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Interactive notebooks for achieving learning outcomes in a graduate course: a pedagogical approach

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Abstract
Social network analysis involves delicate and sophisticated mathematical concepts which are abstract and challenging to acquire by traditional methods. Many studies show that female students perform poorly in computer science-related courses compared to male students. To address these issues, this research investigates the impact of employing a web-based interactive programming tool, Jupyter notebooks, on supporting deeper conceptual understanding and, therefore, better attainment levels of the course learning outcomes in a female setting. The work also highlights the overall experience and enjoyment this tool brought to the classroom. Document analysis and questionnaire were used as data collection methods. A mixed approach was applied, mid-term exam documents were investigated qualitatively, and the questionnaire was analyzed quantitatively. Our results showed that most students correctly perceived the learning outcomes and knowledge introduced within the Jupyter environment. Moreover, the interactive nature of Jupyter enhanced engagement and brought enjoyment to the learning experience.

Keywords Qualitative research · Learning outcomes · Learning objectives · Interactive notebooks · Teaching strategies

1 Introduction

With the widespread of social media platforms available in the current era, the need to understand and analyze social networks and the underlying communication patterns has become increasingly vital. Social Network Analysis (SNA) is

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the science that studies social networks by representing users and relationships as nodes and edges and employing graph theory to mine various descriptive statistics and other hidden patterns of communication dynamics (Easley & Kleinberg, 2010). SNA is rooted in graph theory, discrete math, and social studies (Easley & Kleinberg, 2010), a blend that requires careful planning to deliver effectively. Additionally, many studies (Wagner, 2016), (Crues et al., 2018) state that female students show a gender gap in computer science-related courses compared to male students.

Nowadays, much research is directed towards interactive, hands-on learning as it is effective for learners (Franco & DeLuca, 2019). To address the need to expand understanding of SNA concepts and to help enhance female students' performance in such a course, this research investigates the impact of employing an interactive programming tool, Jupyter notebooks (Perez & Granger, 2007), on supporting deeper conceptual understanding, and therefore, better attainment levels of the Course Learning Outcomes (CLOs).

Jupyter notebook is a web-based application for creating and sharing code. A notebook combines the functionality of a word processor and a "shell" or "kernel" to execute programming statements, where the output is generated in line with the code. In this course, some traditional lectures were replaced with hands-on classes using Jupyter notebooks. A traditional teaching method can mean theoretical lecturing class using PowerPoint slides. Zhou et al. (2020) refer to the traditional programming teaching process as a combination of a separate theoretical class and a computer/lab class, usually conducted at different times and locations. Those programming course lectures relying on either PowerPoint slides only or applying the basic model of theoretical class and other separate computer/lab classes cannot effectively convey the basic points in the course. Therefore, Jupyter is used as a tool to combine theoretical and practical lessons to achieve interactive teaching. A typical notebook contains a series of programming statements explaining a particular concept or a (CLO) followed by coding and open-ended questions to drive the students to think, analyze and articulate their comprehension of the presented topic. A quality assurance practice followed in the faculty under study implies that course objectives should comprise objectives from the three different thinking levels, knowledge, skills, and values. In this work, we focus on the knowledge and skills learning outcomes. The complete list of CLOs is presented in Appendix A.

While many studies shed light on the gender gap, teaching strategies, and STEM education (Science, Technology, Engineering, and Technology), the present study attempts to address other various gaps, thus, makes significant contributions to existing literature. First, this research is the first to analyze the interactive notebooks not as a programming environment but as a tool to deepen understanding of complex topics. Second, this study applies a mixed methods approach and provides a comprehensive qualitative analysis of one of the course assessment artifacts rather than an experience report. Third, the study extends the limited research on female students' performance in a STEM field in Saudi Arabia.

The rest of the paper is organized as follows. The next section introduces the research problem, question, and objectives. The authors elaborate on the background

and literature review in sections three and four. Section five presents the research setting. Section six is devoted to the methodology applied. Section seven presents the analysis and results, while section eight discusses the research findings. Wrapping up with the conclusion and future work in section nine.

2 Problem statement

According to the literature, educators have employed Jupyter notebooks in many CS courses, such as introductory level courses (Zastre, 2019), (Al-Gahmi et al., 2022), artificial intelligence (AI) (Nelson & Hoover, 2020), finance (Zhou et al., 2020), big data and data science (Yuen & Robbins, 2014), object-oriented programming, data structures and machine learning (Al-Gahmi et al., 2022). However, most of the work done emphasize the impact of Jupyter on the final course achievement (Zastre, 2019) and (Al-Gahmi et al., 2022) compares Jupyter to other traditional tools (Zhou et al., 2020) and (Al-Gahmi et al., 2022), or highlight the strengths and weaknesses of the tool for education (Johnson, 2020). In addition, evidence in the literature shows that female students suffer from a performance gap in computer science-related courses compared to male students (Wagner, 2016) and (Crues et al., 2018). The faculty under study accepts female graduates from different universities with varying academic levels, curricula, and cultural backgrounds. Therefore, the classroom typically includes students with excellent, acceptable, and poor programming skills, creating inequality and questioning the validity of assessment criteria. This research builds upon the current work in the literature by equipping female students with a tool that allows better engagement in the course. Concisely, the notebook environment was introduced to achieve the primary skill outcome 2.5, "Construct a social network dataset from raw data, apply social networks analysis techniques to the dataset, and interpret and communicate findings". Performance is assessed by the fulfillment of the course learning outcomes. Jupyter was employed to help achieve other knowledge and skill learning outcomes; more on this is demonstrated in Sect. 7. We hypothesize that using this tool would develop students' computational thinking, improve their level of comprehension, and simplify learning complex SNA concepts. In other words, we assume this tool would facilitate achieving the CLOs and enhance female students' performance in this course. Positive findings, thus proving a better pedagogy, would empower female students in technology-relevant sciences. Formally, the research question of this study is:

Q. How does utilizing notebook technology in the learning environment help elevate the engagement, enjoyment, and attainment levels of the course learning outcomes for female students?

Thus, the objectives of this research can be framed as follows:

1. Evaluate the students' attainment levels of some selected knowledge CLOs after using Jupyter as an educational tool, such as identifying strong and weak ties, homophily, link formation, and segregation models.
2. Evaluate the students' attainment levels of some skill CLOs, such as applying betweenness measures and graph partitioning.
3. Evaluate the effectiveness, enjoyment, and functionality of using this tool for teaching and learning SNA in the classroom environment.

3 Background

3.1 Jupyter notebook

Jupyter is an acronym of three words, JUlia, PYthon, and R, which are multipurpose programming languages but are mainly used for data science and machine learning projects. The ancestor of Jupyter is IPython, an interactive shell for Python programming language (Perez & Granger, 2007). Jupyter is open-source software with a client–server architecture that simplifies creating a scientific research-oriented document that contains live code, text, equations, images, and videos. Jupyter notebooks are widely shared among the popular code versioning control platform GitHub (GitHub, 2022). GitHub provides a rich source of sharable open-source software for programmers and the research community supporting reusability and reproducibility (Randles et al., 2017).

Jupyter was chosen for this course for several reasons; first: it allows integrating graph theory concepts with regular programming functions giving more flexibility in handling data and research problems, in contrast to tools such as Gephi (Bastian et al., 2009) or NodeXL (Smith et al., 2010), where no programming is involved. Second, Jupyter notebooks allow adding normal text and images, thus allowing students to solve assignments, write code, and create research all in one document, a feature not available in other visual tools such as Gephi, or in regular programming development environments.

A notebook comprises three components: the main document, a human-readable document that includes the code, and all the other media. Second, the Jupyter notebook application opens the notebook in the browser allowing editing the document and running the code. Finally, the kernel, a computational engine that executes the code within the main document (Hoyt & Wangia-Anderson, 2018). A sample of a notebook is shown in Fig. 1.

The figure shows that the notebook displays a series of code cells. The other popular cell type is the markdown cell, which enables writing regular text and integrating images, equations, and videos. With the ability to incorporate code with various media, Jupyter has been employed in education, reproducible research (Pimentel et al., 2019), and industry (Johnson, 2020).

NetworkX package (Hagberg et al., 2008) was used in this course's tutorials, assignments, and final group projects. NetworkX utilizes existing Python libraries and allows the programmer to process networks with up to 10 million nodes and 100 million edges (Cherian et al., 2020). It also includes algorithms for various

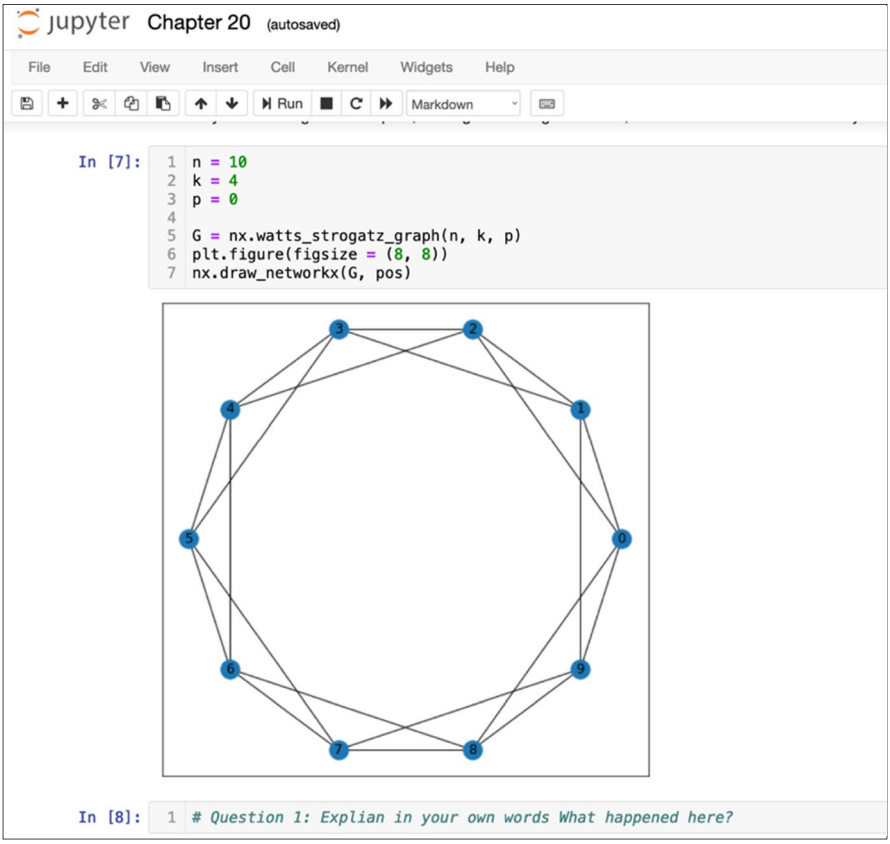


Fig. 1 A Jupyter notebook document

networking tasks, such as calculating centrality measures, detecting clusters, and traversing graphs. NetworkX is scalable, effective, and widely accepted for social network analysis tasks (Cherian et al., 2020).

We hypothesize that this tool would enhance learning and thus increase attainment levels of the knowledge and skill course learning outcomes. We also assume that the interactive, hands-on approach would increase engagement and motivate critical thinking and thus achieve a more enjoyable and functional learning experience.

3.2 Learning outcomes and quality assurance practices

A course learning outcome is "the results of teaching, learning, research, and other activities of an institution or a program." (Education and Training Evaluation Commission, 2022). For quality assurance purposes, the Faculty of Computing and Information Technology (FCIT) at King Abdulaziz University (KAU) follows the

accreditation standards of the Saudi Education and Training Evaluation Commission (ETEC) and the National Center for Academic Accreditation and Evaluation (NCAAA) (Education and Training Evaluation Commission, 2022). In this regard, the FCIT has authored a set of Program Educational Objectives (PEOs) that comprise all the faculty graduate and undergraduate programs. In addition to a list of required Graduate Attributes (GAs) dedicated to graduate programs. A PEO is a "broad statement that describes what graduates are expected to attain within a few years of graduation." (Education and Training Evaluation Commission, 2022). GAs focus on development, management, communication skills, collaborative thinking, and professional responsibility. Each PEO and GA is further mapped with competencies or Student Outcomes (SOs). A competency is "a general statement detailing the desired knowledge and skills of students graduating from a course or program" (Gottipati & Shankararaman, 2018). The IS department has a set of six SOs; in each course, in the graduate or the undergraduate curriculum, two or three SOs should be attained by the course. Thus, a course coordinator has to author CLOs for the course and map them to the appropriate SOs. This mapping assures the alignment between the course outcomes and the general program outcomes (GAs and PEOs). Table 1 shows examples of an aligned set of outcomes where a CLO is mapped to a SO, then GA and PEO. The complete lists of PEOs, SOs, GAs, and CLOs, are listed in Appendix A.

The CLOs, according to NCAAA standards, fall under three types, knowledge, skills, and values. These types are derived from Bloom's taxonomy learning domains, where the cognitive domain includes six subdomains: knowledge, comprehension, application, analysis, synthesis, and evaluation (Gogus, 2012). These levels are ranked from low-order thinking skills, such as knowledge and comprehension, to high-order thinking skills, such as application, analysis, synthesis, and evaluation (Gogus, 2012). On the one hand, low-order thinking skills require recalling facts and the ability to explain some concepts, such as the knowledge domain. On the other hand, high-order thinking skills need the learner to solve problems and create solutions, which in a sense, is a step further from knowledge and comprehension.

In FCIT, designing a course catalogue requires the course coordinator to compose CLOs from three different thinking skills, knowledge, skills, and values. As

Table 1 An example of a CLO and the corresponding SO, GA, and PEO

Outcome	Example
Course Learning Outcome 2.2	Apply betweenness measures, graph partitioning, and community detection algorithms to social media data
Student Outcome 2	Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline
Graduate Attribute 1	Development and Management Skills
Program Educational Outcome1	Work as an integral part of the information systems field, connecting people with information by developing and managing suitable information systems for business and research

such, the course contains a mix of high and low-order thinking skills and, thus, requires a careful alignment between each CLO and a suitable teaching strategy. In this work, we focus on the knowledge and skills learning outcomes.

3.3 Teaching strategies

While lecturing is among the most adopted teaching strategies in universities worldwide, they are not the optimal route for reaching high-order thinking skills objectives (Cashin, 2010). An outcome-oriented approach is recommended for selecting the best teaching and learning strategy. In other words, teaching strategies should be aligned with the CLOs to maximize student attainment levels (Outcome-Based Education, 2022). Several teaching methods are suitable for higher education, such as interactive lectures, flipped classrooms, problem-based, and experiential learning. Some methods are ideal for knowledge-oriented objectives, while others are more suitable for building skill-oriented objectives (Outcome-Based Education, 2022). Moreover, the adopted teaching method should aim to develop skills for solving real-life problems, thus, achieving the SOs and PEOs.

Research shows that integrating technology within the intended teaching strategies enhances the learning process and supports attaining higher-order thinking skills. Four aspects of learning must be considered when integrating technology: active engagement, participation in groups, frequent interaction, feedback, and connection to real-world experts (Teaching and Learning Handbook for Faculty at Vancouver Island University, 2017). Active engagement involves four fundamental features, thinking, task-focused, teamwork, and transcendence (Outcome-Based Education, 2022). The thinking feature implies that the teaching method should motivate the students to focus and dig deeper into the problem at hand to connect theories with practices and how these practices relate to real-life situations. Task-focused denotes that the teaching method allows the students to engage in a specific task, motivating thinking, discussing, and evaluating the learned skills. Teamwork states that the technique allows the students to work in groups with their classmates and within the larger community outside the classroom. Finally, transcendence involves transferring knowledge and skills learned beyond the classroom through discussion forums, conferences, and workplaces (Outcome-Based Education, 2022).

The Jupyter notebook environment adequately targets the four aspects of technology-enhanced learning illustrated above. A Jupyter notebook is lightweight and can be shared via email, Blackboard, or online via a cloud-based storage drive. Conveniently, a common practice among programmers nowadays is to share code via GitHub, a well-known code-sharing and versioning control open-source platform (GitHub, 2022). GitHub offers a significant number of free codes for the programming community, where programs can be downloaded and altered; additionally, participants can engage in discussion forums to solve technical problems and share knowledge. Thus, Jupyter notebooks lend themselves to group work and connection to real-world experts. Among the essential features of the notebook environment is the ability to run the code and observe the output; furthermore, the code

can be altered and rerun as many times as needed so that the learner can deepen the comprehension of a specific concept. Thus, supporting frequent interaction and feedback. Finally, the environment effectively reinforces active engagement, facilitating focusing and motivating deep thinking. Teamwork and transcendence are also achieved, as discussed above.

To help students achieve high-order thinking skills, one must adopt a creative and more engaging teaching strategy. Studies conducted in the educational arena proved that students gain better learning experiences when they are more involved than listening passively to lectures (Kissel & Stuetzle, 2020). Experiential learning (EL) is among the methods widely adopted in STEM education (Kissel & Stuetzle, 2020; Lehane, 2020; Shemroske & Pourang, 2021). A long line of research involving EL was conducted in the twentieth century, starting with the work of Dewey (1938) and Kolb (1984) (Lehane, 2020). Dewey described EL as the learning process of engaging in work practice and non-formal educational activities (Burnard, 1989). Kolb defined EL as learning through experience (Shemroske & Pourang, 2021). Dewey's model of EL involves four stages, concrete experience, reflection, abstract conceptualization, and application. The concrete experience consists of the interaction between the student and the learning tool. Reflection is the behaviours carried out by the student to solve a problem in a practical session. Abstract conceptualization involves relating old knowledge with newly learned material. Finally, the application involves applying the learned knowledge to new use cases or scenarios (Shemroske & Pourang, 2021). Kolb's model stresses that the learning cycle must start with concrete experience (Burnard, 1989). However, Kolb's model shares similar stages with Dewey's model, as illustrated in Fig. 2.

Although computer science curriculums, by default, applies EL due to the nature of the discipline, such as including laboratory sessions, programming projects, co-op

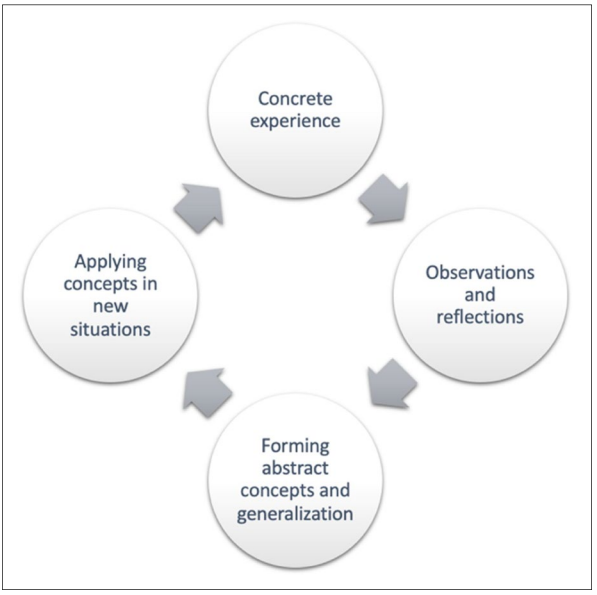


Fig. 2 Kolb's EL learning cycle (Burnard, 1989)

training for credit, and practical test, Kissel and Stuetzle (2020) argue that these activities are not enough to acquire soft skills entailed for a computer science graduate. Kissel and Stuetzle (2020) applied EL in small-size computer science department by following a concrete five-pillar approach: soft skills, real-world focus, group work, student empowerment, and dissemination of student work. Kissel and Stuetzle (2020) intended to apply the EL to the whole computer science undergraduate curriculum and to follow up with alumni and their employers to adjust and improve. Nevertheless, the surveys conducted to collect students' opinions and measure their satisfaction showed positive feedback, especially in soft skills-oriented aspects, such as in-class discussions and presentations. Shemroske and Pourang (2021) followed a similar EL approach in cybersecurity program to upgrade graduates' levels to match the demanding workforce requirements. They argued that EL focuses on the process rather than the outcome and described six essential pillars of EL; these are:

1. Decision-making, responsibility, and feedback from the educator.
2. Dynamicity of the learning environment that promotes creativity, critical thinking, and novelty.
3. Group work and cooperation.
4. Adjustment to different situations, where the students engage emotionally, intellectually, and socially.
5. Handling different results, allowing success, failure, or uncertainty.
6. Developing personal knowledge, the dynamic nature of the learning process enables a customizable learning experience.

Shemroske and Pourang (2021) focused on aligning theoretical educational approaches and workforce requirements. Their findings guide programs that need to enhance their curriculum and improve student outcomes. Nelson and Hoover (2020) stated: "A hands-on approach is at the core of experiential learning." Thus, an EL approach was followed in the SNA course presented in this work, as explained in a subsequent section below.

4 Literature review

Incorporating technology into education has been gaining much attention lately. Ilomäki and Lakkala (2018) investigated the practices at three schools based on six elements; in which one of those elements was pedagogical practices with digital technology. Nowadays much research is directed towards interactive, hands-on learning as it is effective for learners (Franco & DeLuca, 2019). For example, Chan and Reynolds (2022) investigated students' engagement in dynamic mathematics lessons through the contemporary metaphor theory.

Different technology (such as gamification) can also impact students' motivation to learn, especially when their interest is shallow. Jiménez et al. (2020) investigated using a digital escape room, Genial.ly, and a breakout, for learning algebra. They achieved positive student responses and improvement in knowledge and motivation.

Chen and Hsu (2020) found that commercial off-the-shelf games positively affect aspects of language learning. Saving Lives serious game was used to teach Iranian nursing students healthcare knowledge and English vocabulary (Soyoof et al., 2022).

Grover et al. (2019) state that learners struggle with conceptualizing introductory programming concepts such as variables, expressions, and loops and develop a suite of non-programming digital and unplugged activities within the curriculum before students start programming. The results showed that students attained greater use of critical concepts. As for the usage of Jupyter notebooks, educators have employed Jupyter notebooks in many CS courses, such as introductory level courses (Al-Gahmi et al., 2022; Zastre, 2019), artificial intelligence (AI) (Nelson & Hoover, 2020), finance (Zhou et al., 2020), big data and data science (Yuen & Robbins, 2014), object-oriented programming, data structures and machine learning (Al-Gahmi et al., 2022). Nelson and Hoover (2020) employed Google Collaboratory (Colab), a cloud-based version of Jupyter, in two AI courses, focusing on deep learning and reinforcement learning. The study stated that the reason for choosing Colab is twofold; first, it is well suited for experiential learning, and second, it contains all the needed packages for the required tasks, so the students don't need to worry about dependency problems when installing libraries. Many studies reported using Jupyter notebooks in CS introductory level courses, such as in (Zastre, 2019); the course was offered to all first-year students in the foundation year. The author expressed enjoyment in teaching with Jupyter notebooks. He highlighted the tool's features and limitations and recommended solutions to mitigate them.

Several studies compared the impact of Jupyter and other traditional settings on the final course achievement. A study compared Jupyter notebooks and a traditional Python environment in two finance courses (Zhou et al., 2020). The study found that the results of the students who used Jupyter were generally higher than those who used the traditional environment. Also, the study confirmed that using Jupyter created an interactive teaching atmosphere, which motivates students' critical thinking, and logical reasoning and resulted in a richer teaching experience. Al-Gahmi et al. (2022) also compared cohorts of students who used the tool with students who didn't. This experiment incorporated the Jupyter notebook with five CS curricula to improve student engagement and fulfill the required course competencies. The result showed that using Jupyter, students scored better on assignments and projects than the control group. Yet, tests did not exhibit a significant improvement between the two groups.

Regarding enjoyment and engagement in learning, Lee et al. (2022) investigated the problem of students' willingness to communicate in a second language. The study analyzed how foreign language enjoyment mediates the relationship between informal digital learning of English and students' desire to communicate in a second language in class and at other social events. Foreign language enjoyment encompasses teacher appreciation, personal enjoyment, and social enjoyment. The study found that personal enjoyment is the most significant element in mediating the relationship. This result emphasized the importance of increasing enjoyment to increase students' willingness to communicate in a second language. At the same time, Soyoof (2022) studied Iranian students' willingness to communicate in an extramural digital context in an English as a second language course. The study interviewed

50 students and applied thematic analysis. Results found four sources influencing learners' willingness to communicate: educational practices, interpersonal variables, affective variables (confidence), and social variables. Student engagement was also explored during the COVID-19 online environment (Chiu, 2022). The study applied Self-Determination Theory (SDT) to explain engagement in such an environment. SDT states that humans have three universal psychological needs: autonomy, competence, and relatedness. The research assessed whether the digital environment and tools influenced autonomy, competence, and relatedness and how these three needs relate to student engagement. The study found that the digital environment better satisfied students' needs, and all the needs contributed to the level of engagement. The study also showed that relatedness (feeling connected, loved, and interacted) was vital in enhancing engagement.

Many studies in the USA and western countries reported that women are underrepresented in various computer science subjects (Crues et al., 2018; Kemp et al., 2020; Wagner, 2016). This gender gap is especially apparent in computer science (CS) majors. In the UK, for instance, women represented only 16% of graduates of CS major in 2013 (Wagner, 2016), while in the USA, the percentage was not much higher, between 18 and 19% (Crues et al., 2018). In addition to the gender gap, studies stated that the performance gap might be the reason for the low enrolment percentage. Wagner (2016) found that female students were awarded significantly fewer high degrees than males in CS majors; as she explained: while female students suffer from a performance gap in CS majors, they show better performance in other subjects relevant to medicine, business, and administrative studies, mathematics, engineering, and technology. This agrees with Kemp et al. (2020), who argued that males perform better in STEM subjects while females are typically better than males in many other subjects.

Moreover, in programming, studies found that females can suffer from frustration, inadequacy, and a lower self-awareness level than males when working on a similar coding project (Kemp et al., 2020), a finding that would explain the gender and performance gaps. Other studies reported that programming careers are more dominant by men, and women do not excel in programming or show an interest in learning to program (Contreras-Ortiz et al., 2021; Edmondson, 2008). Recommendations to improve the performance gap include upgrading course design and focusing on pedagogy, as studies showed that females favour problem-based learning, in-class discussions, and group work (Wagner, 2016).

Saudi Arabia, in contrast, has a high female enrollment rate of 45.8% (Alghamdi, 2017). Alghamdi (2017) investigated the reasons for this high rate and found that different cultural backgrounds may have contributed to this rate. Female participants said they expect more flexible career opportunities with a CS major than in other disciplines. Although the study provides valuable figures, to the best of our knowledge, no study has investigated the female performance gap in Saudi Arabia. However, female students show a programming performance gap (Contreras-Ortiz et al., 2021; Kemp et al., 2020), which agrees with our observation as computer science faculty teaching female students for more than ten years. Integrating this easy-to-use and friendly application stems from this difficulty we face routinely. Although using Jupyter in this course is not targeted to compare the performance or other aspects

between male and female students, however, it is expected that the features of this tool would contribute to enhancing female students' performance in this course and CLOs attainment levels were used as a measure of performance. Additionally, we were motivated to adequately equip female graduate students with a powerful tool that allows better engagement with the research community, as Python and notebooks are commonplace for sharing research code. According to the literature above, since female students generally perform poorly in computer science courses compared to male students, this study enhances the female students' performance in such classes. It, therefore, opens doors for further research about addressing the gender gap.

5 The research setting

The study presented in this article was carried out during the academic year 2021–2022 in the context of the first semester. SNA elective course was offered at the FCIT for female graduate students from different backgrounds hence, various programming levels. The course delivery was mainly face-to-face and web-facilitated, using Blackboard to post the activities' notebooks. However, due to COVID-19, blended learning was applied as some lectures were delivered online through the Blackboard Collaborate system.

The course involves some delicate and sophisticated theories and requires adequate knowledge of discrete mathematics, such as graph and game theory. The first few lessons introduce basic definitions and motivation behind the course, which were mapped to knowledge CLOs. As the course advances, the topics demand higher-order thinking levels, for example, applying the graph theory concepts within the graph partitioning and community detection algorithms. Although the textbook chapter explains the subject quite well, we anticipate incorporating a hands-on tool would enhance comprehension and increase the CLOs attainment levels. Therefore, some of the traditional lectures were replaced with practical tutorial lectures.

The instructor prepared a notebook for each class and uploaded it on the Blackboard with the course learning material. A notebook contains a series of programming statements explaining a particular concept or a CLO, followed by coding and open-ended questions to reinforce students' comprehension of the presented topic. In the class, the students download the notebook on their laptops to run the coding statements and observe the output. After completing the activity, the students uploaded the notebook through the LMS (Blackboard). The instructor graded the activities and provided detailed feedback for each student. A total of four practical sessions took place over the term of one month.

As mentioned in Sect. 3.4, an experiential learning approach was followed when designing the tutorials used for the practical sessions. Each session starts with a short lecture, 15–20 min, followed by experimenting with code in the notebook. A typical tutorial includes three main components. The first component is a presentation-style introduction to the lesson; during this part, the instructor introduces the topic, a demonstration is shown in Fig. 3. The second component contains coding cells illustrating the concepts explained at the beginning of the lecture; an example is presented in Fig. 4. The

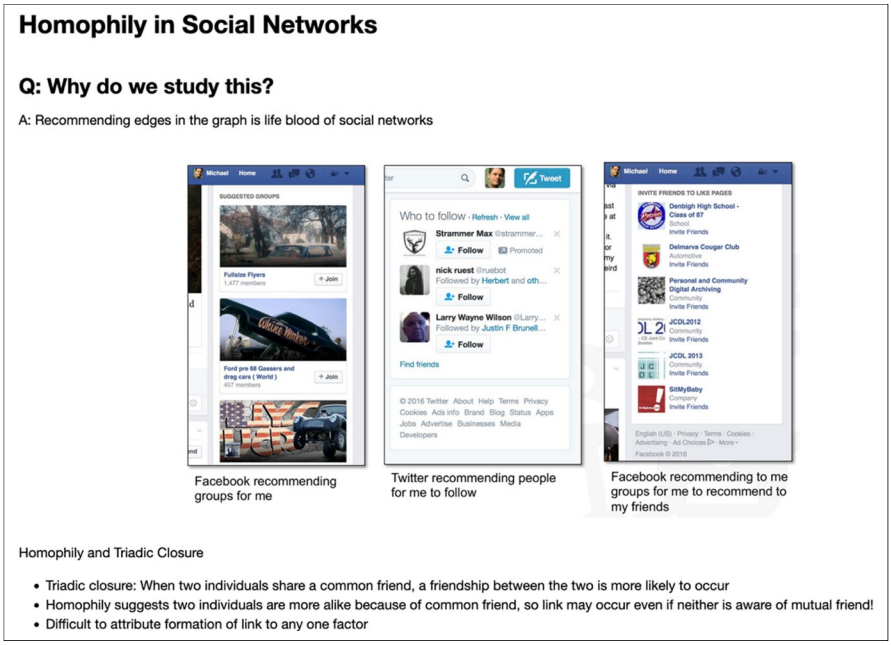


Fig. 3 An example of the lesson part of the notebook

students also have the chance to run or change the code and examine the output; this step represents the concrete experiment part of Kolb's model.

The third component includes three types of questions: reflection-style, coding, and critical thinking questions. The students were asked to complete this part of the notebook and submit their work via Blackboard. An example of a reflection-style question is "explain in your own words what did the code in the previous example achieve?". This type of question targets the reflection phase of Kolb's model. The

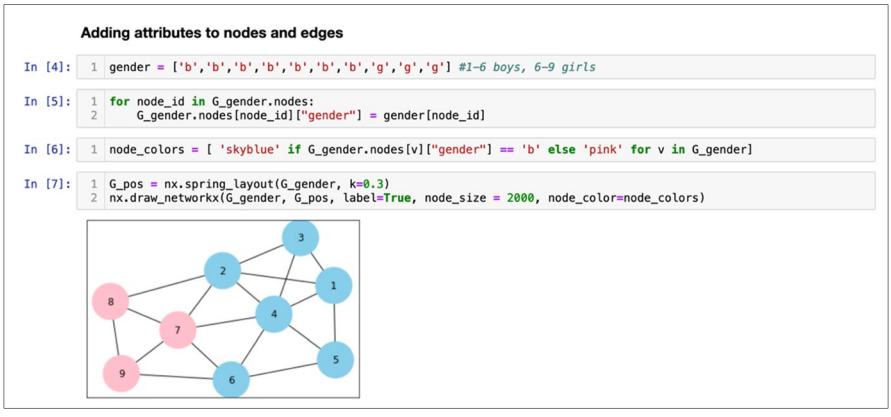


Fig. 4 An example of coding cells

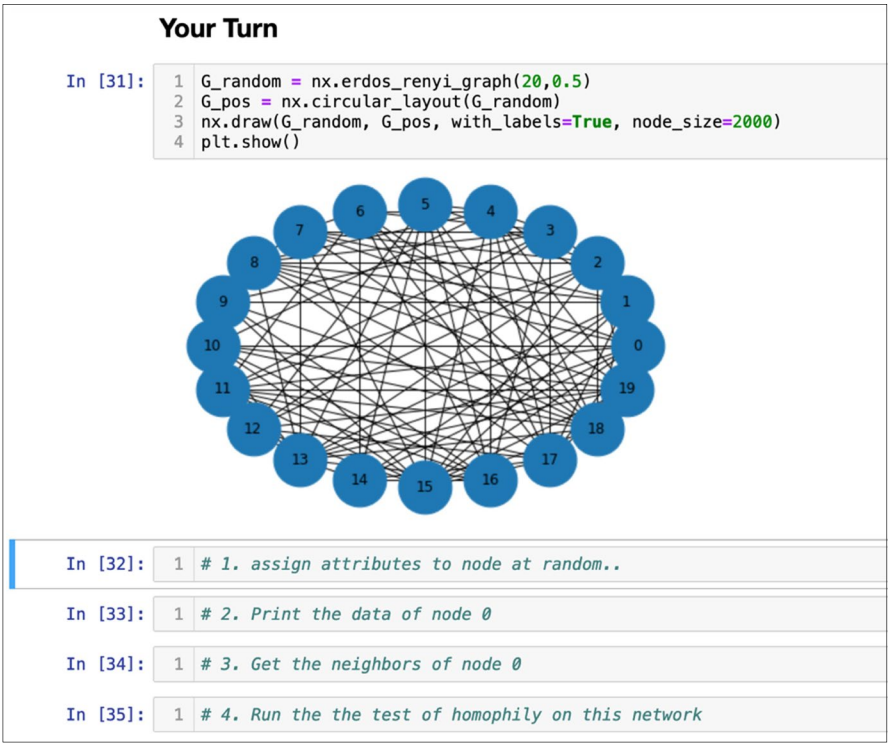


Fig. 5 Coding questions examples

coding questions challenge the students to apply the learned concepts in a new scenario; an example is shown in Fig. 5. This part of the notebook reinforces Kolb's model step: "applying concepts in a new situation." The critical thinking questions motivate deeper thinking and therefore, knowledge formation, some examples are presented in Fig. 6. During this problem-solving process, the student may scroll the notebook back and forth, observing the examples shown earlier by the instructor to

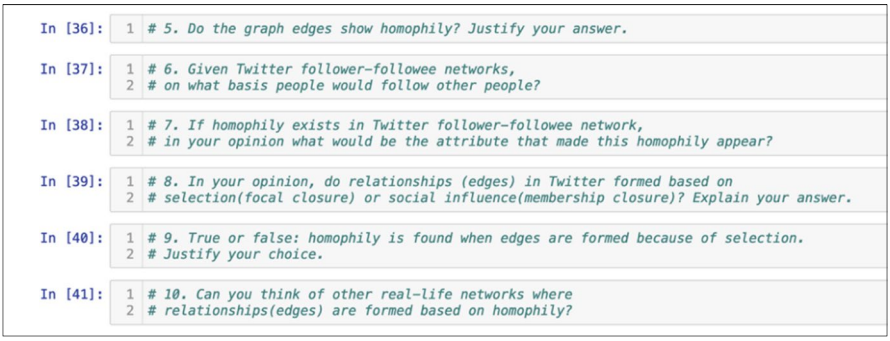


Fig. 6 Critical thinking questions examples

aid her in answering the questions—this iterative process helps build abstract concepts and reach generalization.

The activities covered a broad spectrum of the CLOs, including the knowledge CLOs 1.1, 1.2, 1.3, and skills CLOs 2.1, 2.2, 2.3, and 2.5. We focused on these CLOs as they represent the foundational backbone of the course. Data for the qualitative analysis was collected from all students registered in the class (n = 11) through the middle-term exam. Students had to write down their conceptions without guidance or any other intervention.

6 Methodology

The qualitative research method was applied, as the research is based on a holistic case study design. Case studies are preferred in examining contemporary events when the relevant behaviour cannot be manipulated, unlike experiments, where the researcher can control behaviour directly, precisely, and systematically (Yin, 2003). The case study selected is King Abdulaziz University (KAU). The first author's involvement in this department as an instructor justifies the selection. Many sources are available to collect the evidence for the case study, as suggested by Yin (2003); one is document analysis. To achieve objectives one and two, evaluate the students' attainment levels of knowledge-related and skill-related CLOs using Jupyter; the research problem in this paper was approached using document analysis – a qualitative research method in which the researcher interprets documents to give voice and meaning to an assessment topic (Bowen, 2009). According to O'Leary (2014), there are three primary types of documents; public records, personal documents, and physical evidence. Students' transcripts and handouts fall under the first category. Exploring and analyzing the actual content of the documents involves content analysis, in which the researcher incorporates coding content into themes similar to how focus groups or interview transcripts are analyzed (Bowen, 2009), quantifying the use of particular words, phrases, and concepts (O'Leary, 2014). After determining what is being searched for, the document's frequency and number of occurrences are recorded and organized, leading to identifying meaningful and relevant passages. In addition to content analysis, thematic analysis can be considered a form of pattern recognition with the document's data. Data is read carefully, followed by coding and category construction (Bowen, 2009). In this study, the documents analyzed were the mid-term exam.

A quantitative research method was also used through a questionnaire. Since document analysis is often used in combination with other research methods as a method of triangulation (Bowen, 2009), a questionnaire was used as a quantitative data collection method to achieve objective 3, assessing the effectiveness of the tool from students' perspectives. A questionnaire (n = 11) was disseminated to learn how effective the Jupyter tool is and to evaluate its impact on learning. This study was designed as an exploratory case study. Participants include all postgraduate students (11 female students) registered in the social networks analysis course in the academic year 2021–2022. Ten students responded (response rate = 90.9%). The questionnaire comprises 15 questions plus space for comments, as illustrated in Sect. 6.

Likert scale was used to weigh the degree of agreement with the questionnaire items, where one means strongly disagree, and five means strongly agree. The Likert scale measures people's attitudes, behaviours and opinions towards specific issues such as products, services, businesses, etc. It is most frequently used to measure psychological constructs and people's cognition that can be measured (Nemoto & Beglar, 2014). Some of the Likert Scale advantages provided by the authors include gathering data quickly and supplying highly reliable personal ability estimates. Therefore, the Likert scale was used in this questionnaire to measure students' assessment of the tool using a scale extending from one extreme to another.

Nemoto and Beglar (2014) state that understanding the construct is the starting point for questionnaire development. This can be achieved by reading related academic literature and analyzing items from previous questionnaires designed to measure that construct. Therefore, to develop the questionnaire, we considered the criteria suggested for evaluating e-learning tools in higher education (Anstey & Watson, 2018). The areas of our interest include functionality, accessibility, integration, collaboration, cognitive skills, enjoyment, social presence, and effective learning. The questions listed in the questionnaire adhere to the above areas and reflect on the research question to answer the "*engagement and enjoyment*" part. More specifically, they reflect on the third objective of this study, "*Evaluate the effectiveness, enjoyment, and functionality of using this tool for teaching and learning SNA in the classroom environment*", and therefore, questions 1, 2, 3 and 6 reflect ease of use, ease of learning, and troubleshooting, questions 4, 7, 8 and 12 reflect on collaboration, sharing and interactivity, question 5 highlights the diversity of students, questions 9 and 10 assess the engagement of students, question 11 refers to the level of enjoyment when using the tool, question 13 looks at the popularity of the instrument while questions 14 and 15 assess many aspects of effectiveness. The questions do not include any leading questions or assumptions, and they are not biased toward any specific group of participants; participants are anonymous, and confidentiality is assured.

7 Analysis and results

7.1 Mid-term exam qualitative analysis

For the Mid-term Exam – The total number of questions in the mid-term exam was 17. Refer to Appendix B for the midterm exam questions. The mid-term exam questions were tied to knowledge CLOs 1.1, 1.2, and 1.3 and skill CLOs 2.1 and 2.2. For the multiple-choice questions, categories of students' conceptions had already been set using the different choices, but the frequency of each perception was recorded; the complete analysis is presented in Table 2. As for the essay questions, students' replies were analyzed by hand with a content analysis procedure in an iterative and comparative process. First, particular words and phrases were highlighted using colour in the text and compared with each other (in each iteration) to create categories of conceptions (codes). Students' conceptions recorded under each category are, in fact – mostly – quotations from students' answers, as illustrated in Table 3. When

Table 2 Coding results of the midterm exam true/false and multiple-choice questions

CLO	Q#	Correct Answer/ Frequency	Wrong Answer/ Frequency		
1.1	1	Strongly connected 11 (100%)	Weakly connected 0 (0%)	Connected 0 (0%)	Giant component 0 (0%)
2.1	2	1. It takes into consideration the number of triangles in the network 2. It is another name for transitivity 6 (54.5%)	1. It takes into consideration the number of triangles in the network 2. It is another name for transitivity 3. It is affected by the degree of the node 4. It is the most important measure for the network 1 (10%)		1. It takes into consideration the number of triangles in the network 2. It is another name for transitivity 4. It is the most important measure for the network (36%)
	3	Eccentricity 4 (36%)	Diameter 7 (64%)	Periphery 0 (0%)	Center 0 (0%)
1.2	4	triadic closure 11 (100%)	bridge 0 (0%)	local bridge 0 (0%)	Neighbourhood 0 (0%)
	5	is a gatekeeper 5 (45%)	has high closeness 0 (0%)	has a high degree centrality 1 (10%)	none of the answers is correct 5 (45%)
2.2	6	recalculate the edge betweenness 8 (72.7%)	remove all the edges 0 (0%)	remove most of the edges 1 (9.1%)	none of the answers is correct 2 (18.2%)
	7	edge betweenness 10 (90.9%)	Node betweenness 1 (9.1%)	neighbourhood overlap 0 (0%)	breadth-first search 0 (0%)
1.3	8	the more friends in common the larger the probability 10 (90.9%)	the fewer friends in common the larger the probability 0 (0%)	the more friends in common the smaller the probability 0 (0%)	the probability increases if they share a common interest 1 (9.1%)
	9	bipartite graph 100%	complete graph 0 (0%)	directed graph 0 (0%)	undirected graph 0 (0%)
	10	False 100%	True 0 (0%)		

Table 3 Coding results of the midterm essay questions

CLOs	Q#	Correct Answer (Code/Frequency)	Wrong Answers (Code/Frequency)		
2.1	11	Definitions are complete & simplified/ 6 (54.5%)	Definitions not simplified/ 2 (18.2%)	Definitions not simplified/ incomplete/ 2 (18.2%)	Missing: "betweenness empowers the node by making it central"/ 1 (9.1%)
	12	G or F / Strong relations vs. isolation 10 (90.9%)	Either but no justification 1 (9.1%)		
1.2	13	Real bridges are not common 8 (72.7%)	Real bridges are common 3 (27.3)		
	14	Transfer news / give access to parts hard to reach / correct examples 6 (54.5%)	Access to parts hard to reach/ correct examples 2 (18.2%)	Transfer news 2 (18.2%)	Access to old relations 1 (9.1%)
1.3	15	Social influence / similar interests 8 (72.7%)	Similar interests 1 (9.1%)	Meet new people 1 (9.1%)	Flipped answers 1 (9.1%)
	16	Explained the meaning of the concepts and how it was measured 6 (54.5%)	Explained the meaning of the concepts but not how it was measured 3 (27.3%)	Triadic concept only 2 (18.2%)	
2.3	17	Yes – weak ties 9 (81.8%)	Yes – wrong or no justification 2 (18.2%)		

a set of codes emerged, students' responses were revisited to be aligned to the correct category. This coding process organized the data; for example, in one of the mid-term essay questions, all students' answers were carefully scanned. Four themes were found: "social influence and similar interests," which is the correct full perception of the concepts, "similar interests", "meet new people", and "flipped answers". Themes are used by Braun and Clarke (2006) to capture a common, recurring pattern across a dataset, clustered around a central organizing concept" (O'Dowd, 2021). The frequency of occurrence was then recorded, which is considered a standard tool in qualitative content analysis. Weber (1990) argues that high-quality content analysis uses both quantitative and qualitative analysis of texts. Namey et al. (2008) recommend recording the number of participants who mentioned a theme/code rather than counting how many times the theme was mentioned. For a rigorous analysis, the researchers followed Saldaña's (2013) approach, where extracts of one researcher's coding were shown to the other, who acted as an examiner and auditor, providing feedback on the coding.

A summary of the attainment percentage for each CLO is presented in Table 4. As seen from the table, regarding knowledge CLOs, which satisfy the first research objective, more than half of the students (54.5% or more) achieved the CLOs associated with seven out of ten questions, while at least 45% of the students attained the CLOs related to the other three questions. Regarding the second research objective, which targets the skill CLOs, more than half of the students (54.5% or more) achieved the CLOs associated with six out of seven questions. One question associated with CLO 2.1 had a low attainment percentage (36%).

7.2 Questionnaire results

To achieve research objective three, "Evaluate the effectiveness, enjoyment, and functionality of using this tool for teaching and learning SNA in the classroom environment." a short survey was sent to all the 11 students who took the course this same semester. Effectiveness, enjoyment, and functionality are the focus of the questionnaire. However, we elaborated on effectiveness to include the criteria suggested by (Anstey & Watson, 2018). These are accessibility, technical, collaboration,

Table 4 Summary of the attainment percentage for each CLO

CLO Type	CLO	Percentage of Students who Achieved the CLO
Knowledge	1.1	• 100%
	1.2	• 72% or more in two out of four questions • 45% or more in the other two questions
	1.3	• 72% or more in four out of five questions • 54.5% or more in the other two questions
Skill	2.1	• 90% in one out of four questions • 54.5% in two out of four questions • 36% in one question
	2.2	• 72% or more in two questions
	2.3	• 81.8%

Table 5 Summary of questionnaire results

Category	Criteria	Positive	Neutral	Negative
Functionality	Friendliness	80%	20%	0
	Ease-of-use	90%	0	10%
	Help availability	50%	30%	20%
	Scale	80%	20%	0
Accessibility	User-focused participation	60%	40%	0
Technical	Compatibility and ease of installation	100%	0	0
	Sharing via multiple methods	80%	10%	10%
Collaboration	Group work	90%	10%	0
Cognitive skills	Engagement	90%	10%	0
	Higher order thinking	100%	0	0
Enjoyment	Enjoyment	90%	0	10%
Social presence	Collaboration	80%	20%	0
	Diffusion	50%	30%	20%

cognitive skills, and social presence. Functionality includes friendliness, ease of use, help availability, and scale (Anstey & Watson, 2018). Ten out of 11 students replied. The responses to the first seven categories are summarized in Table 5 and Fig. 7 below. The Likert scale included five categories ranging from strongly agree to strongly disagree. For simplicity, the two positive categories are regarded as positive, the two negative categories are considered negative, and the middle category is neutral. The complete survey questions and results can be found in Appendix C.

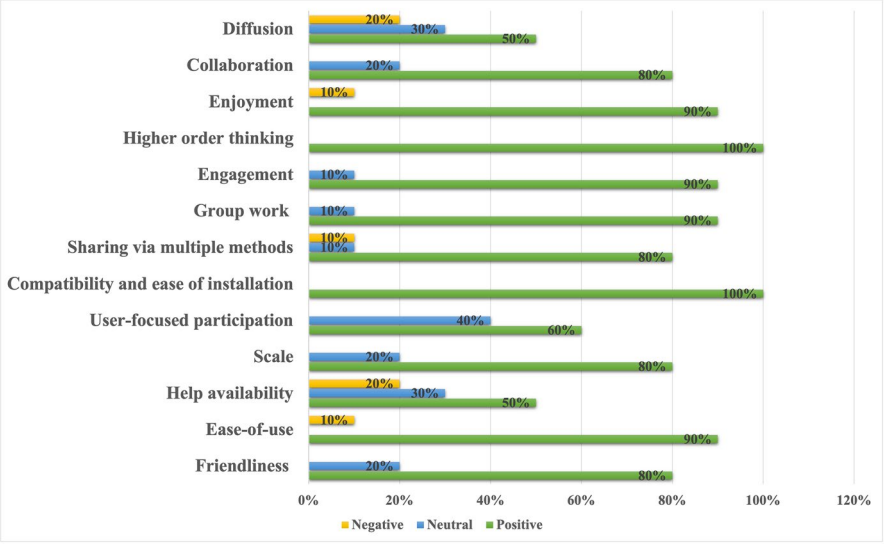


Fig. 7 Questionnaire results

Ease of installation received a 100% positive response. Friendliness was appreciated by 50% of the students as they chose "strongly agree," more than 30% chose "agree," the rest were not sure, and one student found the tool difficult to use. For the group work and sharing category, 80% of the replies were positive, the rest were neutral, and one student responded negatively. 90% of students expressed that using Jupyter in the classroom was more enjoyable than traditional teaching methods such as lecturing.

Regarding the contribution of Jupyter notebooks to effective learning, we asked the students to select the areas from a list of topics from the syllabus that Jupyter aid in deepening comprehension in these areas, the results of these question are shown in Figs. 7, 8, and 9. Most of the students confirmed that the tool helped them in learning the main topics of the course (CLOs). Also, 90% of the students expressed that the tool helped them understand the basics of Python despite not being the course's focus. Two students commented positively, "Highly recommend the teaching method" and "It was great using Jupyter Notebook and created a deep understanding of most of the concepts."

8 Discussion

This study aims to answer the question: "how does utilizing notebook technology in the learning environment help elevate the engagement, enjoyment, and attainment levels of the course learning outcomes?". Accordingly, an investigation was conducted on the effectiveness of the interactive programming tool (Jupyter) on the attainment levels of knowledge and skills CLOs of a social networks analysis masters course offered at a faculty of computing in the fall of 2021. The following argument provides a detailed answer to the research question.

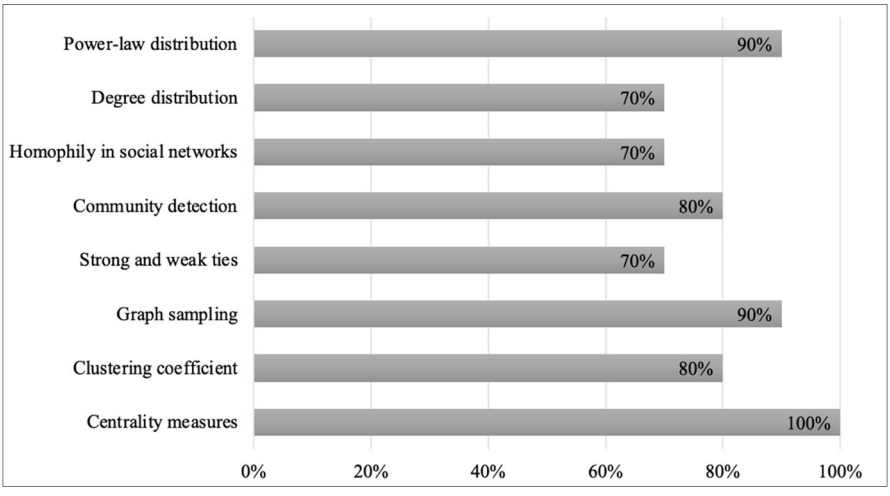


Fig. 8 Students' replies to how the tool help in deepening comprehension

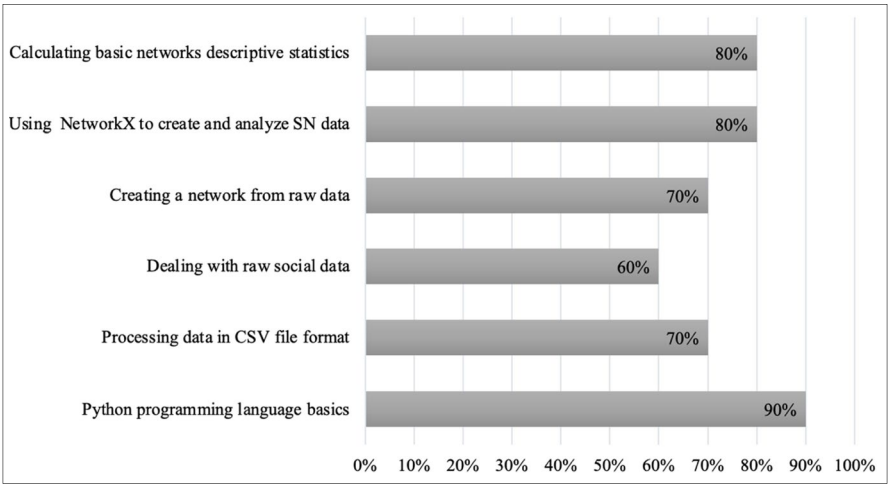


Fig. 9 Students' replies on how the tool help in learning practical skills

A qualitative content analysis of the dataset identified several key themes, providing a more nuanced understanding of student perception of concepts. Similar to O'Dowd's (2021) study, this form of qualitative analysis enabled identifying what students felt they had learned from the experience through identifying learning outcomes. As Xinogalos's (2015) work suggests, "most studies focus on the methodology and recorded results. Little or no reference is made to the programming environments/tools and teaching approach. This fact limits the possibility of taking full advantage of the results for (re)designing more effective courses and repeating experiments to validate their results."

Looking at the codes for the mid-term exam, as presented in Tables 2 and 3, overall, the results provide evidence that most students (more than 50%) perceive the concepts correctly and, therefore, achieve the matching CLO. In fact, in four out of ten short answer questions, all students answered correctly, while in another two short answer questions, ten students (90%) answered correctly. This indicates that many students comprehend graph connectedness, triadic closure, bipartite graph, edge betweenness, and mutable and immutable characteristics. The mastered concepts are relevant to CLOs. As for the essay questions, the correct theme (answer) frequency is higher than 50% in all seven questions.

Thus, the first objective, which targets knowledge CLOs, was achieved as 54.5% or more attained the CLOs associated with seven out of ten questions. At least 45% of the students fulfilled the CLOs related to the other three questions. Regarding the second research objective, which targets the skill CLOs, more than half of the students achieved the CLOs associated with six out of seven questions.

However, some results within the multiple-choice questions raised flags indicating a misconception; students do not perceive the type of centrality measurement correctly, as seven out of 11 answered "diameter" while the correct answer (entered by four students) is eccentricity. This feeds into learning outcome 2: "Recognize the basic concepts

of graph theory, networks descriptive statistics, and centrality measures." Eccentricity is the largest distance a node has in a network, while the diameter is the largest eccentricity in the whole network. The misconception may be due to the similarity between the two definitions or the question's wording. Although the student confused two definitions, eccentricity and diameter, no student picked the other incorrect options: periphery and center. Five out of 11 successfully recognized the gatekeeper concept in another question, but the other six could not. This is related to learning outcome three: "Explain the idea of the strength of weak ties, tie strength in social media, passive engagement, social capital, and betweenness measures". The term gatekeeper was mentioned in a lecture once or twice, which may be why most students did not recognize it.

Various conclusions can be drawn from analyzing the questionnaire disseminated to students. It is essential to highlight that all students believe the activities done in class using the tool support high-order learning tasks such as critical thinking, problem-solving, and reasoning. This is not surprising as research in the literature presented results supporting better final course achievement (Zhou et al. (2020) and Al-Gahmi et al. (2022)). In addition, nine students out of ten agree that using this tool in the classroom is more enjoyable than traditional learning approaches, asserting results by (Lee et al. (2022), Jiménez et al. (2020), and Soyoof (2022). Regarding the "Cognitive skills" part, all students (100%) agreed that Jupyter supports higher-order learning tasks such as critical thinking, problem-solving, and reasoning. At the same time, nine out of ten respondents declared that the notebook approach redefined engagement and provided new strategies previously unachievable through traditional lectures. These findings agree with (Chiu, 2022), who stated that the digital environment better satisfied students' needs, autonomy, competence, and relatedness, as outlined by SDT, and engagement is elevated by satisfying all these needs. Thus, the results of this study can be generalized to similar populations and other computer science courses that can benefit from the Jupyter environment, such as machine learning, data science and big data.

The questionnaire targeted the third research objective. Most answers were positive, confirming that the learning environment was functional, enjoyable, and effective. Item 14 in the questionnaire allowed students to identify the concepts in which better understanding was attained using the tool. All concepts scored more than 50%, with "centrality measures" at the top of the list, followed by "power-law distribution." This, however, contradicts the result of the centrality measure question in the mid-term exam. The reason for this might be the timing of the survey, as the survey was distributed at the end of the term after the students consolidated the course concepts by working on assignments and projects and studying for the final exam. Item eight in the questionnaire gave insight into how effective the tool is for collaboration amongst students, as 90% of students agree. This tool offers many opportunities for students to develop high-order thinking skills, apply and exercise coding, and create research projects in a reproducible form.

The pedagogical implications of this study provide significant insight to educators, students, teacher training bodies, faculty leaders, and researchers. Implications for educators and leaders include: (1) educators should steer clear from lecturing and adopt more modern pedagogies, such as the experiential learning approach presented in this work. (2) Adopted pedagogy should be aligned with the learning domain and the topic

at hand; it should also motivate critical thinking and increase engagement. (3) Special attention should be paid to female students when teaching computing-related courses. We believe that a hands-on experiential approach is beneficial not only to learning programming but also to enhancing comprehension of complex topics. Implications for students include: (1) female graduate students should surpass the technology barrier and embrace hands-on activities even if not asked by the instructor (2) Graduate students should adopt a technical tool for any course at the beginning of the term to allow connecting theory with practice and enhance understanding of the course material. In general, in computing education, a technical tool is a must; it is needed to apply learned concepts and to increase the attainment of learning outcomes.

Some of the hindering aspects of using this method are the amount of time and effort the instructor needs to prepare the activities. Nonetheless, the promising results and positive student feedback encourage implementing this strategy with possible adjustments. Furthermore, the sample size posed another limitation. The number of enrolled students in elective graduate courses usually is low. However, using the qualitative analysis approaches complements this limitation, as qualitative analysis can be conducted for smaller sample sizes. Regarding the quantitative part, all the students enrolled in the class were invited to take the questionnaire, and ten out of 11 replied.

9 Conclusion and future work

This work investigated the effectiveness of the interactive programming tool (Jupyter) on the attainment levels of knowledge and skills CLOs in delivering a postgraduate course. The motivation behind this work stems from the desire to elevate the attainment levels of CLOs and equip graduates with a powerful tool suitable for reproducible research and empowering female students to better engage in such a CS course. Jupyter notebooks have been recently incorporated into many CS curricula worldwide. In this study, some traditional lectures were replaced with interactive notebook sessions following Kolb's experiential learning method. Our results show that the students benefitted from the tools and were able to reach high-order learning objectives. Moreover, most students find this teaching method engaging and more enjoyable.

Future research directions include investigating Jupyter with other teaching methods, such as flipped classroom or problem-based learning, and possibly with other courses. A scarcity of studies exists concerning the gender and performance gaps in Saudi Arabia, which opens doors for significant contributions in this area. The experience of teaching the SNA course using this teaching method was a rewarding experience for both the students and the instructor. We hope that the results of this work encourage educators and students to adopt hands-on approaches to optimize learning outcomes whenever possible.

10 Competing interests

The authors declare no conflicts of interest.

Appendix A

Graduate Attributes.

1. Development and Management Skills
2. Collaborative Thinking
3. Professional Responsibility
4. Communication Skills
5. Business Problem Solver

Program Educational Objectives.

1. **PEO1:** Work as an integral part of the information systems field, connecting people with information by developing and managing suitable information systems for business and research.
2. **PEO2:** Advance in their careers through knowledge of computer information systems, communication skills, and understanding of business and contemporary technological issues.
3. **PEO3:** Actively contribute toward the economic growth and the welfare of Saudi society through the development and management of information systems for business and research.

Student Outcomes:

1. Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.
2. Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.
3. Communicate effectively in a variety of professional contexts.
4. Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.
5. Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline.
6. Support the delivery, use, and management of information systems within an information systems environment.

Table 6 Graduate attributes

Graduate Attribute	PEOs	SOs
Development and Management Skills	1, 2, 3	1, 2
Collaborative Thinking	2, 3	5
Professional Responsibility	1, 3	4
Communication Skills	1, 2	3
Business Problem Solver	1, 2, 3	4, 5, 6

Table 7 Course Learning Outcomes (CLOs) with SO mapping

	Course Learning Outcomes (CLOs)	**SOs**
1	Knowledge	
1.1	Identify the different types of networks, the importance of social network analysis, and their role in solving everyday problems	1
1.2	Explain the idea of the strength of weak ties, tie strength in social media, passive engagement, and social capital	1
1.3	Explain homophily, its mechanisms, link formation, and segregation models	1
1.4	Describe negative and positive social relations, the concept of structural balance, and its applications	1
1.5	Model diffusion and cascading behaviour in social networks	1
2	Skills	
2.1	Recognize the basic concepts of graph theory, network descriptive statistics, and centrality measures	2
2.2	Apply betweenness measures, graph partitioning, and community detection algorithms to social media data	2
2.3	Model the small-world phenomenon using the Watts-Strogatz model	2
2.4	Illustrate the power law distribution phenomenon and check whether real-world social media data satisfy this phenomenon	2
2.5	Construct a social network dataset from raw data, apply social networks analysis techniques to the dataset, and interpret and communicate findings	2
3	Values	
3.1	Describe the concept of social networks and their impact on society	1
3.2	Understand the importance of analyzing social networks for business organizations	6

Appendix B

Table 8 Midterm exam questions

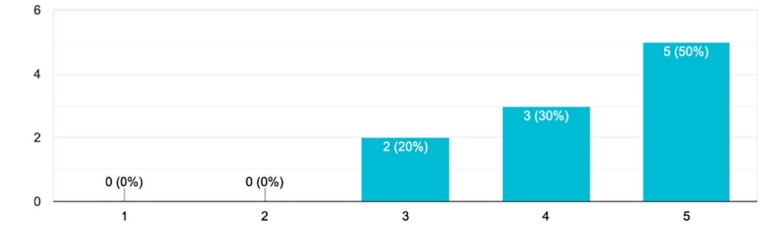
No	Type	Question Text
1	MCQ	In a directed graph, when there is a directed path from each node to every other node, then the graph is said to be:
2	Multiple Answer	Which of the following is true about the clustering coefficient (you can select more than one answer)
3	MCQ	Consider the graph G with nodes (1, 2, 3, 4, 5, 6, 7, 8, 9), the largest distance node 1 has between itself and node 7, which is of length 3. This measure is known as:
4	MCQ	If Salwa has two friends, Fatima and Manal, there is a chance that Fatima and Manal become friends in the future; we call this property
5	MCQ	Farouq is a Pakistani student at KAU; he has an account on Facebook connecting him with his friends and relatives. Of course, he has friends in Pakistan and Jeddah from the university. In Farouk social network, we can say that Farouk:
6	MCQ	Girvan Newman aims at detecting communities by removing edges of high betweenness. If we have one edge with high betweenness, and the rest of the edges have the same betweenness values. In the first step the highest betweenness edge is removed, what is next step of the algorithm?
7	MCQ	The total amount of flow an edge carries for all pairs of nodes using this edge is known as:
8	MCQ	The probability that two people form a link as a function of the number of mutual friends they share:
9	MCQ	A graph where every edge joins two nodes belonging to different sets is called:
10	True/False	Social influence can change mutable and immutable characteristics
11	Short Answer	Each of the social network measures has its definition and mathematical formula, and each one measures something in the graph. Your manager gave you social network data and asked you to analyze it. How would you convince your manager that the measures below are important? You need to explain in plain simple words what these measures tell us about a network, use illustrative examples if needed NOTE: your answer should not be copied from the slides and paraphrased, you should think and then write. Write complete, meaningful sentences 1. Closeness centrality 2. Betweenness centrality 3. Center 4. Periphery

Table 8 (continued)

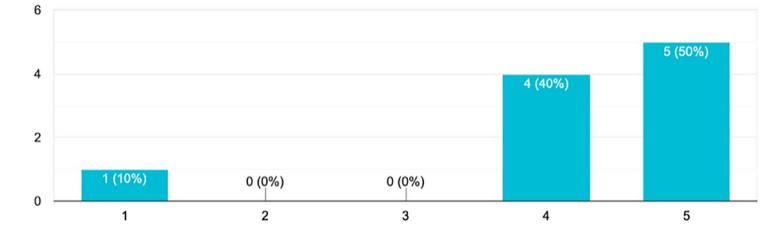
No	Type	Question Text
12	Short Answer	Consider the two social graphs of people living in a city, G and F; G has a high average clustering coefficient while F has a low average clustering coefficient. If you are new in this city, would you rather join the social graph G or F? Justify your choice
13	Short Answer	Bridges are not common in real networks; do you agree or disagree with this argument? Why or why not? • Use an example if it will help you explain the answer better, but you don't have to • Your answer should include at least two complete sentences
14	Essay	In 1973, Mark Granovetter published "The Strength of Weak Ties." This article caused a change in how we look at weak ties. Explain the importance of weak ties using an illustrative example • Do not use slides/book examples • Your answer should include at least four complete sentences (around 50 words)
15	Essay	If Sawasan and Rama are friends and they both like drawing, and they decide to join an art class. They met new people and made new friends. From this scenario, where can you spot a focal and membership closure? Please write complete meaningful sentences
16	Essay	How would triadic, focal, or membership closure be measured in real-world networks? Explain in a general and abstract sense how the experiments were conducted to calculate these three properties
17	Essay	Do you think there is a relationship between the small world phenomenon and homophily? Explain your answer

Appendix C

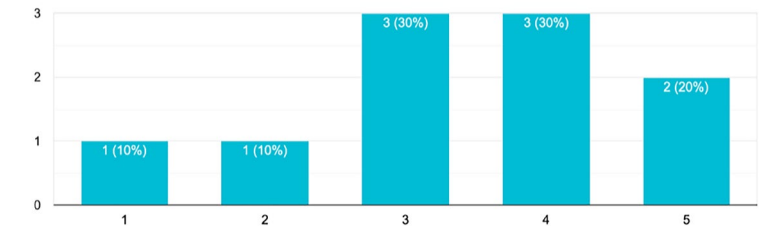
1. The Jupyter/Google Colab notebook environment is friendly and provide guidance.
10 responses



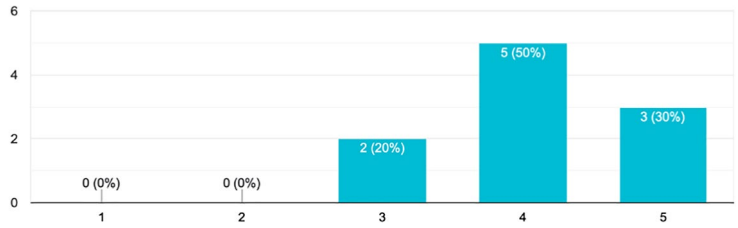
2. It was easy to learn and use notebooks in the classroom.
10 responses



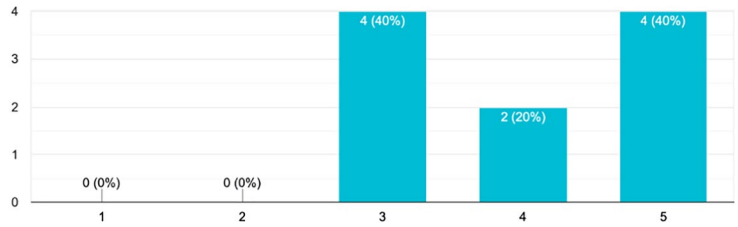
3. When I faced a problem, it was easy to find solutions online, from instructor or colleagues.
10 responses



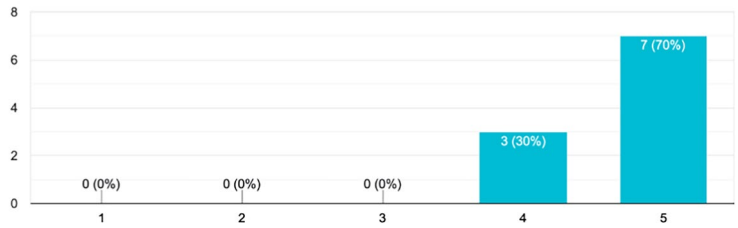
4. Using notebooks supports group-work in this course.
10 responses



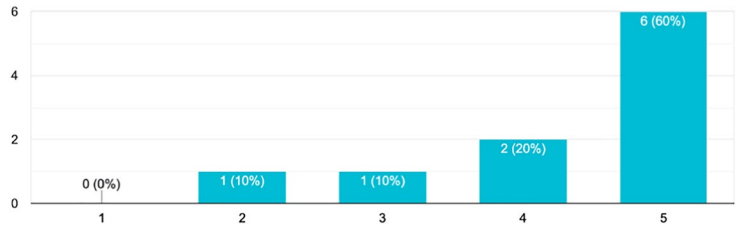
5. The notebooks address the needs of diverse users and accommodate different levels of student capabilities.
10 responses



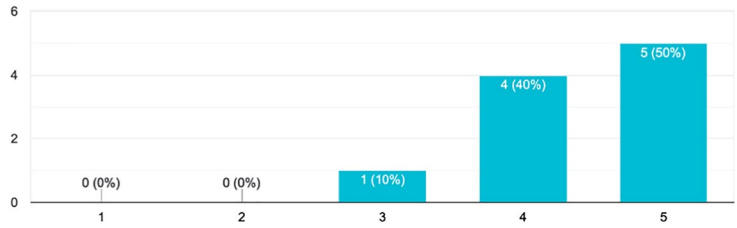
6. It was easy to install and start up notebooks
10 responses



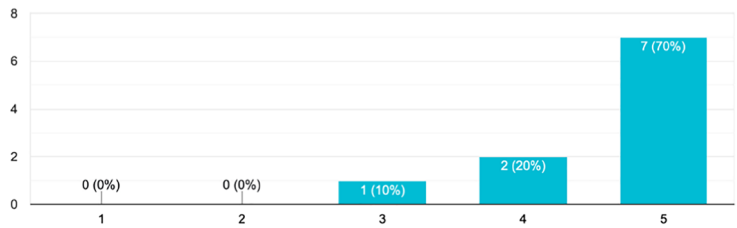
7. Sharing notebooks was simple via various mean, such as Blackboard, email, and GitHub.
10 responses



8. The tool allows collaboration amongst students.
10 responses

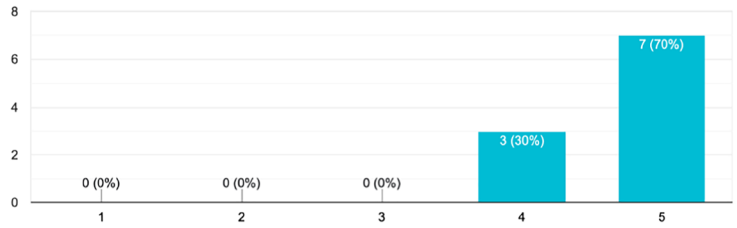


9. Notebooks help transform learning by redefining engagement and provide new approaches previously unachievable through traditional lectures.
10 responses



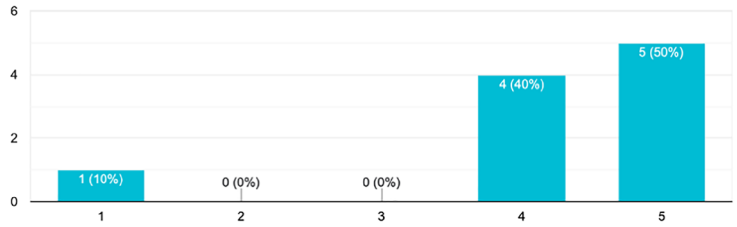
10. An exercise in a notebook such as the ones we did in the class, supports higher-order learning tasks such as critical thinking, problem solving, and reasoning.

10 responses



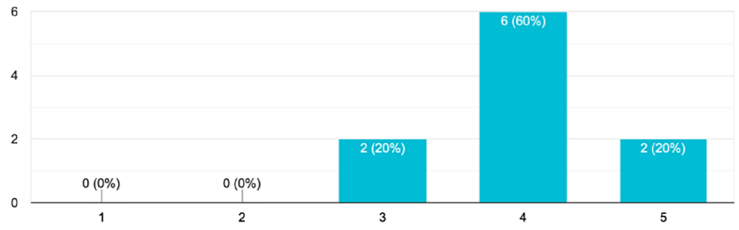
11. Using notebooks in the classroom is more enjoyable than traditional learning approaches.

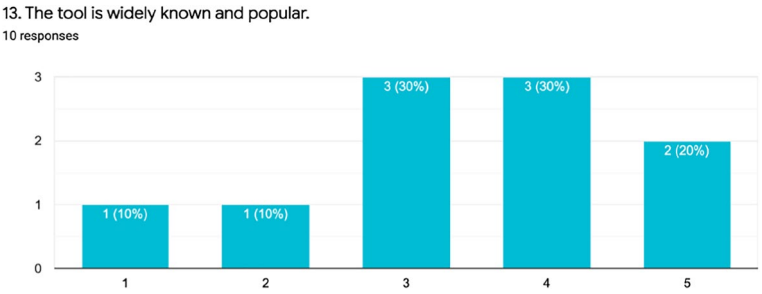
10 responses

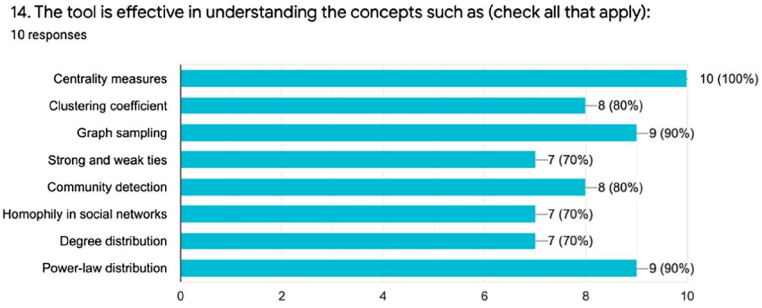


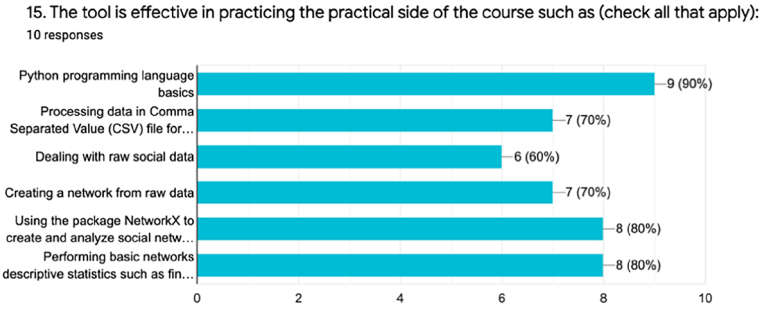
12. The tool has the capacity to support a community of learning through both asynchronous and synchronous opportunities for communication and interactivity.

10 responses









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Data availability Data can be shared with some conditions by contacting the first author.

Declarations

Ethics statement This research has been exempted from getting formal ethical approval by the Research Ethics Committee at King Abdulaziz University.

NCBE Registration No: (HA-02-J-008).
Reference No for Exemption: (19–22).

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