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Original Article

Relationship among Information and Communication Technology Usage, Psychological Well-Being, and Critical Thinking in Chemistry at the Undergraduate Level

Asim Nazir [a], Ayesha Afzal [b], Rabia Hafeez [c], & Tayyaba Muhammad Akram [d]

[a] Assistant Professor, Department of Science Education, Institute of Education and Research, University of the Punjab, Lahore, Pakistan
[b] MPhil Scholar, Department of Advanced Studies in Education, Institute of Education and Research, University of the Punjab, Lahore, Pakistan
[c] Academic Affairs Specialist, Syed Babar Ali School of Science and Engineering, Lahore University of Management Sciences, Lahore, Pakistan. ORCID: 0009-0000-3784-9866
[d] Lecturer, Department of Science Education, Institute of Education and Research, University of the Punjab, Lahore, Pakistan. ORCID: 0009-0000-5856-8406

*Correspondence to: Tayyaba Muhammad Akram, Department of Science Education, Institute of Education and Research, University of the Punjab, Lahore, Pakistan. Email: tayyaba.ier.pu@gmail.com. ORCID: 0009-0000-5856-8406

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ABSTRACT

The purpose of the study was to investigate the relationship among ICT usage, psychological well-being and critical thinking in chemistry at undergraduate level. The study nature was quantitative with correlation research method. The population of the study comprised of all the undergraduate BS chemistry students of the district Lahore and the total sample of the study was 917 male and female from two public and three private universities of district Lahore. Data were collected with the help of three standardized instruments. The instrument for ICT usage adapted to measure by Wickramasinghe and Jayatilleke (2021), for psychological wellbeing adopted by Ryff scale of psychological wellbeing test, and for critical thinking ability adopted by Sumarni et al. (2018). Validity was ensured as per expert opinion and cronbach's alpha reliability was measured after pilot testing. After data were collected, descriptive and inferential analysis was employed to examine the correlations between variables. The findings show that there is high relationship between ICT usage and critical thinking having r-value 0.611 and relationship between ICT usage and psychological wellbeing moderate positive having r-value 0.345 and relationship between psychological wellbeing and critical thinking is weak positive having r-value 0.235. Thus, it is recommended that ICT based activities should be incorporated in the learning process in such a manner that foster students critical thinking abilities and also had positive impact on their psychological wellness.

I. INTRODUCTION

Information and Communication Technology (ICT) significantly contribute to the transformation of higher education by giving students more access to information, facilitating collaborative learning, improving academic engagement, and encouraging the development of higher order thinking skills (Bond et al., 2020; Lu et al., 2021). ICT encompasses a range of technologies including computers, communication networks, and digital learning platforms (Li, et al, 2019). Integrating ICT with university education provides opportunities for teaching and learning in a more flexible and student-centered way. Research has shown how the role of ICT in higher education is changing and how it

facilitates academic communication and knowledge sharing among university students, as well as academic collaboration (Khan et al., 2015; Rose & Kadvekar, 2015). With the increasing importance of the use of ICT in society and the workplace, it is important for students to be competent in utilizing ICT in an academic, professional, and personal context. There is an increasing body of research and reviews focusing on the development and role of ICT in education, and in particular, how ICT can be incorporated in chemistry education (Bortnik et al., 2017; Meesuk & Srisawasdi, 2014; Ratamun & Osman, 2018). There are also an increasing number of research studies, reviews, and literature focusing on incorporating ICT in other science disciplines (Chittleborough, 2014). Some research, albeit limited, focusing on incorporating ICT in chemistry education is available (Gambari et al., 2016; Chittleborough, 2014). It has been shown that the integration of ICT in chemistry education can facilitate the understanding of some of the more abstract concepts in chemistry. The incorporation of ICT, however, is not without drawbacks (Meesuk & Srisawasdi, 2014). The educational value of ICT in chemistry is highly dependent on the teacher's expertise and how ICT is implemented in the education process. It is therefore important to analyze and interpret the effect of ICT and other educational innovations on students' cognitive and psychological experiences.

Critical thinking is essential for the interpretation of scientific evidence in chemistry, as it helps to analyze chemical phenomena, consider alternative solutions and explanations to problems, think critically, make reasoned judgments, draw sound conclusions, evaluate information, reach sound conclusions, and make sound choices. Critical thinking gives students the capacity to consider, assess, and evaluate information systematically, rather than simply accept information (Dwyer et al., 2014). Critical thinking helps students develop the higher order thinking skills, such as analysis, reflection, and evaluation (Facione, 2011). The information and communication technology (ICT) can help students develop and apply critical thinking skills by providing information on various scientific topics, fostering interactive problem-solving, and creating virtual environments for students to examine and probe chemical phenomena. ICT supported learning has been shown to develop students' critical thinking skills (Sang et al., 2010; John et al., 2018). Achieving proficiency with information and communication technology requires cognitive skills, rather than simple familiarity, and can help integrate and evaluate information to reach sound conclusions (Markauskaite, 2007; Johnson, & Johnson, 2017). Undergraduate chemistry education involves encouraging students to think critically about concepts rather than memorize them, to engage in scientific reasoning and evidence-based problem solving. Using ICT in chemistry education brings tremendous potential to facilitate critical thinking. The significant potential of ICT in chemistry education supports the claim that critical thinking is an essential competency for chemistry education.

Psychological well-being encompasses how students evaluate their lives, the psychological experiences people have, including their affective and cognitive judgments (Diener, 1997). It also comprises how people perceive their existence and their experiences of their psychological functioning (Ramirez et al., 2021). Undergraduate chemistry students face considerable academic stress because of the nature of the subject, which includes theory and demanding laboratory work, and due to the assessment methods, which are often integrated and may involve integrating theoretical and practical knowledge. Psychological stress and other emotional difficulties impact students' ability to function cognitively, to sustain attention and to work effectively with challenging academic material, including, for example, how to relate to scientific concepts and methods (Eaton, 2023). Having positive psychological experiences helps people to be motivated and to manage the stress of engaging with psychologically demanding, and often ambiguous tasks. From students' experience, positive use of ICT helps with psychological stress and improves students' ability to focus, to be motivated and to work cognitively with challenging academic material, while excessive and ineffective use of ICT, including negative use of ICT, causes psychological stress (Rosen et al., 2013). Wickramasinghe and Jayatilleke (2021) focused on the use of ICT to access psychological services, as well as the relationship between the use of ICT and psychological health and well-being. Based on the authors' opinions, the use of ICT should be assessed in relation to cognitive and psychological outcomes.

The relationships among ICT usage, psychological well-being, and critical thinking may be important to consider together for the field of undergraduate chemistry education. While technology can serve as a resource to facilitate scientific inquiry and other analytical activities, students' psychological well-being may also impact how they interact with digital environments and perform challenging cognitive activities. Students with positive psychological well-being may be able to pay attention and self-regulate to succeed in dealing with academic challenges in chemistry. Other students may benefit from the ability to critically think and evaluate digital information and make decisions

to approach complex academic activities in chemistry in a systematic way. Critical thinking may support, and lead to, other positive outcomes and challenges people may have in their personal and/or professional life (Tobon & Luna, 2021). It may also impact university students' psychological well-being (Vazquez-Parra et al., 2023). However, extended use of ICTs does not guarantee psychological well-being and/or critical thinking, since the nature and quality of use of ICTs determines the impact. Considering the three variables together in a study may help advance and better integrate the psychological, technological, and cognitive dimensions of undergraduate learning.

While interest in the integration of technology in various areas of learning and the development of psychological well-being and critical thinking is on the rise, these areas have usually been studied in isolation, or with only two variables related to them. Several studies on ICT in education have been carried out, as well as studies on the use of technology and psychological well-being, and the role of critical thinking in students' well-being (Bal & Turan, 2021; Vazquez-Parra et al., 2023; Wickramasinghe & Jayatilleke, 2021). Research on ICT-supported chemistry education has investigated the potential of technological resources to stimulate student engagement and understanding of chemistry concepts and to improve learning experiences (Bortnik et al., 2017; Chittleborough, 2014; Gambari et al., 2016). The integration of various areas of the discipline, for example, abstract theoretical areas and symbolic and quantitative, experimental areas and reasoning, interpretative areas, and learning (and teaching) chemistry, highlight the complexity and breadth of this area. In response to this gap, the present study aimed to understand the relationship among Information and Communication Technologies (ICTs), psychological wellbeing, and critical thinking in chemistry at the undergraduate level. It was postulated that the integration of technologies to enhance chemistry education encompasses other elements, such as the consideration of students' psychological experiences and their potential for analytical and reflective reasoning. Through this research, the author strives to expand the existing debate around technology in science education and student growth in higher education.

The study results may be useful to educators and other stakeholders (i.e. university administrators, curriculum developers and educational policymakers) for meaningful integration of ICTs, while taking psychological well-being and critical thinking into consideration. Understanding these relationships may lead to integration of the above three parameters in undergraduate chemistry education. Therefore, the following research questions have been formulated.

Research Questions

1. What is the relationship between ICT usage (ICTU) and Psychological Well-Being (PWB) of undergraduate chemistry students?
2. Is there any relationship between ICT usage (ICTU) and critical thinking in chemistry of undergraduate chemistry students?
3. What is the relationship between Psychological Well-Being (PWB) and critical thinking in chemistry of undergraduate chemistry students?

II. LITERATURE REVIEW AND THEORETICAL PERSPECTIVE

This section includes the main ideas and theoretical frameworks concerned with the relationships between the usage of ICTs, psychological well-being and critical thinking in the context of undergraduate chemistry education.

Information and Communication Technology Usage in Higher Education

Information and Communication Technology (ICT) refers to the hardware, software and telecommunication infrastructure that can be used in a learning or working environment. ICT can support different learning and working activities and provides an opportunity for educators and learners to utilize interactive and student-centered learning and teaching strategies (Apriani & Hidayah, 2019; Apriani et al., 2020). In higher education, students use ICT to share and receive learning resources, communicate with their peers, and find learning-related resources (Khan et al., 2015; Rose & Kadvekar, 2015). Findings of previous studies show that the integration of ICT in education promotes students' learning and enhances students' knowledge-related skills (Wasif et al., 2011). Based on available evidence, there are many potential uses of ICT to provide and improve students' academic performance. However, there is still a paucity of studies on how ICT can be adapted and integrated to help facilitate learning and teaching (Oulmaati

et al., 2017). As Basri et al. (2018) emphasized, the educational value of ICT will depend on students' ability to use internet-related activities to serve academic purposes.

The need for educators to understand students' information literacy skills in the context of ICT has been recognized. Internet competencies and literacy are similar to those of other types of literacy, and describe the ability of individuals to access, analyze, assess and produce online contents (van Deursen, 2010; Lee & Chae, 2012). These have increased in importance in the context of higher education. Students at this level are presented with large amounts of online information and are required to gauge the reliability of online information, particularly scientific information, and differentiate this from sensationalist or misleading information. While it is important for students to learn how to access information online, it is equally important to teach them how to critically evaluate the online source and the format in which the information is presented. Thus, there is a need to foster understanding in students on the critical analysis of information they acquire, and this is exemplified best in the context of chemistry, which combines abstract concepts, mathematical and numerical relationships, symbolic notations, quantitative and qualitative reasoning, experimental procedures and molecular structures.

Digital simulations and online scientific databases help learners identify, visualize, and analyze chemical processes and other scientific phenomena (Okoro & Ekpo, 2016; Christensson, 2019). Interactive computer-assisted learning environments help learners engage with subject content critically and constructively (Garrison, 2016; McKnight et al., 2016). Further, the integration of digital tools into learning environments provides learners the opportunity to construct knowledge collaboratively (Salmons, 2012). Available evidence shows that digital learning environments help students learn chemistry (Parisozz, 2010). However, academic use of ICT in chemistry learning depends on several factors. These include the quality and relevance of digital resources, learners' ability to assess information and evaluate technology in learning, and the integration of technology in learning and teaching.

Psychological Well-Being Among Undergraduate Students

Positive mental health or psychological well-being is a key aspect of students' academic and personal development. Well-being, in this context, is defined in positive psychological terms (emotional experience and evaluation of life in general). Diener (1997) pointed out that the indicators of subjective well-being overlap with other positive psychological functions, the core of which lies in assessing the quality of life in terms of people's ability to meet their goals. Positive psychological functions are expanded in the psychology literature. Two important school of thoughts differentiate between hedonic and eudaimonic well-being. Hedonic well-being emphasizes positive emotional experiences and the quality of life, including spirituality and the feeling of being connected to others (Deci & Ryan, 2012; Henn et al., 2016; Ryff, 2014, 2018, 2019). Eudaimonic well-being emphasizes self-actualization and the feeling of living life with a sense of purpose. In her theory of psychological well-being, Ryff (1989, 1989b; Ryff & Keyes, 1995) identified six core functions: Autonomous and positive relations with others, personal growth, purpose, environment mastery, self-acceptance and the ability to integrate oneself with the environment.

These dimensions are pertinent to undergraduate students for several reasons. Firstly, learning at the university level demands independence. Secondly, undergraduate students must be able to adjust to more rigorous academic environments. Thirdly, students must be able to develop their personal skills and competencies. Lastly, students have to effectively manage their time and different competing priorities. Students who can regulate their behavior and respond to challenges in a constructive way can be considered to be in a better position to face academic requirements. However, if students are emotionally distressed and unable to regulate their behavior, they are likely to find it very difficult to focus and concentrate on their studies. Research that has been done in the area and which is detailed in the attached literatures addresses psychological well-being, and how it can be impacted by individual differences and person's life experiences. These can also be positively impacted by an individual's social relationships and adaptability to various environments (Bradshaw, 2015; Garcia-Moya et al., 2015; Mayordomo et al., 2016). This is important when considering psychology and chemistry students, as these students are often required to integrate the theory with lab work, as well as with their ongoing assessments and problem-solving activities.

The use of ICT in schools has both positive and negative consequences for students' psychological well-being. ICT-supported learning offers a number of ways of accessing and using educational materials at different times and different places, and provides opportunities for various modes of communication. Przybylski and Weinstein (2017)

found that the use of technology at school can help students to reduce their learning anxiety. On the other hand, prolonged use of ICT can cause psychological problems, e.g. as a result of excessive screen time, digital overload, and stress related to the inability to control the electronic environment. In ICT-supported learning, there is a risk that students can get caught up in the electronic environment and become psychologically lost in the digital world, resulting in digital nightmare (García-Pérez et al., 2017). Twenge (2019) also describe the negative psychological effects of high levels of screen time and digital media use. Overall, there is evidence to suggest that although the integration of ICT in teaching can improve students' psychological well-being, the relationship between ICT usage and students' psychological well-being is generally unclear and may vary depending on the context and the intensity of ICT integration in learning.

Critical Thinking in Higher Education

The ability to think critically is one of the expected outcomes of a higher education. It is defined as the ability to analyze information and evidence to reach an adequately supported conclusion. Bailin (2002) described critical thinking in terms of combining, analyzing, and evaluating information. On the other hand, Ennis (2018) stressed reflective reasoning in determining what to believe or how to act. It is worth noting that critical thinking involves not only analyzing evidence and reasoning but also assessing and determining the quality of evidence in light of the argument being made and other possible reasons, explanations, or assumptions (Hitchcock, 2017). These aspects are critical in today's information era, where students are bombarded with numerous, sometimes conflicting, pieces of information, and must be able to identify, analyze, and appraise it in light of reason, evidence, and argument.

Critical thinking in the context of university education involves the application of knowledge, rather than simply the acquisition of information. Anderson & Krathwohl, (2013) described certain cognitive processes that are typically considered high-order, such as analysis, synthesis, and evaluation. Similar processes involving the assessment of various viewpoints, evaluating claims, and identifying logical contradictions are considered essential by Elder and Paul (2020). Given the nature of chemistry, which involves interpreting and evaluating experimental observations and chemical relationships, and applying the principles of chemistry to different contexts, students of chemistry must engage in these processes. According to DeWit (2006), in the teaching of chemistry, it should be the goal of the instructor to help students to understand and be able to explain and predict chemical phenomena, rather than helping them to memorize. Additionally, research discussed in the literature showed that critical thinking and problem-solving are intimately related (Bertacchini et al., 2017; Stoica & Muraru, 2015).

Critical thinking can be nurtured by engaging with problems and ideas in a reflective and inquiring way. In chemistry, digital simulations and virtual labs can stimulate the investigation of chemical phenomena and outcomes, analysis of evidence, and evaluation of alternative solutions (Smetana & Bell, 2012). Discussion forums and digital activities can be used to promote student consideration of different interpretations and integration of varying opinions (Akyol, & Garrison, 2013). However, for the opportunities mentioned above to promote critical thinking, students need to actively engage with the ideas and information provided by various sources and technologies and develop judgments and opinions based on evidence and technology-enabled information. Thus, beyond the use of ICT for educational purposes, critical thinking involves the analysis and interpretation of information, and judgment and opinion development.

Relationship Between ICT Usage, Critical Thinking and Psychological Well-Being in Chemistry

The relationship between ICT and critical thinking may be illustrated in the numerous ways digital environments may offer opportunities for students to explore information and engage in scientific inquiry and analysis to frame problems. Effective use of ICT may enlarge students' access to scientific resources, aid students visualize and work with complex chemical structures, and create virtual environments where students can design and conduct their own experiments. Okoro and Ekpo (2016) and Smetana and Bell (2012) discuss the roles of digital resources for chemistry education and the use of simulations in science education, respectively. Through these resources, students may investigate relationships among variables, scientific phenomena, and possible solutions. Other benefits of ICT use relevant to critical-thinking skills include the promotion of critical discussions and openness to alternative ways of understanding things. Garrison and Akyol (2013) centered their discussion on the assessment and integration of knowledge within the framework of interactive learning environments. McKnight et al. (2016) focused on how ICT facilitates learning that is flexible, learner-centered, and reflects constant feedback. Technology

use and critical thinking should not be confused with each other, however. Using ICT frequently can mean students are engaged in activities not necessarily involving critical thinking. Digital resources do not necessarily mean students critically assess or integrate information. Learning should not just be about locating information; students should also be able to assess information and understand its meaning. Therefore, the assumption that high levels of ICT use enhance critical thinking skills in chemistry should be studied rather than taken for granted.

There is a positive correlation between the use of Information and Communication Technologies (ICT) and students' psychological well-being. Several authors have described the use of ICTs in different contexts and at various levels to positively influence students' well-being, whether as a source of information, a means of communication, a source of entertainment, a source of interaction with teachers and peers, a tool to facilitate learning or as a mechanism to stimulate and integrate students with learning difficulties (Lei & Zhao, 2007). Conversely, ICT may lead to symptoms of anxiety and stress due to excessive exposure to digital media and the inability to disengage from academic activities. Twenge (2019) reported psychological difficulties related to prolonged exposure to digital devices and screens. Digital overload and information overload are phenomena that occur as a result of the pervasive use of ICT. These may also pose challenges to students in different educational contexts, e.g. developing a deeper understanding of chemical concepts and processes by integrating digital materials (Wang et al., 2021). Furthermore, difficulties may arise when students attempt to integrate digital materials to facilitate the understanding of chemical concepts or processes, or as a result of a lack of support to integrate digital materials.

Psychological well-being and critical thinking are related yet distinct dimensions of students' academic functioning. Psychological well-being encompasses positive psychological functioning and the capacity to adequately manage the demands of life. Critical thinking, on the other hand, is about the systematic evaluation of the sufficiency of information, arguments and evidence, to draw conclusions, and be open to critical evaluation. Many researchers affirm the link between thinking and well-being. Further, Luna et al. (2020) and Tobon & Luna (2021) affirm that reflection assists individuals to evaluate their beliefs, seek alternative perspectives, and ultimately make better-informed decisions. Turashvili, & Japaridze, (2012) and Williams & Carroll (2015) affirm the association of critical thinking and the level of anxiety. It is worth considering the relevance of psychological well-being to chemistry, considering the aspects of the discipline that require the ability to persist in problem-solving that involves emotional self-regulation and control (e.g. understanding rate and equilibrium processes, interpreting transport and reactions in thermodynamic systems, etc.). Critical thinking can help with systematic evaluation of whether there are premature conclusions, support students manage academic challenges, and achieve academic goals (e.g. understanding concepts and solving problems). However, it is necessary to confirm, quantify and describe the extent to which psychological well-being and critical thinking are associated with undergraduate students in chemistry.

Theoretical Perspective

This research is based on three theories integrated in the attached literature: constructivist learning theory, Bandura's social learning theory, and Csikszentmihalyi's flow theory. Together, they provide a foundation to analyze the relationship between ICTs and psychologocal well-being and critical thinking among undergraduate chemistry students. Knowledge construction and cognitive engagement describe the relationship between the individual and the environment.

Constructivist Learning Theory

Constructivism is based on the active role of individuals in the process of constructing and refining their meaning and understanding. In this research, constructivism is grounded on Piaget (1972), Bruner (1990), and Vygotsky (1978). Dewey (1938) also has been pivotal to my understanding of how students actively explore their experiences, reason, reflect, and draw conclusions for the development of their understanding. Engagement requires activity, and activity requires the interaction of students with the environment to mobilize their prior knowledge for the construction and refinement of their understanding. Cognitive constructivism is focused on the development of the mental structures. Social constructivism focuses on the contribution of collaboration and interaction to the construction and development of understanding, as well as the importance of shared experiences.

This perspective is especially valuable to chemistry education at the undergraduate level as students at this stage develop the skills to form meaningful relationships among chemical representations and abstract concepts and

representations with experimental observations and theoretical frameworks. A variety of learning environments offered by ICT, such as interactive simulations, virtual laboratories and molecular modeling, and online databases may help students gather information about chemical phenomena, and assess their understanding. Students might be able to evaluate hypotheses, compare evidence, identify relationships and construct scientific knowledge through their interaction with these learning environments. Jonassen and Rohrer-Murphy (1999) explored the role of technology in supporting construction of knowledge and problem-solving. He also indicated that social and cognitive elements, such as the presence of the facilitator and interactive learners, are critical to the success of online educational experiences. Finally, constructivism provides a framework to describe the role of technology in the development of critical thinking and the importance of engaging in purposeful learning activities rather than assuming that the use of technology automatically leads to critical thinking.

Bandura's Social Learning Theory

Bandura's social learning theory adds to the understanding of individual attributes, contexts, and learning behaviors. Bandura (1986) wrote that learning happens through observation and modeling, as well as through direct experience. His social cognitive perspective emphasizes the relationship among personal factors, behavior, and the environment. Self-efficacy, that is, an individual's judgment about his or her ability to perform a certain activity, is one element of this theory, and such judgments are related to the level of effort and persistence with which an individual approaches a task (Bandura, 1997). In undergraduate chemistry education, ICT has the potential to foster learning situations whereby students can observe demonstrations, conduct simulated experiments, receive feedback and learn via digital interaction with peers and instructors. Especially for novices, working with ICT in this way may help develop confidence with respect to engaging with technology and performing chemistry tasks. Technological confidence was related to motivation to work with digital scientific information and to engage in challenging learning activities. Persistent and uninterrupted technical problems led to students' irritation and apathy.

Bandura's viewpoint connects constructs of psychological well-being and scholarly behavior. Personality, feelings and self-confidence of learners may impact how they approach more complicated learning tasks, and how they interpret learning situations. Learning successes and supportive learning environments may enhance students' perceptions of competence. Complex and advanced problem-solving situations in chemistry may require students' self-confidence, ideas and determination, and may benefit from social support, including constructive and critical feedback, and individualized instructional aids. This study uses social learning theory to speculate about learners' technology and learning environments as the reasons for the observed relationships between learners' critical thinking, their psychological well-being and their use of ICT. Although these theories connect study variables, they do not establish cause and effect relationships. Assuming a correlational research design, the empirical evidence should be interpreted as an indication of associations rather than causes.

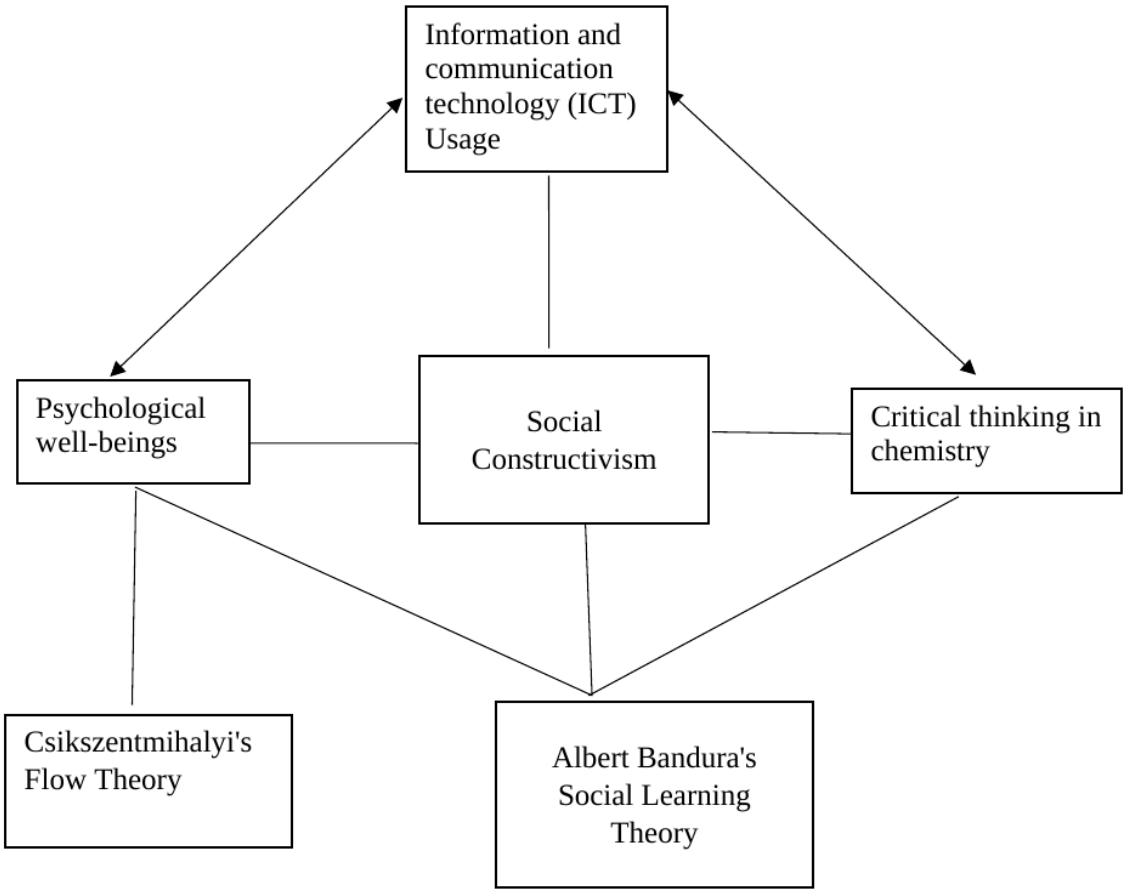
Csikszentmihalyi's Flow Theory

Csikszentmihalyi's (1990) flow theory defines flow as a psychological state where one is entirely focused on an activity and experience a deep sense of enjoyment and fulfillment while becoming completely aware of self and environment. Flow happens when the challenge of an activity is congruent with one's skill. According to flow theory, flow experience occurs when people perceive their goals or objectives as clear, provide feedback and presents a challenge that is neither very hard nor very easy. ICT-based Chemistry education may offer a flow-like experience when Chemistry simulations or activities are developed to challenge students to manipulate or interact with variables, explore chemical phenomena, reactivity and derive consequences. Some students may become engaged in deeply investigating chemical phenomenon and manipulating variables in a chemical simulation for long periods of time and remain motivated to undertake similar activities with respect to different phenomena or situations.

This suggests positive and stimulating learning experiences can strengthen students' feelings of engagement and sense of accomplishment. Digital activities can be appropriately designed to help students engage with their interest and sense of competence with challenging chemistry concepts. Not all digital environments are created equal. Poor design or excessive cognitive demands can discourage engagement, as can technically glitches and a lack of teacher preparation. The relationship between ICT usage and psychological well-being should not be assumed to be positive. Flow theory suggests ICT-supported learning can help students engage in activities requiring critical thinking. It

highlights the role of engaging, challenging learning experiences, as opposed to focusing on the role of ICT in learning situations.

Figure I: Theoretical Framework



The literature reviewed herein demonstrates the role of ICT, psychological well-being and critical thinking as three important dimensions of higher education, with specific relevance to undergraduate chemistry education. Numerous studies have discussed the educational benefits and psychological risks of ICT use, psychological well-being of students, and the role of critical thinking in science and other disciplines. However, the attached literature does not provide a comprehensive account of the integrated role of all the three variables in undergraduate chemistry education. This gap is important since chemistry being a science integrates various strands, like the understanding of abstract concepts, quantitative reasoning and evaluation of scientific evidence, along with practical activities and thinking. Use of ICT may facilitate engagement in various activities of chemistry education. Psychological well-being of students may be related to their capacity to manage the demands of education along with the cognitive challenges. Critical thinking of students may be related to their capability to evaluate digital information and systematically address the problems of chemistry. A focus on integrated role of all the three variables, may be helpful to understand the psychological, cognitive and technological aspects of chemistry education at the undergraduate level. That is the aim of the current study. The study intends to explore the relationships of ICT usage, psychological well-being and critical thinking in chemistry at the undergraduate level.

III. METHOD

The study adopted a quantitative, correlational design to examine the association of information and communication technology (ICT) use, psychological well-being and critical thinking in chemistry among undergraduate students. The quantitative design enabled the researchers to numerically define and measure the study variables and explore the nature of association through statistical methods. The design was correlational because the study aimed to understand the type of relationships that exist among the variables, as they naturally

occur. The study was undertaken within the positivist research approach, and subsequently within the paradigm of science and research, where the focus is on objective measurement, systematic observation, and assessment using science and technology.

Participants

The target population comprised both male and female undergraduate students enrolled in the Bachelor of Science (BS) Chemistry programs in public and private universities in Lahore District, Pakistan. A multistage sampling method was carried out to select participants from both sectors. First, universities were categorized as public and private. Second, two public and three private universities were selected through simple random sampling. Third, cluster sampling was employed to select BS Chemistry students from the selected universities. The final sample comprised 917 undergraduate students of chemistry from both public and private universities to reflect different institutional settings within the geographical limits of the study.

Measures

Three research tools, designed to measure the usage of ICTs, psychological well-being and critical-thinking in chemistry, were used for data collection. The research tool for measuring the usage of ICTs was adapted from Wickramasinghe and Jayatilleke (2021) while that for psychological well-being was based on the work of Ryff (1995) and the measurement of critical thinking in chemistry was adapted from the grid described by Sumarni et al. (2018). The research tools were designed differing in formats based on the constructs being assessed. **[I]** A 46-item measurement tool of ICT Usage Questionnaire was adapted from Wickramasinghe and Jayatilleke (2021). The measurement tool had six main dimensions. These were smartphone usage (12 items), social media usage (13 items), internet usage (9 items), device usage (4 items), video gaming (3 items) and television usage (5 items). Respondents were required to indicate the level of agreement on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The higher the score, the higher the level of agreement with the statement, and thus greater usage of that ICT. The overall internal consistency of the measurement tool was assessed during the pilot study. **[II]** Psychological well-being was evaluated using the 42-item version of Ryff's Psychological Well-Being Scale, reported to be Ryff (1995) in the methodology. It assesses six aspects of psychological well-being which are: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. Each of the six aspects is assessed by seven items. Responses are provided on a 1 to 6 scale with 1 being strongly disagree and 6 being strongly agree. The scale is administered to evaluate the six aspects of psychological well-being of the respondents. Items that are reverse scored and included in the scale need to be recoded before computing the subscale and total score.

[III] Critical-thinking skills in chemistry were evaluated through a 15-item constructed-response assessment described as a 'critical-thinking grid' in the source based on Sumarni et al. (2018). This type of assessment requires students to identify the essential elements to solve chemistry-related problems, especially those relating to acid-base solutions. It also requires students to answer essay-type and other problem-solving questions. Each question was designed to assess the students' capacity to identify assumptions, evaluate sources, interpret observations, make decisions, draw inferences, understand arguments, and determine the best course of action. Other cognitive skills needed to solve chemistry-related problems were identified, such as the ability to determine chemical problems, state causal relationships, identify alternative solutions, and make decisions, and reflect on the process of solving the problem. The focus is on the quality of the response given to each item, and the response is scored using the rubric developed for the instruments. The 250 BS Chemistry students, who were not part of the main study sample, were involved in a pilot study to test the instruments and assess their validity and reliability prior to the main study. Content validity was assessed through expert review. The appropriateness of the adapted questionnaire was evaluated through expert opinions. Internal consistency reliability was evaluated using Cronbach's alpha. The reliability coefficients of the three instruments are presented in Table 1.

Table I: Cronbach's Alpha Reliability of the Scales

Instrument	Cronbach's α
ICT Usage Questionnaire	.915
Ryff's Psychological Well-Being Scale	.880
Critical-Thinking Assessment Grid	.878

Procedure

The study's methodology reported that the researcher obtained permission from the administrative authorities of the participating universities to conduct the data collection exercise. Respondents were assured of the confidentiality of their information. Completing demographic information was voluntary. Data were collected from BS Chemistry students enrolled in some public and private universities in Lahore District. The researcher conducted the surveys himself. This permitted him to explain the purpose and answer questions about the process. Participants worked on the surveys at their own pace as the time required to respond by different participants varied. Prior to surveys' administration, the researcher obtained permission from the administrative authorities of the relevant universities. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21. To answer the research questions, both descriptive and inferential statistics were performed. Means and standard deviations were computed for the three variables of interest (i.e. ICT usage, psychological well-being and critical-thinking in chemistry). The direction and magnitude of association between the three variables was determined using Pearson's product-moment correlation.

IV.RESULTS

Table II: Classification of Information and Communication Technology (ICT) usage of Undergraduate Chemistry Students

Classification	Range	*n*	%	*M*	*SD*
High	Above 179	295	32.2%	192.19	10.51
Average	157 – 178	314	34.2%	167.00	6.39
Low	Less than 156	308	33.6%	141.74	13.17

Table 2 shows that undergraduate Chemistry students' ICT usage is classified as high, average and low. The category of high ICT usage is between 132-222, covering 32.2% of the total sample, with a mean score of 192.19, and a standard deviation of 10.51 which represents moderate variability within this category. The ICT group averaged 157 to 178 students. This is the biggest group and makes up 34.2% of the sample. Its standard deviation of 6.39 is relatively low, meaning that levels of ICT engagement among the members of this group are fairly similar. The mean score of 167.00 suggests moderately high levels of ICT usage. Low ICT usage was scored below 156, and this group made up 33.6% of the sample, suggesting that about a third of the students in the sample have low ICT usage. The mean of 141.74 of this group suggests lower levels of ICT usage as compared to other groups, with a standard deviation of 13.17, which suggests a higher level of variability within this group.

Table III: Classification of Psychological Well-Being of Undergraduate Chemistry Students

Classification	Range	*n*	%	*Mean*	*SD*
High	Above 180.01	305	33.3%	198.43	14.31
Average	159.01-180	295	32.2%	169.62	5.89
Low	Less than 159	317	34.6%	145.93	12.60

Table 3 shows psychological wellbeing of undergraduate Chemistry students is categorized as High, Average and Low. Students who fall in the High category of psychological wellbeing were 33.3% of the entire sample and had a mean score of 198.43 and a standard deviation of 14.31. Students with Average psychological wellbeing constituted 32.2% of the sample and had a mean score of 169.62 and a standard deviation of 5.89. Students with Low psychological wellbeing were 34.6% of the sample and had a mean score of 145.93 and a standard deviation of 12.60.

Table IV: Classification of critical thinking in chemistry of undergraduate chemistry students

Classification	Range	*n*	%	*M*	*SD*
High	Above 143	296	32.3%	154.65	7.81
Average	115 – 142	303	33.0%	129.54	7.93
Low	Less than 114	318	34.7%	96.68	13.91

Critical thinking among undergraduate chemistry students has been classified as high, average, and low, as shown in Table 4. The high category of critical thinking comprises 32.3% of the sample and has an average score of 154.65, with a standard deviation of 7.81, which indicates that the respondents in this category demonstrate a fairly high level of critical thinking. Students with average critical thinking comprise 33.0% of the sample, and have a mean score of 129.54, indicating moderate level of critical thinking. The standard deviation of 7.93 shows that respondents in this category have a fairly low level of variability, and thus have similar levels of critical thinking. The remainder of the sample, 34.7%, comprised the low category of critical thinking, with an average score of 116.25, which is low and shows a fair level of variability, 8.93.

Table V: Pearson Product Moment Correlation for chemistry students' ICT usage and psychological wellbeing at undergraduate level

Variables	*n*	r-value	Sig.
ICT Usage and Psychological Wellbeing	917	0.345	0.000

Table 5 shows a moderate, positive, and statistically significant relationship between ICT usage and psychological well-being among undergraduate chemistry students ($r = .345$, $p < .001$). This indicates that the ICT usage among students is positively related to psychological well-being.

Table VI: Pearson Product Moment Correlation for chemistry students' ICT usage factors and psychological wellbeing factors at undergraduate level

ICT Usage Factor	Statistic	Autonomy	Environmental Mastery	Personal Growth	Positive Relations	Purpose in Life	Self-Acceptance
Smart Phone Usage	r	0.290	0.183	0.207	0.223	0.173	0.211
	p	0.000	0.000	0.000	0.000	0.000	0.000
Social Media Usage	r	0.224	0.225	0.230	0.263	0.216	0.224
	p	0.000	0.000	0.000	0.000	0.000	0.000
Internet Usage	r	0.267	0.198	0.224	0.260	0.202	0.220
	p	0.000	0.000	0.000	0.000	0.000	0.000
Device Usage	r	0.173	0.185	0.163	0.192	0.207	0.175
	p	0.000	0.000	0.000	0.000	0.000	0.000
Video Gaming	r	0.152	0.144	0.120	0.120	0.151	0.090
	p	0.000	0.000	0.000	0.000	0.000	0.000
Television Viewing	r	0.123	0.143	0.152	0.148	0.160	0.102
	p	0.000	0.000	0.000	0.000	0.000	0.000

Note. r = Pearson correlation coefficient; *p* = significance (2-tailed).

From Table 6, the dimensions of ICT usage and psychological well-being have positive and statistically significant relationships ($p < .001$), which show weak relationships. This shows that among undergraduate chemistry students, higher ICT usage is related to the psychological well-being of the students.

Table VII: Pearson Product Moment Correlation for chemistry students' ICT usage and critical thinking in chemistry at undergraduate level

Variables	*N*	r-value	Sig. (2-tailed)
ICT Usage and Critical Thinking	917	0.611	0.000

Table 7 reveals a strong positive and significant relationship between ICT usage and critical thinking in chemistry among undergraduate students ($r = .611$, $p < .001$). Higher ICT usage is associated with higher levels of critical thinking in chemistry among undergraduate students.

Table VIII: Pearson Product Moment Correlation for students' ICT usage factors and critical thinking in chemistry at undergraduate level

Factors	*N*	r-value	Sig. (2-tailed)
Smart Phone and Critical Thinking	917	0.482	0.000
Social Media Usage and Critical Thinking	917	0.528	0.000
Internet Usage and Critical Thinking	917	0.465	0.000
Device Usage and Critical Thinking	917	0.377	0.000
Video Gaming and Critical Thinking	917	0.324	0.000
Television Viewing and Critical Thinking	917	0.231	0.000

As shown in Table 8, the ICT usage factors and critical thinking in chemistry have positive and significant relationships with Pearson correlations ranging from .231 to .528 ($p < .001$). The relationships vary from weak to high, and positive associations are generally found between higher ICT usage and critical thinking in chemistry among undergraduate students.

Table IX: Pearson Product Moment Correlation for chemistry students' psychological wellbeing and critical thinking in chemistry at undergraduate level

Variables	*N*	r-value	Sig. (2-tailed)
psychological wellbeing and critical thinking in chemistry	917	0.235	0.000

Table 9 shows that among undergraduate students, psychological well-being has positively weak and significantly related to critical thinking in chemistry ($r = .235$, $p < .001$). Thus, higher psychological well-being is associated with higher critical thinking in chemistry.

Table X: Pearson Product Moment Correlation for chemistry students' psychological wellbeing factors and critical thinking in chemistry at undergraduate level

Factors	*N*	r-value	Sig.
Autonomy and Critical Thinking	917	0.213	0.000
Environmental Mastery and Critical Thinking	917	0.204	0.000
Personal Growth and Critical Thinking	917	0.178	0.000
Positive Relations and Critical Thinking	917	0.219	0.000
Purpose in Life and Critical Thinking	917	0.148	0.000
Self-Acceptance and Critical Thinking	917	0.179	0.000

As shown in Table 10, among undergraduate students, various dimensions of psychological well-being are positively weak and significantly associated with critical thinking in chemistry, with Pearson correlation coefficients ranging from .148 to .219 ($p < .001$). In general, among undergraduate students, higher levels of psychological well-being are related to higher critical thinking in chemistry.

V. DISCUSSION

This research analyzed the relationships between the use of information and communication technology (ICT), psychological well-being, and critical thinking in chemistry, among the undergraduate students of Lahore, Pakistan. The results showed positive and significant relationships among the three variables; however, the strength of the relationships varied. Usage of ICT was positively related to psychological well-being and critical thinking in chemistry, but the former was more related to the latter. Psychological well-being was positively related to critical thinking in chemistry, but the relationship was weak which is according to Cohen (1988) guidelines for interpreting the results of the correlation coefficient. Therefore, use of ICT, psychological well-being, and critical thinking in chemistry are integrated in the learning experiences of undergraduates. As the study was limited to the correlational design, the results should be interpreted as relationships among the three variables. The study contends that there should be

distinctions while dealing with ICT in the context of education, since the use of digital devices does not always mean students are engaged in academically productive activities.

Results showed that students represented all high, average and low ICT usage categories. No single category represented a large majority of the sample. Thirty-two-point two percent (32.2%) of the sample was categorized as high ICT usage; 34.2% as average and 33.6% as low. Overall, the results show that the sample used ICT in a varying manner. The levels of variation of the participants' engagement with digital devices and technology may be related to a number of factors, e.g., differences in the participants' surroundings; individual preferences and digital competencies; academic and discipline requirements; students' everyday technology use patterns; context of learning; teachers' instructional design, pedagogical aims and rationale; integration of educational technologies to help students attain planned learning goals, as well as other factors (Bond et al., 2021; Nkomo, 2025). Based on findings of this study, technology in undergraduate chemistry education can facilitate access to learning resources, and visualization of abstract concepts, as well as collaborative inquiry and analysis of scientific data and information. This research did not determine whether the participants' ICT use was predominantly academic, recreational or social. Therefore, the distribution of the participants' ICT use should not be interpreted as an indication of educational technology use in chemistry. The findings of this study suggest that there is a need to further examine students' integration of digital technologies in the classroom, specifically how meaningfully students engage with technological devices during learning activities.

A positive correlation was observed between the use of ICT and the psychological well-being of undergraduate chemistry students, suggesting that students with higher ICT usage scored higher in psychological well-being. The correlation represents a modest positive association which is according to the Cohen's guidelines. Therefore, the role of technology in the psychological well-being of students may not be a determining factor, but it may be relevant in other ways to the psychology of students. In this context, digital technologies may facilitate communication and provide access to information, and strengthen opportunities for academic collaboration and independent learning. Some activities done using digital technologies may also help students to be socially active, approach academic help, and find academic and learning resources. A digital intervention, according to the results of a systematic review and meta-analysis by Ferrari et al. (2022), may improve university students' psychological well-being. The study assessed use of ICT in various areas, such as the use of the Internet and other electronic devices, social networks, television, and video games. These activities, depending on the reason for their use, their duration, and their context, may have positive or negative effects on individuals' well-being.

Further analysis of the relationship between the individual ICT dimensions and psychological well-being is shown below. Use of smartphones was positively related to autonomy (r=.290). Positive relationships were found between social media use and positive relations (r=.263), and between Internet use and positive relations (r=.265). These findings suggest that various kinds of technology use may be related to various aspects of students' psychological functioning. Smart phones and Internet use may facilitate students' ability to make independent choices and organize their academic life in ways that are functional and psychologically beneficial. On the other hand, social media may be a means to an end for students to interact and communicate with others. However, these assumptions are tentative because the study did not evaluate the reasons for students' technology use. A positive relationship was found among the six dimensions of psychological well-being (autonomy, environmental mastery, personal growth, positive relations, purpose in life, and self-acceptance). These results show that the use of information and communication technologies has a positive influence on psychological functioning. The weaker correlations found in the other two communication and entertainment technologies (video games and television) suggest that the relationships may vary with respect to strength and type of technology use. The results of the study highlight the importance of analyzing technology use in ways that go beyond the equivalence of all digital activities. Also, the results of the study indicate that using a particular technology, for example, a smartphone, may positively impact psychological well-being, however, the authors of the study argue the direction of the relationships was not assessed.

One of the major findings was the positive correlation of ICT usage and critical thinking in chemistry. This correlation was much stronger than the correlation between ICT usage and psychological well-being, indicating that students with higher ICT usage showed stronger critical thinking in chemistry. This study demonstrated a positive association

between ICT usage and critical thinking, but it did not prove that ICT usage positively affected critical thinking. This aligns with research that shows positive effects of technology on critical thinking when integrated with appropriate pedagogy and instruction. Moustaghfir and Brigui (2024), in a systematic review of technology-enhanced critical thinking, stressed the role of pedagogical approaches that encourage students to engage in reflection and research, question, and evaluate. Results of the systematic review by Pedraja-Rejas et al. (2024) show that mobile learning integrates technology with other pedagogical approaches like inquiry learning, peer assessment and self-regulated learning and positively affects learning and critical thinking. These findings are especially relevant to chemistry education as many chemistry concepts require students to interpret data, and evaluate and compare competing explanations. Therefore, it was interpreting the observed association as evidence of the relationship between reported ICT usage and critical thinking, rather than as evidence of a positive effect of a particular type of digital instructional intervention on critical thinking.

Further analysis on individual ICT dimensions revealed that the strength of the relationship with critical thinking varied by technology category. Use of social media showed the highest correlation with critical thinking (r=.528), followed by use of a smartphone (r=.482), the Internet (r=.465), general device use (r=.377), video gaming (r=.324) and use of television (r=.231). All the relationships were significant at the (p<.001) level. These findings suggest that type of ICT activity employed has an impact on the relationship with critical thinking. Critical thinking can be promoted, for example, through use of social media and the Internet to search for, evaluate and interpret evidence to construct an explanation, and compare and/or contrast sources. However, the Internet can also promote uncritical acceptance of information. It all depends on how students critically evaluate what they encounter online. Although use of a smartphone can provide instant access to learning resources, and a general device can help students engage with learning activities involving digital documents, a television and video gaming have weaker associations with critical thinking, their use in teaching chemistry can promote students' development of critical thinking skills to interpret evidence and arrive at a justified conclusion, as well as evaluate reasoning to support claims or explanations. This may be reflected in students' ability to explain their thinking processes underlying the justification of answers. The example of pH simulation indicates the educational significance of certain digital learning activities in undergraduate chemistry, particularly in regard to students' conceptual understanding. The difference between educational technology and everyday use of technology should be recognized when analyzing the results of the present study. It is assumed that designing useful educational activities will ultimately yield positive impacts on educational practices (Richards, 2005; Fill, 2005).

Positive psychological well-being correlated positively with critical thinking in chemistry, although this correlation was relatively weak. What this means is students who reported higher levels of psychological well-being, in general, demonstrated stronger performance in critical thinking in chemistry. It is worth noting that the correlation between ICT and critical thinking was much stronger than the correlation between psychological well-being and critical thinking. One explanation could be that psychological well-being may be associated with the context under which students engage in cognitively-demanding activities. As previously explained, conducting effective problem-solving in chemistry requires students to sustain attention and be persistent, among other things. As such, students that demonstrate a high level of autonomy, for instance, may be better positioned to engage in effective problem solving. Once again, this study does not empirically demonstrate this. Overall, positive relationships were found among the dimensions of psychological well-being and critical thinking, including autonomy (r=.213), environmental mastery (r=.204), and personal growth (r=.178), and positive relations (r=.219), and purpose in life (r=.148) and self-acceptance (r=.179). All of these were statistically significant at (p<.001). Positive relations showed the strongest correlation among these dimensions, and purpose in life showed the weakest correlation. Although the differences are descriptively valuable, this study does not assess whether these correlations are statistically different from one another. Thus, the findings indicate that the performance of students' critical thinking in chemistry is related to their psychological experiences, and it cannot be assumed that psychological well-being, on its own, explains substantial variation in students' critical thinking.

The findings, therefore, broaden the understanding of chemistry undergraduate learning by demonstrating positive relationships between the use of ICT, psychological well-being and critical thinking. The positive relationships between the use of ICT and critical thinking, compared with the other relationships, indicate that the use of ICT plays a more important role in students' cognitive learning experiences, and the positive relationships between

psychological well-being and critical thinking indicate that other psychological functioning of the students is improved, as well. The three relationships should not be interpreted as evidence of a causal pathway in which the use of ICT improves psychological well-being and ultimately affects critical thinking. A long-term, controlled, or mediation-based research would allow for the determination of such a pathway. Finally, the psychometrically significant relationships, based on the sample size of 917 participants, must be interpreted considering the context and the other variables that may influence the relationships.

Recommendations

Following the findings of the research, the recommendations below are outlined for chemistry educators, university managers and administrators, policy makers, and future researchers.

1. Universities need to offer initiatives that enable students to develop the competencies to assess the credibility of scientific information, appraise online sources, differentiate between evidence-based claims and misinformation, and use the Internet responsibly to facilitate and support their learning.
2. The psychological and counseling services available in universities should be improved. Additionally, managers and administrators of universities should enhance other peer support initiatives, and improve the quality of Academic advising. Chemistry educators should promote constructive feedback and a safe learning environment that facilitates achievement of academic workloads that are approachable and not overwhelming, while supporting students to participate actively and tackle challenging tasks with confidence.
3. Students should be directed to make appropriate use of digital devices and platforms to help promote academic engagement while maintaining the appropriate boundaries between educational, recreational and social activities. The effects of various technology use patterns were not established by the current study; therefore, universities should not assume that frequent use of technology has positive effect on student psychological and academic well-being.
4. While integrating digital technologies into learning, university administrators and education policymakers should consider equitable access to educational resources, teacher training and student support. Regarding the integrating technology into education, policies should be more concerned about the effective use of technology to improve learning and learning outcome than just being concerned with the introduction and use of technology in education.
5. Future studies should examine whether the use of specific ICTs improves critical thinking and psychological wellbeing by adopting a longitudinal or experimental design. There is also the need to study possible moderating and mediating factors like academic motivation, self-regulated learning and digital literacy.
6. Further research should be extended to students in various geographical regions, universities, academic disciplines and institutional frameworks. Whether the observed relationships are consistent in other educational contexts can be ascertained by undertaking comparative studies involving public and private universities and various academic programs. Recommendations are also made to education practice and future research. Educational practice is to implement the recommendations to balance student centeredness and integrate ICTs and critical thinking in psychologically supportive teaching. The recommendations should be implemented with fidelity and their impact assessed.

Scope and Limitations

The study was confined to Lahore District and focused on BS Chemistry students only. The source methodology states that data collection in some universities was not done because of scheduled end of term examinations and summer vacations. Thus, the findings of the study can at best be generalized to the chemists' students enrolled in public and private universities in Lahore. Further, the correlational research design can at best identify statistical relationships among the variables in the study. It may not identify the reasons (causes) for the relationships.

VI.CONCLUSION

The present study analyzed the associations of information and communication technology (ICT) usage, psychological well-being, and critical thinking in chemistry, among undergraduate students from Lahore, Pakistan.

The results showed positive associations of the three variables, demonstrating the integrated nature of students' technology, psychological, and cognitive learning outcomes. ICT usage showed a positive association with psychological well-being, and a comparatively stronger positive association with critical thinking in chemistry. Psychological well-being showed a positive association with critical thinking in chemistry, and the association was relatively weak. These results imply that, with regard to students' learning, technology engagement is especially critical to students' critical thinking performance; while, psychological well-being is part of the broader undergraduate learning experience. The study showed that relations with critical thinking differed with the different types of ICT usage, showing that technology should not be treated as a unified construct. Positive relationships between ICT usage and the various dimensions of psychological well-being indicate that students' engagement with digital technologies is likely related to several dimensions of their psychological functioning. The results do not necessarily indicate that greater technology usage improves students' psychological well-being or critical thinking skills. It is likely that the educational potential of ICT is determined by the spectrum of cognitive and psychological functions it allows students to engage, as well as by the other learning activities, the teaching-learning context, and the academic environment. Thus, in addition to contributing to the existing body of knowledge, the current study aims to enrich the discourse on the integration of technology in higher education by considering ICT, psychological well-being, and critical thinking, in the context of undergraduate chemistry education in Pakistan. The results show that it is not enough to analyse students' use of digital devices at university in terms of access and frequency. It is necessary to consider the quality of students' digital engagement, which is also pedagogically instructed. Universities need to analyse students' psychological experiences, along with their cognitive (i.e. academic and disciplinary) and metacognitive experiences (i.e. higher-order thinking and reasoning) when designing learning environments. The results of the study give us ample opportunity to reflect pedagogically for the advancement of learning, research and practice. Although the results give potential for research on students' learning, well-being and digital technologies, further longitudinal and experimental studies are necessary to analyze causal relationships and investigate the effectiveness of integrated digital technologies for supporting learning and improving students' well-being.

Disclosure Statement

No conflict of interest was reported by the authors.

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