into a smart, wise, fair healthy, and happy country by the year 2050, underpinned by seven strategic focus pillars:

- Human capital development, gender, youth, and people empowerment;
- Wealth creation;
- Institutional development and service delivery;
- Security and international relations;
- Environmental sustainability and climate changes;
- Spiritual, cultural and community development;
- Strategic planning, integration, and control [22].

PNG DSP provides strategies as to how to achieve a high quality of life for all PNGeans and become a prosperous middle-income country by 2030 [[5], p. 10] [22]. Therefore, DSP 2010-2030 is guided by the PNG Vision 2050 [22], illustrated in **Figure 1**.

In order to realize the PNG Vision 2050 and PNG DSP 2010-2030 and exceed many of the 17 sustainable development goals of the United Nation such as

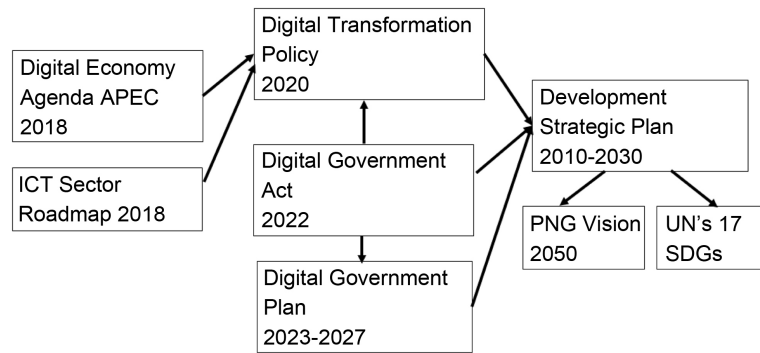


Figure 1. DGP 2023-2027 and its relationships with other national policies.

health, education, gender, connectivity, and smart cities [20], the PNG government has expedited its policy development in recent years. For example, national ICT sector Roadmap 2018 and Digital Economy Agenda APEC 2018 bring about the development and adoption of Digital Transformation Policy 2020 that focuses on six strategic pillars: digital infrastructure, digital government (e-government), digital skills, innovation and entrepreneurship, cybersecurity and privacy, and financial inclusion. Digital Government Act 2022 is a consequential legislative and operational framework for deploying ICT and digital technologies to realize the mentioned six strategic pillars and then enhance the delivery of digital government services: G2G, G2C, and G2B services, where G, C, and B are abbreviated from government, citizen, and business, respectively. Digital Government Act 2022 then would drive PNG towards a digital government, digital market, digital economy, and digital society based on digital services (also see Section 3.4).

The PNG Digital Government Plan (DGP) 2023-2027 [4] is the further development of PNG Digital Transformation Policy (DTP) 2020 in terms of its vision, mission, and goals. The objective of DGP is to provide an action strategy for implementing the digital services envisioned in the Digital Government Act 2022. More specifically, DGP 2023-2027 aims to plan, coordinate, and integrate ICT and digital technology in public administration through government processes, operations, and structures and to eventually enhance the G2G services, G2C services, and G2B services [7]. All these services should have the characteristics of transparency, efficiency, accountability, and citizen engagement.

All mentioned national policies on ICT and digital technologies are based on the information from Deloitte and PricewaterhouseCoopers, and the PNG government's engagements with World Economic Forum, the United Nations Development Program, World Bank, and other international organizations. For example, the PNG Department of Treasury, working together with Deloitte and PricewaterhouseCoopers, provided the MTRS (medium-term revenue Strategy) revenue projections from taxed-based revenue and other revenues for 2018-2022 [4]. MTRS is a framework for tax reforms aimed at boosting domestic revenues which have been declining over time (in Kina Millions) [23]. The MTRS treats the policy, administrative and legal components of the tax system in a holistic

and interactive way. It provides for essential coordination between the policy, administrative and legal elements of the system [23]. The revenue projections of medium-term revenue development plans of DGP 2023-2027 from tax-based revenue and other revenues will increase from 13,720 to 28,817. The research of the Department of Treasury demonstrates that digitalization added to the 4.6% forecasted GDP growth rate of PNG in 2023 [23].

Therefore, the PNG government has been striving to catch up with other countries in general and developing countries in particular to achieve sustainable development, and improve governance and social integration through the adoption of ICT and digital technologies.

3. Computing Technologies in PNG

This section looks at the development of computing technologies in PNG. It first overviews the ICT industry in PNG, then it will examine the use of computing technologies, mobile network development, and eSMACS goods and services in PNG.

3.1. ICT Industry in PNG

The computing industry includes the development and application of ICT technologies, systems, devices, and apps for processing, storing, and managing data, information, and knowledge. Computer hardware and component manufacturing, software development, communication equipment, and services are parts of the computing or ICT industry. The PNG ICT industry includes telecommunication, electronic media, eSMACS (electronic, social, mobile, analytics, cloud and security) products and devices [10] [24]-[26].

Since the Internet services started in PNG in 1997, five commercial Internet service providers (ISPs) have been licensed in the early time [8]: Datron electronics Ltd., Datec (PNG) Ltd., DG computers, Global technologies Ltd., and online south Pacific (data nets).

Datron electronics (<https://www.daltronpng.com/>) was established in 1977. Daltron is an IT solutions provider with a corporate culture that recognizes that the world of ICT is a rapidly changing environment.

Datec (<https://www.datec.com.pg/>), started more than 30 years ago. Datec specializes in providing innovative solutions, valued services to businesses and communities in PNG. Datec is one of the largest end-to-end ICT solutions and services providers in PNG.

DG computers (<http://www.pngbusiness.directory/dg-computers-png-boroko>) provides computer equipment sales and services in PNG.

Global technologies (<http://www.global.com.pg/global-internet>) provides a quality Internet service with flexible plans and tools for delivering the ultimate experience for businesses and organizations.

Online South Pacific (<http://www.online.net.pg/>) is a division of Data Nets, one of the leading specialist data communications and computer networking

companies in PNG, established in 1993. This company has used its extensive data communications experience to build a highly sophisticated and geographically distributed network for providing Internet services in PNG.

Overall, the mentioned companies provided services at that time covering computer networking, data communications, Internet, PC distribution, software, mobile phones, broadband, domain names, email accounts and pre-paid wireless Internet access cards (also see the following sections).

The computing industry in PNG has been slowly but steadily developing in the past two decades [4] [10]. 20 years ago, Internet use was hardly found in homes because telecommunication started to move from nothing to a satellite-based system and availability of Internet cafés in a single leap in some rural areas of PNG. Internet services were virtually nonexistent in primary, secondary, and tertiary institutions, except for a few universities in PNG [10]. In contrast to 2002, Internet services will be popular in urban areas in 2024. Internet services have also covered most rural areas. Affordable and cheap mobile phones and smartphones have played significant roles in the Internet services in particular, and eSMACS services as digital services (see Section 4.4) in general.

The public sector organizations implement finance, personnel, and decision support systems and other management information systems on local or wide area networks [10]. Processing control systems have been used in some private sectors. Most retail shops have used transaction processing systems. The banking sector introduced wide-area networking for their banking systems throughout the PNG over two decades ago. However, the cost of digital services is extremely high, compared with the GDP per capita. Computers, laptops, and smartphones are still luxury items for most people in PNG. A significant percentage of the population could not access the Internet in PNG two decades ago [10], in contrast to 2002, there were 3.29 million Internet users in PNG at the start of 2023, when Internet penetration stood at 32.1% in 2023 [27]. Even in the past eight years, PNG has made remarkable progress in the penetration of the Internet. In 2015, the Internet signals were so weak that the academic staff could not use the Internet to process teaching and research activities properly. Now, it is easy for them to upload and download files using the Internet. In Australia, the author used Blackboard and Moodle as an online teaching and learning platform. In PNG, the author has used Google Classroom as the online teaching and learning platform. He and his students share similar functions for teaching and learning.

Overall, PNG is primarily an end-user of ICT and digital technologies and services rather than a manufacturer [6]. Therefore, almost all ICT and digital products, computing hardware and software are imported from many different countries to PNG. IT professionals administer and maintain the software systems purchased off the shelf or online or freely downloaded from the Internet. Therefore, the ICT or computing industry of PNG has been relying on foreign countries, Australia, China, and other Asian countries in particular. In other words, foreign companies have played a significant role in developing the com-

puting industry in PNG. Digicel and Vodafone provide Internet or mobile services. Huawei provides telecommunication devices in PNG.

3.2. Use of Computing Technologies in PNG

Computing in general, ICT and digital technologies in particular have been used widely in universities, mostly corporates and large business organizations in PNG. For example, cloud technology and cybersecurity have been used in PNG's national policies and strategic implementation to realize PNG Vision 2050 [4] [5]. It is evident in PNG that some young people in urban societies and rural areas are using mobile phones and tablets. Most university students are also enjoying smartphones. Some young people use phones not necessarily for communication but mostly for entertainment. Furthermore, Pathak, et al, investigated the use of ICT in public service delivery in PNG in 2010, and found that e-governance should be improved to provide more satisfying public services and e-government services to the people in PNG [28]. Daniel looks at enterprise information systems and e-government and their applications in PNG in 2016-2017 [11] [12]. Reijswoud promoted the spread of free and open-source software at all levels of education in PNG in 2009 [3]. Creating a computer laboratory that solely used free and open-source software is also an interesting initiative and attempt by Divine Word University in 2009 to mitigate the ICT resource scarcity in PNG [3]. Mobile technologies, geographic information systems, and electronic national health information systems have been used to capture and report geo-coded, case-based malaria data for malaria elimination in a high-quality timely [29]. The malaria data included 160,750 malaria testing records with the village information of residence in 2015. Mobile technologies, GIS, and electronic national health information systems worked together to optimize malaria information management and provide big flexibility to facilitate malaria elimination in the future [29].

The adoption of 1G, 2G, 3G, and 4G cellular network technologies reflects the performance of a nation's socio-technological development. PNG has adopted 1G, 2G, 3G, and 4G network technologies following the timeline listed in **Table 2**.

Table 2. 1G, 2G, 3G, and 4G adopted in PNG: A timeline representation.

x G network technology	Internet came to PNG	1G	2G	3G	4G
PNG started to use	1997	2002	2004	2011	2014

In what follows, we elaborate **Table 2** in some detail from a historical perspective.

The Internet came to PNG in 1997 [10] [25]. Cellular mobile communications were introduced in PNG in 2002 [6]. Telikom PNG provided mobile services based on a first-generation (1G) cellular technology. Those services were only

available in Port Moresby and Lae. In 2004, B-Mobile provided mobile services based on a 2G cellular network. 2G is the Global System Mobile digital system, supporting digital voice communications over switched networks. 2G was widely available in PNG in 2004. The operation of Digicel PNG Ltd has made an unprecedented growth of mobile services across PNG since 2007 [6].

3G cellular network technology was introduced in PNG in 2011 [6]. 3G technology upgrades the basic architecture of 2G to support the transmission of voice, video, and data over a communication system.

4G cellular network technology was introduced in PNG in 2014. 4G provides mobile services with a much faster speed, more stability, and access to a larger variety of online activities [30]. 4G had only been available to 30% of PNG's population at the end of 2021 [31]. Digicel completed its expansion on the infrastructure in May 2022 and 55% of PNGeans can enjoy the 4G mobile services. Port Moresby and Lae have been covered by 4G

(<https://www.nperf.com/en/map/PNG/2098329.Daru/227660.Digicel-Mobile/sign-al/>, retrieved on August 25, 2022). The Internet signals remain much lower than most developing countries taking into account the international standards. Even so, the big challenge is that the Internet signal is not stable, sometimes, it is still in the 3G state. As a user of Digicel, we couldn't enjoy the 4G signals using smartphones until 2022. We still cannot enjoy the stable 4G mobile services of Digicel on the campus of the PNGUOT in Lae when we wrote this section.

Around 32.1% of the people in PNG have connected to the Internet in 2023 [27]. This lags far behind the recommended targets set in the country's National Broadband Policy drafted in 2013, which aimed to provide broadband access to 90% of the total population by 2018 [1]. Nevertheless, accessibility to mobile networks has expanded considerably with population coverage increasing from less than 3% in 2006 to more than 90% by early 2021 [1].

Finally, strengthening national and regional centers of excellence of higher education in ICT and other selected priority areas, building modern ICT infrastructures and ICT systems, and enhancing ICT availability and training capacity in ICT in all higher education institutions have been listed in the PNG Higher and Technical Education Strategic Implementation Plan (2017-2038) [32]. This will facilitate the use of computing technologies in higher education and beyond in PNG.

3.3. Mobile Network Development in PNG

Digicel Mobile Ltd, Telikom-Mobile, B-Mobile Ltd, and Vodafone PNG (Digitel Communications Ltd) are four mobile network carriers offering mobile services in PNG. In what follows, we will look at each of them in some detail.

Digicel PNG entered the PNG market in 2007 [8], thanks to PNG's liberation of national policy for telecommunication and mobile networks, and allowing competition in the mobile phone sector in 2007 [33]. Digicel extended mobile

services covering both urban areas and rural areas and has brought a greatly increased uptake of mobile technology in PNG since then. Digicel holds the dominant position in all the Pacific countries in which it operates, except for Fiji [33]. Digicel has become a monopoly in PNG and has a 92% share of the mobile phone services market.

Telikom PNG is the monopolistic corporation established by the PNG Government in 1996 to provide telecommunications services including wholesale services relating to Internet and data services [7] [8]. It owns and operates the vital satellite and submarine cables that keep PNG connected to the outside world [7]. Its subsidiaries include Telikom-Mobile and B-Mobile.

B-Mobile was established in 2002 to provide the mobile phone services [7] [8]. B-mobile is a 100% the PNG government-owned company since November 2016, and has been operated by Kumul Consolidated Holdings in PNG since 1997 (<https://www.bmobile.com.pg/about>, retrieved on September 22, 2022). It is the first-ever mobile carrier with operations in PNG since 2008 [8]. Its network mainly is 3G covering most parts of PNG (<https://www.bmobile.com.pg/NetworkCoverage>, retrieved on July 26, 2024). B-mobile has 190,000 subscribers (2.1%); Telikom Mobile has 40,490 subscribers (1.2%) [19]. Both have 260,000 mobile customers [7]. Telikom's mobile and B-Mobile were merged as Telicom Ltd. (<https://www.telikom.com.pg/>) to create one of the more efficient and competitive operators [34], based on the decision of the PNG government in 2021 [35] [36]. Telikom also ended the Kumul Consolidated Holdings' era [36].

Vodafone PNG as a new mobile network operator entered in PNG in 2022 [37]. Vodafone PNG is a subsidiary of Amalgamated Telecom Holdings and Austel Investment Pty Ltd, based on their successful operation and management of the business in Fiji [37] [38]. Vodafone is a new entrance competitor to Digicel in the 4G mobile services in PNG. Currently, Vodafone has a big advantage over Digicel in providing a very low price for data plans in GB monthly, because Vodafone and Digicel prepaid charge for 30 days is 40 GB/K50, and 20 GB/K100, respectively, as on July 20, 2023 [39]. Therefore, in the coming years, Digicel customers churning to Vodafone will become a new trend if Digicel has not any countermeasure to retain its customers in the competition, because Vodafone and has been ranked the cheapest Internet data plan in PNG [39].

From the above analysis, we can observe that the market power of Digicel is very strong. The competition and privatization forced the monopoly of Telikom PNG over mobile phone services in 2006 to transfer to Digicel within a few years [7]. However, Telstra purchased Digicel with significant support from the Australian Government in later 2021 to dominate the market of mobile services in PNG in particular and the South Pacific in general [33]. Therefore, the PNG government should introduce a second competition in the mobile services market. New mobile services operators should be encouraged to join the market to break the current dominance and monopoly. Vodafone has participated in the

competition between players in the mobile sector in PNG. The customers in PNG will get more benefits and cheaper prices in mobile services as mentioned earlier.

3.4. eSMACS Goods and Services in PNG

eSMACS (electronic, social, mobile, analytics, cloud, and security) goods and services and other digital services reflect the penetration of contemporary ICT technologies, systems, tools, and apps in PNG. In other words, the maturity of using eSMACS goods, services, and other digital services reflects the adoption maturity of the ICT industry and technologies in PNG, as illustrated in **Table 3** [24].

From a historical viewpoint, e-services were introduced in 1997 because the Internet was available in PNG. Social (networking) services were introduced in the 2000's. Mobile services were introduced in 2011 because the 3G arrived in PNG. Analytics services were introduced in 2014 because the 4G arrived in PNG. Security services have been provided for desktop computing since 1975. In what follows, we will provide a general summary for the eSMACS services in PNG.

Table 3. eSMACS services in PNG.

eSMACS Services	Maturity in PNG	Remarks
E-services	Over 50% of PNGeans can access e-services [17] [19].	e-government services have become significant in PNG's national policy on ICT.
Social (networking) services	Meta, WhatsApp, WeChat, and TikTok have been used in PNG. The time used for social networking services might be shorter because the power outage is frequent [19].	Blogs and wikis are not used by most PNGeans. Search as learning is still not a minute-level activity, but daily work.
Mobile services	Mobile services can be accessed in PNG. However, the consumption of mobile services is very fundamental or low [17] [19].	Mobile businesses are still very limited. No services similar to Amazon's o2o services are provided in PNG.
Analytics services	About 50% of PNGeans can access analytics services [17] [19].	The diversity of analytics as a service is still limited in PNG.
Cloud services	Cloud services are available in PNG, they are very limited because 4G is only available in some urban areas [19]. The 4G signal is still not stable. 3G signal is more popular.	Free Software as a service has been welcomed in PNG.
Security services	Security as a service is still at a very rudimentary level [19].	Security services have become important in the national policy on ICT.

E-services include e-government services, the latter refers to information services, online services, and facilities that connect users with agencies [12] [26]. The information includes plans and government policies. Online services include applications for e-passport and e-registration. Facilities include polling, feedback, forums, and social media [4]. E-government services are a part of e-governance, which is the application of ICT to the government to bring simple, moral, responsive, and transparent governance [28]. Briefly, e-government provides e-governance through providing smart e-government services.

E-government services can be classified into three categories: Government to Government (G2G) services, Government to Citizens (G2C) services, and Government to Business (G2B) services [4] [40] [41].

G2G services include eBudget, eHR, eAdministration, eFinance, eCabinet, eProcurement, eContracts, eParliament, eCustom, and eJustice, all these G2G services will be based on a government platform of information systems that enable various departments to collaborate to integrate and consolidate hard and create platforms for shared functions [4].

G2C services include ePolice, eCensus, eAgriculture, ePassport, eHealth, eLands, eJustice, eVoting, eEducation, Digital ID, and eCommonRoll. All these G2C services will be based on an integrated digital platform between governments and businesses that can communicate with each other with timely and readily available information for different business use cases [4].

G2B services include GovService Portal, SME Startup Portal, ICT Cluster Portal, and Investment Portal. All these G2B services will be based on an integrated digital platform between governments and citizens that allow individuals to monitor the administration's use of their personal data and access digital services at an affordable price [4].

PNG has made meaningful progress in e-government development even under difficult circumstances and transitioned itself from the low EGDI (e-government development index) group in 2018 to the middle EGDI in 2020 ([17], p. 54).

The PNG government has been striving to provide advanced ICT infrastructure to cover every corner of the country and improve the delivery and accessibility of e-government services in particular and eSMACS services in general [12] [24]. However, the consumption of digital services is still at a basic level [12]. This is consistent with the finding from the UN that PNG still has a very low online service index (OSI = 0.2235) and telecommunication infrastructure index (TII = 0.1233) ([17], p. 54).

4. Development of Computing Education in PNG

In order to realize the PNG Vision 2050, the education sector's strategic plan highlighted the importance of ICT in education both in learning and teaching [32]. This section will examine the development of computing education in tertiary institutions in PNG. It also analyzes the cultural factors and their influence on education development in PNG to some extent.

4.1. Computing Programs Development in PNG Universities

Computing education includes training for computing skills enhancement and computing technology and tools usage, as well as specific computing certification programs to produce computing and ICT-related professionals for the workforce. Computing education at universities falls into two categories: one is offered as a subject for non-computing undergraduate programs and the other offered as a computing undergraduate program. For example, at PNGUOT, every undergraduate student of business school must study a course on introduction to computing in the first year's study, and then accounting students will study at least two computing courses such as Accounting Information Systems and Management Information Systems. Most students who choose to undertake computing programs end up working in computing or ICT sections and departments across all the industries and businesses in PNG. Some computing programs or courses enable graduates to use their computing or ICT knowledge and skills to excel in other fields such as business administration management or others due to the interdisciplinary approach of how the courses are implemented.

There are six universities in PNG. Among them, the University of PNG and the PNGUOT were established in 1965. Divine Word University (DWU) was established as a university in 1996

(<https://www.dwu.ac.pg/en/index.php/about-dwu>). The University of Goroka (UOG) was formed in 1997 (<https://www.unigoroka.ac.pg/about-us>).

PNGUOT is the only university in PNG that offered degree courses in computing covering IS, and Computer Science till the early 2000s [10] [25]. An undergraduate computing program was introduced in PNGUOT in the 1970s [10] [42] [43]. It was information sciences and data processing in 1976, and which was transferred into Commercial Computing from 1975 till 2005 and renamed IS and then IT from 2014 onwards. It is still a combination of IS and IT in the past decades. The computer science degree program has been offered by the Department of Mathematics and Computer Science at PNGUOT since 1993. PNGUOT currently offers computing programs including Bachelor of Electrical and Communications Engineering, Bachelor of Business in IT, and Bachelor of Science in Computer Science. It also offers Master of Philosophy in IT and Ph.D. in IT. Two students have been studying for the Master of Philosophy in IT. However, few have interests in pursuing Ph.D. programs or there are insufficient enrollments of Higher Degree Research students at the moment although a few have an intention rather than action. The annually enrolled number of new students of computing programs have increased from 80 to 120 in the past decade.

UPNG offers a Bachelor of Science (Major in Mathematics, Statistics, and Computer Science). It also offers IT and IS as courses with the name Business Information Systems and another course with the course name Accounting IS and a major in Information & Communication Science in Bachelor of Arts (www.upng.ac.pg, retrieved on August 31, 2022).

DWU offers a Bachelor of Information Systems (combined with IT) and a Bachelor of Mathematics and Computing Science (<https://www.dwu.ac.pg/>, retrieved on July 26, 2024) as undergraduate programs.

UOG offers Computer Science as an undergraduate program.

The above analysis indicates that computing, currently, is either an undergraduate program, a major, or a course has been offered at every university in PNG. IT, IS, and Computer Science are offered as undergraduate programs in computing in PNG. Software engineering, computer engineering, and cybersecurity are offered only as courses at universities in PNG like PNGUOT. PNGUOT has played an important role in providing undergraduate graduates of engineering and computing in PNG [44].

Australia and New Zealand have been playing a significant role in producing Master's degree holders and several Ph.D. degree holders for PNG through national scholarships. For example, many IT experts of PNG received Master of IT or Master of Computer Science courses and even few PhD degrees in Australia, New Zealand, or other countries. PNG has been relying strongly on Australia for financial, capacity, and education support because of historical reasons [3]. This is also true for ICT development in the setting of education, infrastructure, and services although it cannot be seen from the PNG government policies explicitly [4]. For example, Australia developed an Australian Qualification Framework, and then PNG also developed a National Qualification Framework [32], Both are similar and used to provide a guideline for developing education in both countries.

The computing undergraduate programs have evolved by learning development experience and curriculum development from other countries including Australia and also ACM computing curricula, just as the evolution of the educational system in PNG has been influenced by educational policies and development experiences in other countries since 1975 [45]. PNGUOT has the tradition of developing its IS/IT undergraduate progress based on the ACM computing curricula. For example, the IS/IT curriculum and its development at PNGUOT were based on ACM computing curricula 1978, IS 2002, IS 2010, IT 2017 and computing curricula 2020 [46]. The reason behind it is that IS/IT staff always include expatriates. The author continues to use ACM/IEEE/AIS computing curricula to develop or redevelop the curriculum of IS/IT since joining in PNGUOT. At the same time, we also study the computing curricula of a few universities in Australia to develop our curriculum of IS/IT. For example, we have introduced cybersecurity, business intelligence and analytics, and enterprise database systems as three courses for our IS/IT program taking into the latest computing curricula and IT curriculum of Monash University.

Furthermore, IT is at its essence a universal program with universal knowledge and technology. Therefore, taking the ACM computing curricula as a reference to develop IS, IT, and Computer Science programs is a short and easy way for a university. Learning from others, first of all, learning from the ACM

computing curricula is essential for undergraduate computing program development and teaching and learning. For example, we have also put AI, big data, data science, business intelligence and analytics, cloud computing, the Internet of everything (IoE), and blockchain as courses or teaching content in our IT program. We have also intensively undertaken research in big data, big data analytics, and AI and published dozens of peer-reviewed quality research articles with international visibility and acclaimed globally. From this viewpoint, the digital gap between PNG and other countries, in particular, developed countries, has been narrowed.

4.2. A Cultural Perspective on Computing Education in PNG

Culture and society in PNG have significantly changed since 1975. In the early years of independence, following the rules, keeping to expectations, and respecting others, especially the elders, were three important values of PNG culture. Families ensured their children to know about these human values. However, such values are slowly disappearing due to many social issues faced these days. Furthermore, adults ensure that their children strive to achieve through education. In the past, emphasis was placed on educating boys rather than girls since most traditional customs and cultures in PNG focused on males as leaders and females as less important or followers. This has changed over the past decades. Daughters naturally take care of their families and their in-laws. An educated female is a strategic asset to the family. Even though some rural people still enjoy rural or village life, most know that education is the key to getting formal employment, getting out of simple but mostly difficult life, and enjoying the material things that knowledge and money bring. People pragmatically talk about getting educated in order to get good jobs. They embrace that studying computing, ICT, and digital technology can get good jobs. This is why computing programs are still their most favorite undergraduate programs in PNG.

Kelegai & Middleton analyzed the influence of cultural factors on IT education. In PNG, parents at home, teachers at school, and at the workplace, encourage independence. However, students are reluctant to speak up in class. Students do not respond to questions for fear of either a wrong or a right answer. This is still valid for our computing undergraduate students. Therefore, the students are asked to write down the answer to the question asked in class teaching. It is successful sometimes. This also reflects students' lacking confidence and courage. This also results in the people in PNG lacking confidence and courage to prepare for further studies in other countries including Australia and New Zealand. Self-financed study overseas is still a remote dream for a PNGean at the moment. This might not only have a cultural impact but also an economic consequence.

In contrast to 20 years ago, computing lecturers are the main PNGeans and have received Master's degrees from either Australia or New Zealand, or other countries. They use similar instructional methods used in Australia. For example, they include case studies, group work, debate, simulation, group prob-

lem-solving activities, team-based learning, and student-centered learning based on constructivism in which each student constructs knowledge. Besides, “research-informed teaching” is also used as our teaching philosophy.

Taking into account economic factors and cultural factors, PNG can use free and open-source software such as databases, websites, and servers as their ICT infrastructure [3]. At least this can be used in the class teaching to the computing undergraduate students. We have lectured and encouraged computing students to use free and open-source software such as MySQL database, Python, Google documents, and Open Office. We also encourage students to follow the principle of “study as a search” to search and go deep into the software and apps at General Public License (<https://www.gnu.org/licenses/gpl-3.0.html>). However, it is difficult to use them to completely replace Microsoft Office Suite, because the students said that the latter has been used in organizations. Therefore, they must improve their skills in using Office Suite to show the employer that they can use it to process the work of the office.

5. Conclusions

This article examined the history of computing in PNG by examining the development of national policies on ICT and digital technologies, development of computing education in PNG in the post-independence Era, from 1975 to 2023. This research highlighted that 1) How have computing technologies been used in PNG? 2) What have national policies been developed on ICT and digital technologies, and how has computing education been developed in PNG in the past few decades? The research demonstrates that PNG has made solid progress in computing, ICT, digital technologies, national ICT policies, and computing education at universities since its independence in 1975.

In future work, we will delve into how to develop postgraduate computing programs and higher degree research students’ computing programs and how to expedite computing, ICT, and digital infrastructure with the help of global engagement to facilitate socio-economic-technological development in PNG.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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